



Application of the continuous wavelet transform on the free vibrations of a steel–concrete composite railway bridge

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ABSTRACT

In this article, the Continuous Wavelet Transform (CWT) is used to study the amplitude dependency of the natural frequency and the equivalent viscous modal damping ratio of the first vertical bending mode of a ballasted, single span, concrete–steel composite railway bridge. It is shown that for the observed range of acceleration amplitudes, a linear relation exists between both the natural frequency and the equivalent viscous modal damping ratio and the amplitude of vibration. This result was obtained by an analysis based on the CWT of the free vibrations after the passage of a number of freight trains. The natural frequency was found to decrease with increasing amplitude of vibration and the corresponding damping ratio increased with increasing amplitude of vibration. This may, given that further research efforts have been made, have implications on the choice of damping ratios for theoretical studies aiming at upgrading existing bridges and in the design of new bridges for high speed trains. The analysis procedure is validated by means of an alternative analysis technique using the least squares method to fit a linear oscillator to consecutive, windowed parts of the studied signals. In this particular case, the two analysis procedures produce essentially the same result.

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1. Background

The dynamic properties of railway bridges are known to depend on a rather large number of phenomena. These consist of soil–structure interaction, train–bridge interaction, interaction between the track and the bridge superstructure and the material properties of the structure. For certain bridge types, some of these phenomena give rise to more or less pronounced non-linearities, which may have noticeable effects on the dynamic properties of the structure [1].

Today, many railway owners wish to upgrade existing bridges to meet the increasing demand on train speed and axle loads. In this context, the damping ratio is highly important and can have a large influence on theoretical estimates of the dynamic response of the structure. Also, in the design of new railway bridges for high-speed railway lines according to the Eurocode [2], the vertical bridge deck acceleration is often decisive for the dynamic analysis. The vertical bridge deck acceleration must be limited in order to ensure that the wheel–rail contact is maintained and to eliminate the risk for ballast instability in the case of ballasted railway bridges. For these reasons, it would be desirable to learn more about the phenomena governing the dissipation of energy in railway bridges.

One approach to increasing our knowledge within this field would be to establish a reliable experimental methodology to determine how the damping ratio varies with the amplitude of vibration and then use that knowledge as a basis for theoretical studies of the phenomena which are believed to govern this behavior. For this purpose, alternative methods should be used to verify the outcome of the experimental procedures. This paper aims at describing the application of such an alternative, namely the *Continuous Wavelet Transform* (CWT). This mathematical tool has traditionally been applied in quantum mechanics and signal analysis [3,4], but during later years, several authors have presented applications in system identification and to some extent also damage detection (see [5] and the references therein), though most publications describe theoretical and/or laboratory studies. Staszewski [6] used the CWT to estimate the damping of simulated linear and non-linear multi degree of freedom systems with additive noise, based on the assumption that the system is viscously damped. Slavič et al. [7] succeeded in applying the CWT to experimental data produced in a laboratory, for a linearly elastic, viscously damped beam. Le and Argoul [8] described procedures to identify the eigenfrequencies, damping ratios and mode shapes of linear structural systems from free vibration data by means of the CWT. An extension towards applications of the CWT to identify non-linear systems was suggested by Staszewski [9] where the CWT was used to estimate the skeleton (the variation of the amplitude with time) of different signals. These concepts were further elaborated by Ta and Lardies [10], who applied their methodology to simulated numerical data and

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