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Validation and Fit of a Biomechanical Bipedal Walking Model for Simulation of Loads Induced by Pedestrians on Footbridges

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Abstract : The simulation of loads induced by walking people in civil engineering structures is still challenging It has been the focus of considerable research worldwide in the recent decades due to increasing number of reported vibration problems in pedestrian structures. One of the most important key in the designing of slender structures is the Human-Structure Interaction (HSI). How moving people interact with structures and the effect it has on their dynamic responses is still not well understood. To rely on calibrated pedestrian models that accurately estimate the structural response becomes extremely important. However, because of the complexity of the pedestrian mechanisms, there are still some gaps in knowledge and more reliable models need to be investigated. On this topic several authors have proposed biodynamic models to represent the pedestrian, whether these models provide a consistent approximation to physical reality still needs to be studied. Therefore, this work comes to contribute to a better understanding of this phenomenon bringing an experimental validation of a pedestrian walking model and a Human-Structure Interaction model. In this study, a bi-dimensional bipedal walking model was used to represent the pedestrians along with an interaction model which was applied to a prototype footbridge. Numerical models were implemented in MATLAB. In parallel, experimental tests were conducted in the Structures Laboratory of COPPE (LabEst), at Federal University of Rio de Janeiro. Different test subjects were asked to walk at different walking speeds over instrumented force platforms to measure the walking force and an accelerometer was placed at the waist of each subject to measure the acceleration of the center of mass at the same time. By fitting the step force and the center of mass acceleration through successive numerical simulations, the model parameters are estimated. In addition, experimental data of a walking pedestrian on a flexible structure was used to validate the interaction model presented, through the comparison of the measured and simulated structural response at mid span. It was found that the pedestrian model was able to adequately reproduce the ground reaction force and the center of mass acceleration for normal and slow walking speeds, being less efficient for faster speeds. Numerical simulations showed that biomechanical parameters such as leg stiffness and damping affect the ground reaction force, and the higher the walking speed the greater the leg length of the model. Besides, the interaction model was also capable to estimate with good approximation the structural response, that remained in the same order of magnitude as the measured response. Some differences in frequency spectra were observed, which are presumed to be due to the perfectly periodic loading representation, neglecting intra-subject variabilities. In conclusion, this work showed that the bipedal walking model could be used to represent walking pedestrians since it was efficient to reproduce the center of mass movement and ground reaction forces produced by humans. Furthermore, although more experimental validations are required, the interaction model also seems to be a useful framework to estimate the dynamic response of structures under loads induced by walking pedestrians.

Keywords : biodynamic models, bipedal walking models, human induced loads, human structure interaction
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