21st International Conference ENGINEERING MECHANICS 2015
Svratka, Czech Republic, May 11 –14, 2015
Paper #219, pp. 24–25

Full – Scale Testing of the Highway Arch Viaduct

Jan Benčat

University of Žilina, Research Centre of UZ, Univerzitna 1, 010 26 Žilina, Slovak Republic

jan.bencat@gmail.com

Keywords: bridge structures, railway viaducts, modal identification, full - scale dynamic testing, static and dynamic, loading tests, spectral analysis

Abstract: Full–scale dynamic testing of structures can provide valuable information on the service behavior and performance of structures. With the growing interest in the structural condition of highway bridges, dynamic testing can be used as a tool for assessing the integrity of bridges. From the measured dynamic response, induced by instructed passing trucks, modal parameters (natural frequencies, mode shapes and modal damping values) and system parameters (stiffness, mass and damping matrices) are obtained. These identified parameters can then be used to characterize and monitor the performance of the structure in the future. Analytical models of the structure can also be validated using these parameters [1,2].

Introduction

This paper refers the assessment of dynamic tests parameters of the highway viaduct [3] that were performed shortly after the end of its construction as part of standard requiring tests that include also static load tests. The *dynamic tests* consisted in the measurement of heavy lorries induced vibrations. Excitation of the bridge was performed by 25 tons testing lorries crossing the bridge with scheduled runs and known variable speeds. Further details of instrumentation layout, test and data processing procedures adopted are given in [1,2].

The paper presents, therefore, the results obtained in those tests, both in terms of levels of vibration measured during the passage lories (e.g. dynamic load factor – DLF) and also in what concerns the identified dynamic properties. For the experimental modal parameters identification the spectral procedures via software package *NI LabView* were used [4]. The identified bridge dynamic characteristics were also compared with the frequencies computed with finite element models and a good agreement was obtained between the experimental and FEM results.

Description of the Highway Viaduct and FEM

Highway viaduct description. The steel arch highway *Viaduct Structure 205* (*BS 205*) constructed on Highway D1 in the northern part of Slovakia (*Spiš region*) crosses part of this region. The viaduct bridge consists of two independent bridges (left and right bridge – LB and RB) with two traffic lanes, on each bridge for one direction only and sidewalks on both sides. The *Viaduct Structure 205* (*BS 205*) has a long length in total 670 m, but is composed by 9 dilatation modules (DM) that are structurally independent with common transition piers. Seven arch steel structure modules (DM2 – DM8) have a total length of 500 m, with spans 60 + 70 + 80 + 80 + 80 + 70 + 60 m. The remaining two modules (DM1 and DM9) with total length of 2 x 84,3 m are bridge junctions from both sides of viaduct.

FEM Calculation. Finite element models were developed in order to help in the preparation of the static and dynamic tests and in the interpretation of their results. The software FEM – IDA NEXIS 32 [5] was used for that purpose. Different models were developed for the tested modules since there is a slight difference in their geometry. Since there are several structural and material parameters that would affect the modal behavior of the viaduct bridge, such as the mass, the vertical and transverse bending stiffness of the deck etc., the calibration of the FE model was performed using the results of field vibration measurements.

Dynamic Tests. The dynamic tests of the *BS 205 – Right Bridge* were carried out in May 2010 and dynamic tests of the *BS 205 – Left Bridge* in November 2012, [1,2].

Conclusions

The dynamic tests of the viaduct *Bridge Structure 205 – Right Bridge*, allowed measuring the vibrations in the structure induced by a total of 17 runs of different crossing the viaduct with speeds from 4.95 km/h to 50.6 km/h. From the analysis of the levels of vibration, expressed in the *maximum* and *RMS* values of both accelerations and displacements, the following conclusions were taken:

i) The experimental analysis of the bridge dynamic response caused by moving load it possible to identify 10 basic natural frequencies of bridge vibration. These frequencies have been received by analysis of small amplitude vibration and so the analysis corresponds to linear vibration.
ii) In relation to the natural frequencies of vibration, the results obtained by spectral analysis are also in good agreement with the frequencies computed with finite element models.
iii) The experimentally achieved values of dynamic load factor $\delta_{EXP}(v)$ shows the real stiffness of structure is fully comparable with the corresponding standard value of the dynamic load factor δ (DLF) used by the designer for the bridge structures according to relevant standards [6,7].
iv) The logarithmic decrement corresponding to the first mode of the bridge vibrations varies in the range 0.16 ÷ 0.25, then the damping ratios of the steel bridge structure were found to be 0.025 % ÷ 0.040 % of critical damping, respectively. It was possible to evaluate the damping characteristics of the bridge structure only from limited number of measurements. They are therefore only indicative.
v) The comparison of the numerical and experimental results of the bridge parameters shows good agreement of theoretical and experimental values of natural frequencies and DLF respectively. The required criteria of all loading states by the Slovak standards have been also fulfilled. It should be noted that the recorded levels of vibration and the identified dynamic characteristics are an important contribution for the characterization of the global behavior and condition of the viaduct *Bridge Structure 205* and of the dynamic effects of future highway traffic [8,9].

Acknowledgments: We kindly acknowledge the project "Research Centre of University of Zilina", ITMS 26220220183, supported by European regional development fund and Slovak state budget.

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