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EIGENVIBRATION OF ROAD BRIDGES: MEASUREMENT AND NUMERICAL ANALYSIS

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Abstract: *Experimental and numerical analysis of existing highway concrete prestressed bridges were done. In order to obtain good agreement between the numerical and experimental analysis, threedimensional finite element models of the bridges were used. The eigenfrequencies and eigenmodes were obtained by the subspace iteration method with Gram-Schmidt orthonormalization in the reduced problem. The eigenfrequencies and eigenmodes obtained from the numerical analysis and from experiment were compared and very good agreement was attained.*

Keywords: ***highway bridges, eigenmodes, eigenfrequencies, experimental analysis, subspace iteration method.***

1. Introduction

The bridges analysed are highway concrete prestressed bridges in Prague. They are six-span structures made from the concrete C35/45-XF2+XD1. The length of the left bridge is 560.976 m while the right bridge has the length 551.540 m. Both bridges are horizontally curved with radius 747.5 m and 753.75 m for the left and right bridge, respectively.

2. Finite Element Model

With respect to the complicated bridge geometry, a three-dimensional finite element model was created. The model is based on brick finite elements with eight nodes and linear approximation functions. The three-dimensional model was used because of the curved shape of the bridge. In order to generate the mesh as easily as possible, the bridge was modelled as a straight one and a special short computer code was developed which bends the original mesh into the curved one. Special attention was devoted to the bridge bearings. In order to describe the bearings correctly, local coordinate systems were defined in the nodes of the mesh because of the movable supports.

In the finite element model, the bridge piers were replaced by a set of 588 springs. The bridge piers were modelled separately because they are also curved and even non-prismatic. Each pier was described by its three-dimensional model and all neccessary stiffnesses were obtained. The bridge stiffeners near the bridge supports were also modelled by spring elements. The mesh contains 51 642 nodes, 39 750 finite brick elements, 588 bar elements representing the bridge piers and stiffeners, 154 926 unknowns (degrees of freedom). The generalized eigenvalue problem was solved by the subspace iteration method Bittnar and Šejnoha (1996). System of linear algebraic equations is solved by a sparse direct solver based on modified minimum degree algorithm which can be found e.g. in reference Kruis (2006).

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3. Experimental Modal Analysis

The experimental modal analysis was performed for both highway bridges. The electrodynamic exciter TIRAVIB 5140 was used for excitation. The position of the exciter was determined based on the calculated eigenmodes to be able to excite basic natural modes of the bridge, it was placed in one third of the 4th span on the left side of the bridge cross section. Sensors should be located in antinodes because of significant displacements which can be measured more precisely than small displacements near the vibration nodes Polák et al (2005). The driving force was measured using three force transducers S35 LUKAS located between the exciter and the bridge. The force transducers were connected to one channel to measure the total driving force. The response of the bridge was measured by six acceleration transducers B12/200 Hottinger Baldwin Messtechnik (HBM).

The response measurement was done only from the 3rd to the 6th span of the bridge because of the character of the calculated eigenmodes which have the amplitudes of the mode shapes much higher in the spans No. 3, 4 and 5 than in the first two spans. The lengths of the 3rd, 4th and 5th measured spans of the bridge were divided into ten equal parts and the length of the 6th span was divided in four parts. The response was measured in five points in each cross section on the upper road surface. The point positions were determined based on the finite element model. The total number of measured cross sections was 35 and the total number of measured points was 175 on each bridge. The vibration of the bridge was measured in the vertical direction in all points in the first part of the experiment and in the horizontal direction in the second part. The temperature was measured during the experiments with respect to the methodology published in reference Polák and Plachý (2010).

The time data records of the response were saved during the measurement and evaluated in off line mode on the control computer. The Frequency Response Function (FRF) was evaluated for each point of measurement. The values of the Frequency Response Functions were determined as an average of the 8 measurements with 75% overlap of the windows. The length of each signal window in time domain was 64 s, the frequency range of the window was set to 10 Hz. According to the fact that the excitation force could be affected by additional dynamic forces, the Operating Deflection Shapes Frequency Response Functions (ODS FRF) were evaluated.

4. Conclusions

The measured eigenfrequencies and eigenmodes were compared with the eigenfrequencies and eigenmodes obtained from numerical analysis based on the finite element three-dimensional model because of the curved shape of the bridges. All compared eigenfrequencies satisfy conditions given in the code ČSN 73 6209. The experimentally obtained eigenmodes contain the same number of vibration nodes and lines as the numerically obtained eigenmodes. Moreover, the vibration lines are located in the same bays of the bridges.

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