Vibration Response due to Group Movements on a Footbridge

Mehdi Setareh

Virginia Tech University, Blacksburg, VA, USA

Contact: setareh@vt.edu

Abstract

Footbridges can be susceptible to large vibrations when a group of people move across them. To evaluate the vibrations of a footbridge, the structural engineer usually computes the response of the structure due to one person crossing at the footbridge resonance frequency or its subharmonics. The response due to a group of pedestrians can then be found by magnifying the computed response using a so-called "enhancement factor". Unfortunately, not much research has been conducted to define this factor. This study is an attempt to define the enhancement factor using an existing footbridge. It details the footbridge response when various groups of people marched in unison or walk randomly over it. Enhancement factors were computed for various group sizes and a closed form equation is proposed to compute enhancement factors for design purposes.

Keywords: footbridge vibrations; enhancement factor; vibration serviceability; vibration evaluation; vibration dose value; frequency-weighting function; walk tests.

1 Introduction

Human movements can cause large vibrations of footbridges. The excessive vibrations of the Millennium footbridge over the Thames River in London [1] is the most widely known case of a footbridge susceptible to such vibrations.

To predict the dynamic response of a footbridge, it is customary to compute the response of a footbridge subjected to a single pedestrian walking at the resonance frequency or its subharmonics and increase the result for when a group of people cross the structure. A few researchers have studied the vibration amplification when a group of pedestrians cross a footbridge as compared to that due to an individual. This amplification is named as the "enhancement factor".

Matsumoto et al. [2] proposed an enhancement factor *of* $\sqrt{N}$ to estimate the vibration amplitude of a footbridge when crossed by a group of N pedestrians, assuming a Poisson arrival probability distribution. From the study of 505 pedestrians walking naturally along roads, Matsumoto et al., concluded that their average gait was about 2 steps per second with a very small standard deviation.

Bachmann and Ammann [3] modified Matsumoto's relationship for a specific range of natural frequencies. They considered $\sqrt{n}$ as the enhancement factor for footbridges with natural frequencies of approximately 1.8 to 2.2 Hz. They recommended that when more than four pedestrians cross a footbridge, the enhancement factor varies linearly to 2.0 for structures with natural frequencies equal to 1.6 and 2.4 Hz. They didn't provide any enhancement factors for footbridges with natural frequencies outside these ranges.

Wheeler [4] considered loads from randomly walking people and performed an analytical study of the generated structural response. He concluded that if the fundamental frequency of the footbridge was away from the average human step frequency of 2.0 Hz, the structural response for a group of people walking randomly was smaller than that