Abstract

Simulations may be used to evaluate the serviceability of pedestrian structures. A realistic analysis requires a sophisticated load model which considers the inter- and intra-subject variabilities in the walking parameters and the corresponding induced loads. For small pedestrian densities it is appropriate to assume that each person can cross the structure with its preferred walking speed. When the flow becomes denser, slower persons force faster persons to reduce their walking speed. The paper presents field studies on how persons adjust their walking parameters when the walking speed is set by a leading person. A simple probabilistic model is developed which allows a first simulation to study the effect of restricted walking on the excitation frequencies. Basically, the mean value of the step frequency reduces with decreasing walking speed.

Keywords: random pedestrian flow; conflicting traffic; adoption of slower walking speed; change of step frequency and step length

1. Introduction

Crossing persons may excite pedestrian structures to considerable vibrations. The corresponding acceleration amplitudes and their frequency of occurrence have to be evaluated in regard to serviceability demands. One possible strategy is based on simulation. A realistic load model considers the inter- and intra-subject variability of the process [1]. The random pedestrian flow can be modelled as independent Poisson processes for individuals and groups. If required, the describing parameters can be introduced as time dependent [2]. A further refinement deals with the walking behavior in conflicting traffic.

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For very low pedestrian densities and/or predominantly uni-directional traffic, it is appropriate to assume that each crossing person can deliberately choose the preferred walking speed and crosses the structure following a straight line. If the density increases, slower persons force the faster person to overtake, i.e. the actual path deviates from a straight line. If there is not sufficient space for overtaking, the faster person has to adopt the velocity of the slower person by changing the step frequency and/or the step length. Studies on human gaits across different speeds exists, e.g. [3]; however, typically these tests are performed on treadmill devices. If walking on ground is studied, often only three different walking speeds – slow, preferred, fast – are used [4]. Treadmill devices are less suitable since usually for a specific speed persons on a treadmill tend to walk with smaller step length and larger step frequency compared to walking on the ground [5, 6]. Therefore, this study is based on field tests. The basic test layout is described in section 2. Aim of the study is a probabilistic model for the intra-subject variability of the walking parameter step length for a preset walking speed as it is experienced when following a leading person. Altogether, 17 persons have been monitored each following 100 arbitrarily chosen persons. Section 3 summarizes the basic information on each test person in terms of the preferred walking speed and step length and the respective walking speeds of the leading persons. In section 4, the first approach to a probabilistic model is discussed. In section 5, the change of step frequency is shown for restricted walking.

2. Basic test layout

The bridge chosen to monitor the pedestrian behavior is close to the campus of the Ruhr-Universität. The bridge connects the station of the tramway to the University area. Figure 1 shows a bird’s eye view of the bridge. The vertical lines in Figure 1 mark the clearly visible construction segments. Each segment has a length of 17 m. The test person following an arbitrary person is observed during the passage of two segments, i.e. for 34 m. The test person takes the time for crossing the two segments and counts the required number of steps. The observation starts when the first segment is entered and ends when the second segment is left, i.e. the monitoring phase extends from the first ground contact of a foot in the first segment and ends with the ground contact of a foot just outside the second segment.

Six female and eleven male test persons participate in the study. Their age is in the range from 22 to 32 years. For each test person, at first a free walking test is performed, i.e. the test person walks with the preferred walking speed and simply takes the time and counts the steps for crossing the test passage of two segments. Then, each test person follows 100 persons and adopts their walking speed. The monitored crossing times and the counted steps form the basis of the probabilistic model.

3. Walking parameters for free walking

The initial free walking tests with the 17 test persons lead to the preferred walking speed and the corresponding step length. In figure 2, the observed free walking speeds and the step lengths are shown in normal probability paper. The mean value of the free walking speed is 1.54 m/s, the corresponding variation coefficient is 6.9%. For the step length, the observed mean value is 0.79 m with a variation coefficient of 6.8%. The obtained ranges are large enough to assume that the ensemble of 17 test persons is sufficiently representative.
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