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Dynamic Tests of a Railway Viaduct

Jorge Rodrigues[1], Maíra Ledesma[1]
[1]Structures Department, LNEC – National Laboratory for Civil Engineering, Lisbon, Portugal
email: Jorge.Rodrigues@lnec.pt, mledesma@lnec.pt

ABSTRACT: This paper refers to the dynamic tests of a railway viaduct that were performed shortly after the end of its construction as part of reception tests that included also static load tests. The dynamic tests consisted in the measurement of railway traffic induced vibrations and in ambient vibration measurements. The paper presents, therefore, the results obtained in those tests, both in terms of levels of vibration measured during the passage of trains and also in what concerns the identified dynamic properties. For the modal identification, two procedures were used, the enhanced frequency domain decomposition method (EFDD) applied to the ambient vibration tests data and the covariance driven stochastic subspace identification method (SSI-COV) applied to the free vibrations measured immediately after a train had crossed the viaduct. The results obtained with the two identification procedures are in good agreement, but with larger damping values evaluated from the free vibration records. The identified dynamic characteristics were also compared with the frequencies and mode shapes computed with finite element models and a good agreement was obtained between the experimental and model results.

KEY WORDS: Railway viaducts; Dynamics tests; Modal identification; Railway traffic induced vibrations.

1 INTRODUCTION

There are several types of dynamic tests that can be performed for modal identification of civil engineering structures, namely, forced vibration, ambient vibration and free vibration tests. In forced vibration tests, adequate excitation equipments are used to apply the dynamic forces that, therefore, are under control by the persons performing the tests. Ambient vibration tests take advantage of the natural dynamic loads that usually excite a structure, like wind, micro-tremors, traffic in the vicinity of the structure or, in the case of bridges, passing over it. Free vibration tests have also been applied with success, consisting in imposing an initial deformation to the structure, by hanging a weight or pulling a cable, followed by its sudden release and consequent free vibration of the structure.

In railway bridges the traffic of trains introduces vibrations of considerable level and at the end of a train passage there is a situation of free vibration of the structure that, usually, can be clearly identified in the corresponding vibration records. This last part of the records, of railway traffic induced vibrations, can be used for modal identification purposes, by applying adequate methods for that situation, like the two stage time domain methods [1]. It is important to note that it is not difficult to obtain such kind of records in railway bridges in normal operation, therefore, the practical advantage of ambient vibration testing, also exists when using the free vibrations after the passage of trains. There is no need for additional excitation equipment and it is not necessary to interrupt the normal operation of the bridges.

It must be noted also that the free vibration records after the train passages, correspond to a higher level of vibration than the one measured in the "ambient vibration" circumstances, without any trains passing on the bridge. The free vibration situation can, therefore, be considered as a better one, especially in what concerns the evaluation of modal damping.

The use of free vibrations, measured after the passage of trains, for the identification of the dynamic properties of railway bridges has been reported previously by the authors [2] and it is further explored in this paper, where the results obtained in another structure are presented.

This paper refers, therefore, to the dynamic tests performed on a railway viaduct located in Santana do Cartaxo, in the region of Ribatejo in Portugal. This viaduct is integrated in the North Line of the Portuguese Railways Network, which connects the three major cities of the country (Lisbon, Porto and Coimbra) and therefore is subjected to intense railway traffic.

The dynamic tests of the Santana do Cartaxo Viaduct were part of the reception tests performed shortly after the end of its construction and included also static load tests. The dynamic tests were performed in a situation of normal operation with trains already crossing the viaduct. They consisted in the measurement of the railway traffic induced vibrations and in ambient vibration measurements. This paper presents, therefore, the results obtained in those tests, both in terms of levels of vibration measured during the passage of trains and also in what concerns the identified dynamic properties.

For the modal identification, two different types of testing data and analysis methodologies were used. In the first one, the ambient vibration records were considered to apply the enhanced frequency domain decomposition method (EFDD) [3, 4]. In the second methodology the free vibrations, measured immediately after a train crossed the viaduct, were considered to apply the covariance driven stochastic subspace identification method (SSI-COV) [5].

The results obtained with the two modal identification procedures are compared with each other and with the frequencies and mode shapes computed with finite element models.