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NUMERICAL ANALYSIS OF VIBRATIONS IN SUSPENSION FOOTBRIDGE UNDER PEDESTRIAN TRAFFIC

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Summary

This work aims to contribute to the development and characterization of dynamic numerical analysis, as well as to show its relevance in structures of footbridge built with wood Eucalyptus Cytriodora and subject to pedestrian loads. This wood has satisfactory mechanical properties and it is to use for structural purposes. These characteristics are responsible for generating light structures with reduced cross-section. However, in structures such as footbridges, increasing flexibility can lead to serious vibration problems, compromising the user comfort and, in extreme cases, structural safety. In this work, the Piracicaba Suspension Footbridge will be studying numerically using ANSYS 15 ®. The results obtained from the simulations in different scenarios were confronted with normative prescriptions that have specified methods to qualify the structural dynamic performance and show that the studied footbridge can present problems of excessive vibrations in the vertical direction, when analyzed the traffic from one or more pedestrians walking or running on the footbridge.

Keywords: dynamics; vibrations; suspension footbridge; vertical vibration; ANSYS

1. Introduction

The problem of vibrations induced by human walking have been observed for almost two centuries [1]. The footbridges are often subject to dynamic actions, of a periodic nature or similar, caused by pedestrian's loads. Such loads which are representative of activities such as walking and running, occur at low frequencies that may result closely to natural frequency of the structure. In this case, the vibrations grow considerably compromising the comfort of users and in some cases the structural safety.

Therefore, it is understood that the dynamic analysis of footbridges subject to vibration induced by pedestrians extends to the different structural systems and the various regulations in operation. In this sense, this work focuses on the study of a suspension footbridge built using wood Eucalyptus Cytriodora and is part of a larger research that aims the study of different structural systems used in footbridges.

The normative guideline considered for the calculation of footbridges follow two different lines. The first line, based on the analysis of frequencies, establishes a minimum frequency to be avoided. The second line concerns the evaluation of the level of acceleration of the structure, where limits are specified, in such a way as to ensure the comfort of pedestrian. In this work, the following standards are addressed: NBR 7188 [2], ISO 10137 (2007) [3], Eurocode 5 (2004) [4], ONT (1991) [5] e Sétra (2006)) [6].

2. Numerical Analysis of the Piracicaba Suspension Footbridge

2.1 Finite element model

For the numerical study of the Piracicaba suspension footbridge, a three-dimensional finite element model was created with the aid of the software ANSYS 15. In the model, the beams, metal towers and cables were represented by elements “Beam 188” of six degrees of freedom per node connected rigidly and continuities in the structure were taken into consideration. The deck also in wood and attached over the top stringers was modeled by elements “Shell 181” of six degrees of freedom per node. To simplify, the anchorage of the main cables were replaced with fixed supports and the same procedure were adopted to represent the connection of the towers to the foundation blocks. The handrail and guardrail were considered as mass elements, applied on the board of the footbridge. The discretized model has 5180 nodes and 3674 elements

2.2 Modal analysis

The modal analysis was performed for the first 120 modes and the results of the first relevant frequencies found on the deck identified values within a range considered critical for the performance of the pedestrians actions, with the first vertical and horizontal mode of the trajectory characterized by frequencies equal to 1,27 and 1,57 Hz, respectively.

2.3 Transient analysis

The cited standards were analyzed in search of dynamic parameters so that it was possible to evaluate the level of acceleration of the structure and thus classify the footbridge as to comfort. Scenarios with one, ten and 30 pedestrians, with step frequencies equal to 1,3 and 2,55 Hz, to simulate the behavior of pedestrians walking and running on the structure, were analyzed.

3. Discussion and Conclusions

The results show that the footbridge studied in this work may present excessive vibration problems, once the natural frequency of the structure in the vertical direction are below the limits established in the standards analyzed. Regarding the natural frequencies in the horizontal direction, the structure presents a good behavior when considering the requirements of the guide Sétra [8]. For the others standards evaluated, the vibrations in this direction could be a problem.

Based on the transient numerical analysis, it´s verified that there is a possibility of discomfort to users due to the vertical accelerations are above the values proposed in the regulations analyzed, considering scenarios with a pedestrian walking or running on the structure, as well as people flow scenarios. It should be noted that for a single use of the pedestrian footbridge, just the ISO 10137 [5] classifies the structure as unsatisfactory. In relation to accelerations in the horizontal direction, the structure displays good behavior in the transient analysis, not presenting values indicating the possibility of discomfort to users.

3.1 References

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