CERIS Civil Engineering Research and Innovation for Sustainability

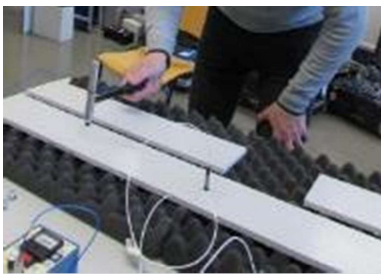
Effect of viscoelastic damping of polymer-based composite materials in the mitigation of footbridge vibrations

Summary

The construction of structures with progressively longer spans and current aesthetic trends advocating very slender and lightweight solutions has resulted in an increased sensitivity of walkways to dynamic actions, which may require the implementation of measures to mitigate vibrations and meet human comfort criteria. For this purpose, it is imperative to have a good understanding of the effects of loads on this type of structure. In this context, the actions caused by pedestrians involve, in most cases, the control of comfort issues and not of structural stability. To ensure acceptable levels of comfort, some strategies can be implemented which aim to mitigate vibrations in footbridges. One of the possible forms of action is to move away from the resonance frequencies (natural) of the footbridge from the typical frequencies of pedestrian actions, which can be achieved by increasing the stiffness of the structure or just the deck. However, the mass increase generally associated with the stiffness increase negatively affects the aesthetics of the footbridge. On the other hand, the increase in structural damping is currently the most frequent and effective measure in the attenuation of vibrations associated with pedestrian actions. In this sense, the structural use of fibre-reinforced polymer composite materials, based on a polymeric matrix, is a feasible strategy to mitigate, or even control, excessive vibrations that may generate discomfort to users because it combines the structural versatility of polymer-based composites (stiffness, lightness and durability) with its high damping capacity. These materials present a dynamic behaviour that can be described by the viscoelasticity theory, according to which polymeric materials, when subjected to harmonic load cycles, present harmonic deformation cycles, with the same frequency, but with a phase delay about the corresponding load cycles, which characterises the material damping. In this thesis, the viscoelastic damping capacity of polymer-based composites was investigated and its applicability to the composition of a walkway was assessed, taking advantage of the characteristics and benefits that can result in the dynamic behaviour of these structures. The thesis is composed of five papers that have been published or submitted for publication. The first three papers focus on viscoelasticity and the behaviour of polymeric materials (and their composites), namely the creep and relaxation functions and their relationship with the dynamic storage and loss modulus. Based on the Exponential-Power Law, two new methods of data fitting in viscoelasticity were presented. In the last two papers, an experimental campaign was conducted to investigate the dynamic behaviour of glass fibre reinforced polymer (GFRP) based composites. Initially, through laboratory experiments of beams with free support, and applying modal identification methods, the aim was to identify and quantify the difference in damping of steel and a GFRP composite, demonstrating that the damping of the latter is higher than that of steel. Finally, based on environmental vibration tests and impact tests, a campaign of modal identification tests of the São Silvestre footbridge, located in the city of Ovar, Portugal, produced with GFRP profiles and steel fibre reinforced self-compacting concrete (SFRSCC) deck, was performed. Through the measured data and with a numerical and analytical analysis, it was possible to demonstrate that the GFRP structure of the pedestrian bridge has damping characteristics capable of attenuating the vibrations of the structure.

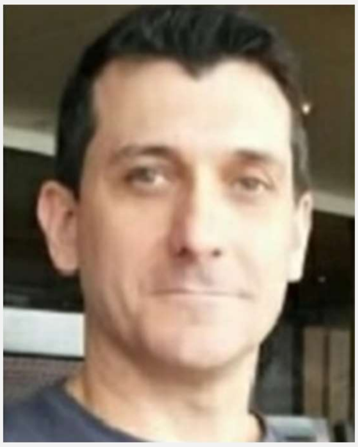
Keywords

Viscoelasticity, composites, GFRP, natural frequency, damping, Dynamic Behaviour, dynamic mechanical analysis, footbridges.



Dynamic characterization of free-supported FRP-Beam

Dynamic characterization of GFRP-SFRSCC hybrid footbridge



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