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EVALUATION OF THE EXPERIMENTAL AND ANALYTICAL DYNAMIC RESPONSE OF PEDESTRIAN BRIDGES

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Summary

This paper presents the results of ambient vibration tests carried out on ten pedestrian bridges located in the city of Querétaro, Mexico. Mathematical models of some bridges were developed and calibrated with the results of the experimental data. Afterwards, pedestrian load models were used to study the analytical response of the bridges and damping devices were simulated based on data available in the literature. The main objective of the study was to decrease the magnitude of structural vibrations and improve human comfort for pedestrians.

Keywords: ambient vibration; dynamic response; human response; human-structure interaction; damping devices

1. Introduction

In this work we describe typical vibration tests performed in a group of 10 pedestrian bridges in order to obtain their vibrational characteristics; only the results of the most flexible of these bridges will be presented and used to calibrate an analytical model developed with the aim of proposing special devices to decrease the effects of high vibrations on pedestrians.

The bridges that were monitored are located in some of the main avenues of the city of Querétaro, Mexico. We presume that human structure interaction effect was not explicitly considered in the design of the pedestrian bridges studied; human bodies were likely considered as inert masses. These bridges were selected based on the perception of insecurity informed by pedestrians that cross the bridges on a daily basis; the bridges studied presented different structural systems such as trusses, frames, girders, arches, etc., which are mainly composed of steel or reinforced concrete elements.

2. Ambient vibration tests

Ambient vibration tests are a very popular technique for obtaining dynamic properties of a structure, such as vibration modes and frequencies.

Frequencies associated to characteristic modes of vibration are derived from the analysis of frequency functions. After the analysis of several sets of functions, fundamental frequencies were identified for each bridge studied. On the other hand, maximum acceleration values were obtained for each type of pedestrian activity (walking, marching, trotting and jumping) and the vertical and lateral acceleration amplitude spectra were calculated.

3. Results

According to the results obtained, it was observed that 3 arch steel bridges provided the greatest sensation of insecurity for pedestrians. This consideration was confirmed quantitatively when comparing their dynamic properties with the serviceability criteria included in the design standards. The rest of the bridges at least complied with the AASHTO recommendations [1] regarding the values of natural vibration frequency. However, the Eurocode [2] is a little more demanding in this regard although this criterion does not guarantee a better behavior in terms of maximum accelerations. The problem of excessive vibration in these bridges has a solution, and it is necessary to experimentally identify other important dynamic parameters such as critical damping and modal mass percentages, which are required for the design of vibration dissipation devices such as tuned mass o viscous dampers.

4. Numerical modelling

A finite element model of each bridge was prepared. The models were calibrated with the results obtained from ambient vibration tests. Dynamic loads generated by pedestrians were also modelled as a function of time and position on the bridge.

On the other hand, in order to provide an alternative for the reduction of the perceived discomfort, a tuned mass damper (TMD) was proposed to be used in the bridges with the greatest vibrations. This device was designed taking into account its length, mass and damping.

5. Conclusions

Human-structure interaction is a phenomenon in which the properties and dynamic response of pedestrian bridges change depending on the pacing frequency of pedestrians, and can cause discomfort to people. Apparently this fact was not explicitly considered in the bridges studied.

From the ambient vibration tests, it was possible to identify the dynamic properties of the studied bridges using a spectral analysis of time histories of accelerations; mainly the frequencies and periods associated with the first vertical and lateral modes of vibration, as well as the first torsional mode of each pedestrian bridge were identified. It was also possible to study their behavior considering the effect of the pedestrian-structure interaction when a group of people crossed the bridges walking, marching and trotting.

The method used to test the bridges will be improved in a new set of tests that will be carried out with the most flexible bridges and trying to conform the frequency of pedestrians crossing. Another set of different bridges will be selected, as well. These activities and the number of tests and bridges will be defined by the owners.

6. References

[1] AASHTO (2009), "**LRFD Guide specifications for the design of pedestrian bridges**", American Association of State Highway and Transportation Officials, Washington, D.C., United States of America, 13 pp.

[2] Eurocode 5 (2004), "**Design of Timber Structures-Part 2: Bridges**", EN1995-2, European Committee for Standardization, Brussels, Belgium 28 pp.