Crowed-induced vibration of footbridges and the application of tuned mass damper for vibration mitigation

Mohammad Jafari [1], Amir Keyvan Ghorbani-Tanha [2]

1- M.Sc student, University of Tehran
2- Assistant professor, University of Tehran

Mohammad_jafari@ut.ac.ir

Abstract

In the past few years the issue of excessive footbridge lateral vibrations attracted great attention. There are three possible mechanisms that stand for lateral vibration; direct resonance, dynamic interaction, and internal resonance. This paper investigates direct resonance which is activated if the pedestrian excitation is in resonance with a specific mode of vibration. A single double-foot force model for the lateral component of force is employed. Based on it, the footbridge random load, in which pedestrians are modeled as loads interring the footbridge with average time intervals, is modeled. In this model, a stochastic approach is employed to calculate the acceleration power spectral density in any arbitrary position of the footbridge. Resonant effects are observed when the footbridge natural frequencies fall within the frequency range of crowd excitations. To suppress the excessive acceleration for human normal walking comfort, the application of tuned mass damper system, is shown to be satisfying.

Keywords: Direct Resonance, Crowd-induced Vibration, and Tuned Mass Damper.

1. INTRODUCTION

Nowadays, by the over increasing speed of high-performance material and new bridge construction technologies, there is a more tendencies to construct slender footbridges [1]. Recently excessive lateral vibration of some cable stayed footbridges like japans Toda Bridge and the London millennium footbridge [2], have attracted more interest to the field. Consequently, to evaluate footbridges resonance phenomenon, a lot of human-induced dynamic load models have proposed, which most of them are for vertical vibrations.

During walking, a pedestrian produces a near periodic dynamic time varying force which has components in three directions; vertical, horizontal-lateral, and horizontal-longitudinal. The horizontal-lateral component (which will be referred as lateral component in the rest of the article) of single pedestrian walking force, is due to the movement of body's center of mass as illustrated in figure 1.

Assuming that the force is perfectly periodic it can be represented by Fourier series

$$F_l(t) = \sum_{i=1}^{\infty} G\alpha_{i,l} \left((2\pi i \frac{f_{pv}}{2})t - \varphi_{i,l} \right) \quad (1)$$

Where G is the person's weight (N), $\alpha_{i,l}$ the lateral Fourier coefficient of the ith harmonic, i.e. dynamic load factor (DLF), f_{pv} vertical rate (Hz), $\varphi_{i,l}$ the lateral phase shift of the ith harmonic, i the order number of the harmonics.

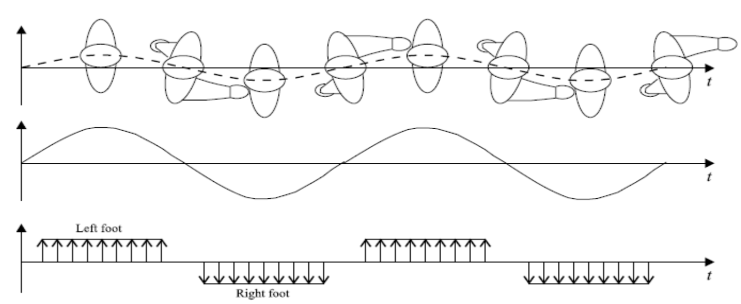

Figure 1. center of body movement, movement pattern, schematic lateral force [1]