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Experimental Testing of a Bridge

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Abstract. The submitted paper is dedicated to describing of experimental processes and experimental technique needed for realization of experimental tests. The dynamic loading test was carried out on the monitored bridge. The time courses of bridge vertical displacements were registered. The power spectral densities of obtained records were used for determination of the basic natural frequency. The experimentally obtained results were compared with numerically obtained ones.

Introduction

Fundamental natural frequency of a bridge represents the important characteristic defining the dynamical properties of a bridge structure [1]. It can be obtained by numerical or experimental way. The best way is the combination of both mentioned advances. The experimentally tested so called Varin Bridge is situated near the town Zilina, Slovak Republic, Fig. 1.

Fig. 1 The Varin Bridge

The bridge is composed from three single supported bridge spans. In every field there are 8 reinforced factory made beams of the type I-73 with the span 29 m. The height of the beams is 1,4 m. The concrete of the class B500, modulus of elasticity E_b = 38,5 GPa.

Experimental technique

For the registration of the dynamic bridge response the accelerometers Bruel – Kjaer BK 8306 with amplifiers BK 2635 were employed. The frequency band of accelerometer is 0,3 – 1000 Hz. The amplifiers BK 2635 operate also as integration unit. So the output signal can represent the values of accelerations or deflections. In this specific case the deflections were observed. Signals from the sensors were leaded by means of coaxial cables to measuring central. Measuring line consists from these components: sensor, amplifier, signal cable, AD interface, operating computer, Fig. 2. Analog signal was transformed by the AD interface to numerical values. The sampling frequency 1000 Hz was used during digitizing. All the analyses were carried out by numerical way through the program system DISYS. The sensor was located on the edge of pavement in the bridge mid-span. The bridge response on the passing of vehicle Tatra T815 was registered. The so called smooth runs and runs over standard obstacle were realized.

Fig. 2 The view on the measuring string

Analysis of experimentally obtained data

The consideration about basic bridge natural frequency was carried out on the basis of frequency analysis of vibration records. The power spectral densities were used for the analysis of frequency composition of bridge vibration. The power spectral densities were obtained by numerical way using the program system DISYS. The Fast Fourier Transformation was used at calculation of power spectral densities. The sections containing 4096 samples were analysed. Hanning weight window was used during analysis. The whole records or its selected sections were analysed. Typical record of displacements, representing the dynamic component of bridge mid-span vertical vibration, is illustrated in the Fig. 3. Power spectral density calculated from this record is on the Fig. 4. The dominant peak in power spectral density corresponds to frequency f = 4,042 Hz.

In the next step only the final part of the record corresponding to the free bridge vibration after going off the vehicle from the bridge was analysed, Fig. 5. Power spectral density calculated from this final part of the record is on the Fig. 6. The peaks in both power spectral densities, Fig. 4 and Fig. 6, corresponding to frequencies f = 4,042 Hz and f = 4,046 Hz are uniquely interconnected with the bridge vibration in the 1st natural mode and they represent the experimentally verified value of the 1st natural frequency.

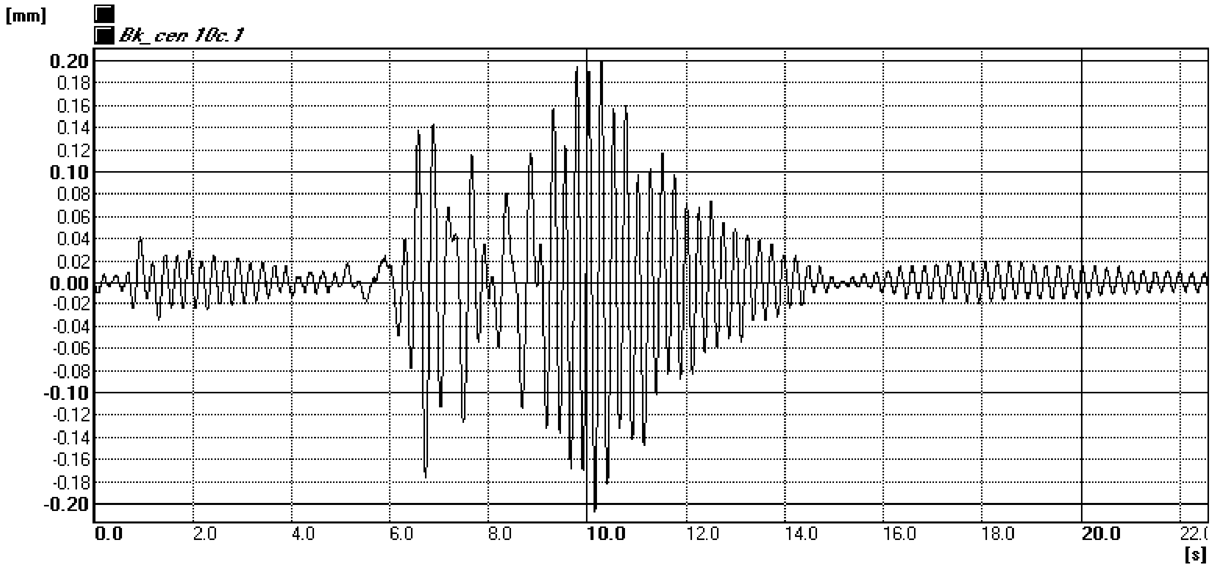


Fig. 3 Dynamic component of vertical mid-span displacement, record No. 10

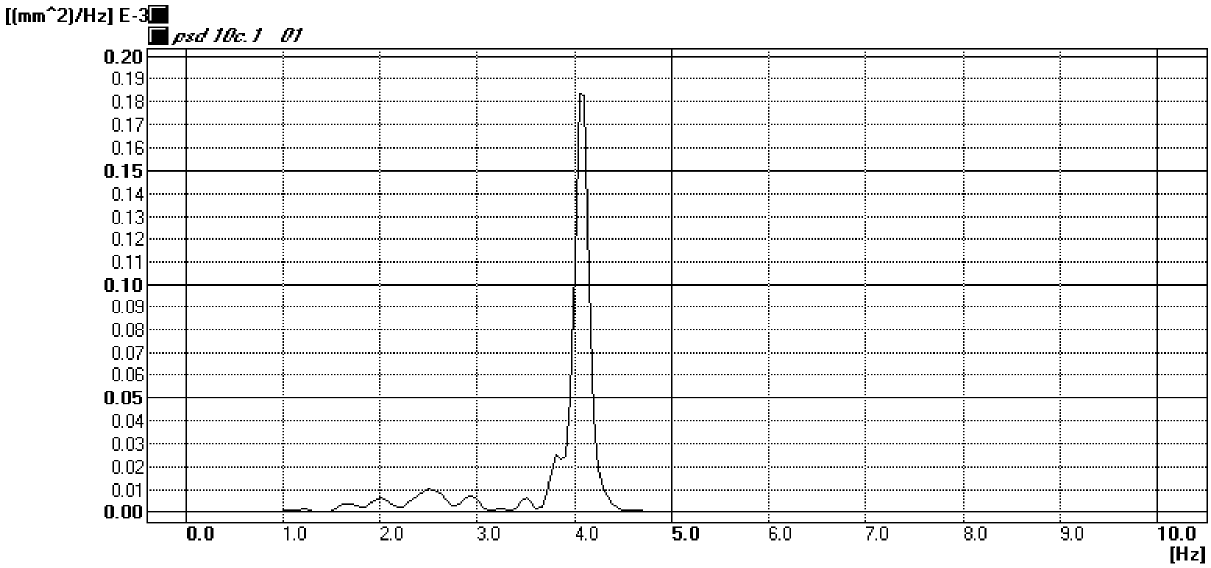
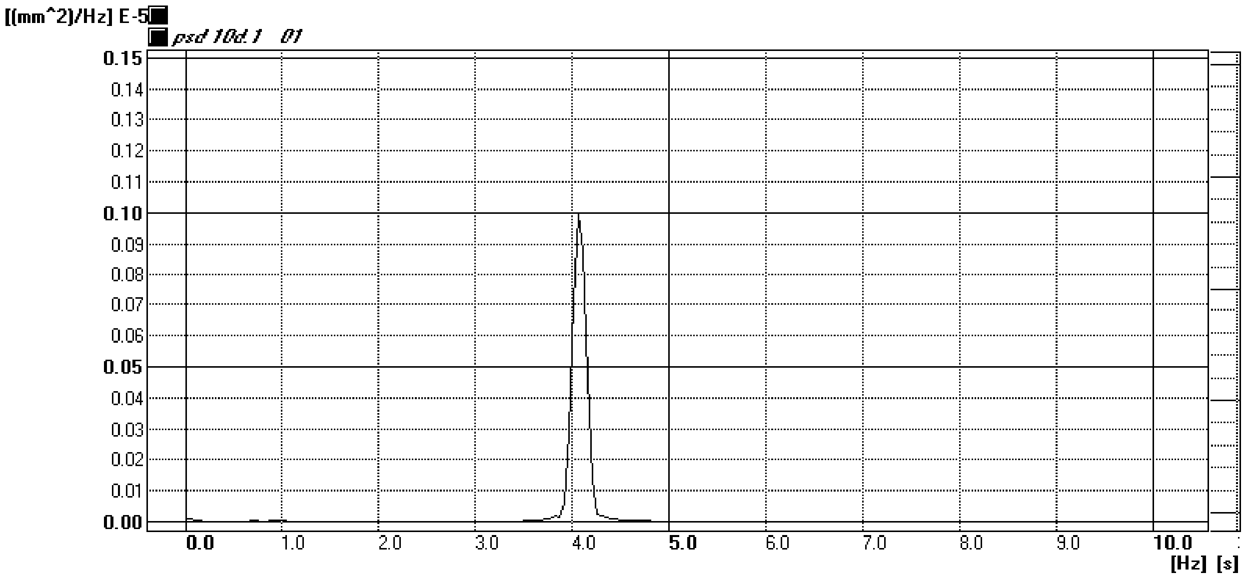


Fig. 4 PSD evaluated from the whole record No. 10, f = 4,042 Hz
Fig. 5 Final part of the record No. 10
Fig. 6 PSD evaluated from the final part of the record No. 10, f = 4,4046 Hz

The 1st mode of the bridge vibration is represented by bending surface in the shape of sine half – wave. When vehicle passes along the bridge, the structure deforms to the bending surface very



similar to the 1st natural mode. This fact give a hand to the fact that the bridge starts to vibrate by the frequency very closed to the 1st natural frequency. Such vibration is obvious mainly after going off the vehicle from the bridge. Free vibration closed to vibration in the 1st natural mode can be very good excited by passing of vehicle over artificial unevenness in the shape of standard obstacle situated before the bridge mid-span. The load occurs after passing of vehicle over obstacle, especially in the case of losing contact between pavement and the tire, has the character of impulse load. From the theory of impulse load we know that the response of a dynamical system on the short time impulse load is vibration in some natural mode. This fact is uniquely confirmed by the frequency analysis of all vibration records induced by passing of vehicle over standard obstacle. The typical record of the dynamic component of vertical mid-span displacement excited by passing of vehicle over standard obstacle is in the Fig. 7. Power spectral density calculated from this record is on the Fig. 8. Dominant peak in power spectral density corresponds to frequency f = 4,048 Hz.

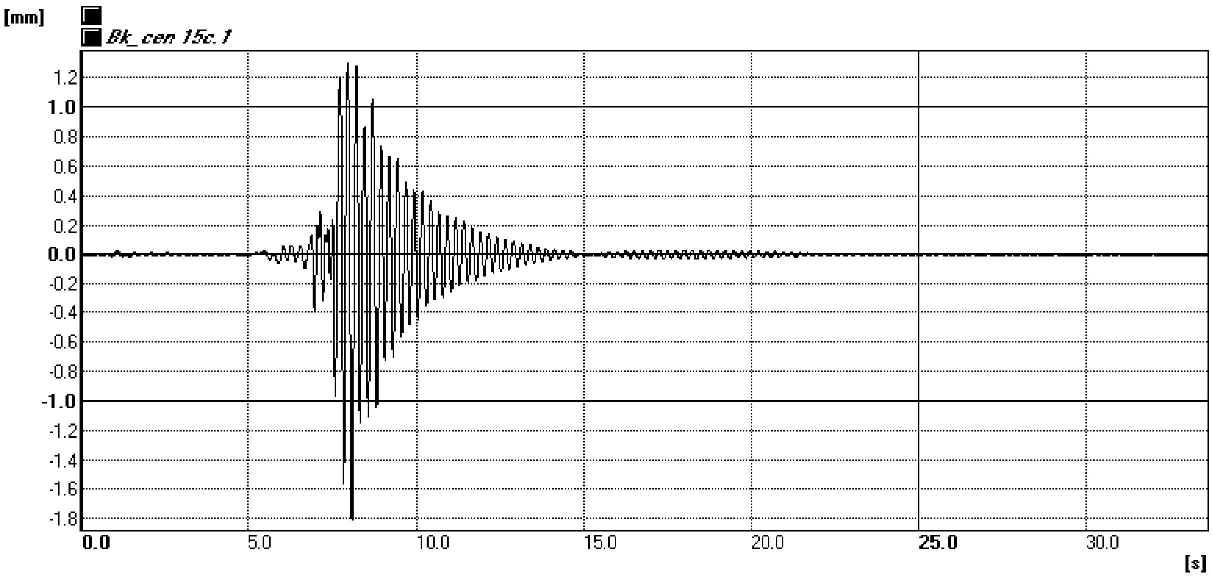


Fig. 7 Dynamic component of vertical mid-span displacement, record No. 15, standard obstacle

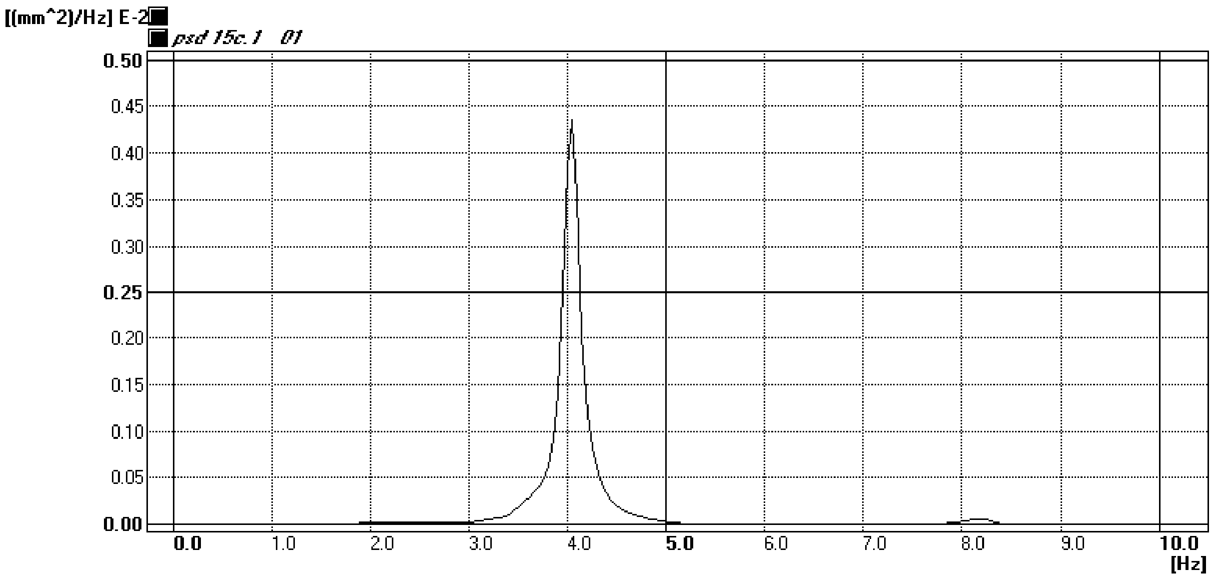


Fig. 8 PSD evaluated from the whole record No. 15, f = 4,048 Hz

Numerical calculations

The natural frequencies and natural modes of the bridge structure were calculated by the use of finite element method in program system ANSYS. For the creation of computing model the SHELL 181 elements were adopted, [2]. The values on natural frequencies are in the Table 1. The 1st natural mode of the bridge vibration is plotted on the Fig. 9.

Table 1 Natural frequencies of the Varin Bridge

Mode No.	Frequency (Hz)	Mode No.	Frequency (Hz)	Mode No.	Frequency (Hz)	Mode No.	Frequency (Hz)
1	4,0355	6	24,7479	11	35,5395	16	53,3326
2	8,4236	7	25,0567	12	37,6682	17	54,6023
3	14,9014	8	33,2280	13	46,6942	18	54,7077
4	17,2741	9	33,8214	14	47,5195	19	60,3689
5	20,0797	10	35,2380	15	51,5661	20	62,4498

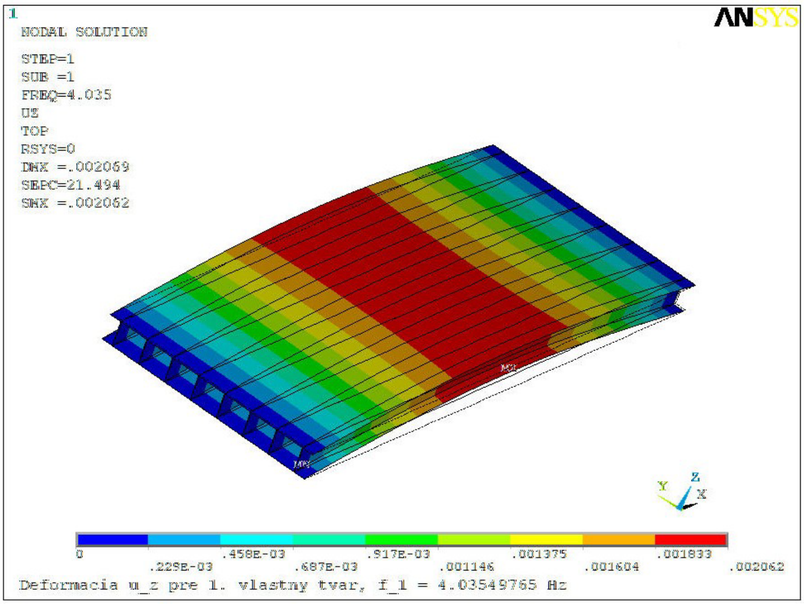


Fig. 9 The 1st natural mode of the Varin Bridge vibration

Summary

Natural frequencies and natural modes represent the important characteristics uniquely defining the dynamic individuality of every dynamic system. The knowledge of these characteristics is important during verification of computing models and during prognosticating of structure response on the known dynamic load. At the single supported one span bridge structure it is important to know the fundamental natural frequency. Because the results of experimental tests verify that the bridge vibration in the 1st natural mode represents more than 80 % of the power of the final vibration. The 1st natural frequency of the single supported one span bridge structure can be reliably verified by unpretentious experiment using one sensor only. In the case of the Varin Bridge the experimentally verified the 1st natural frequency floats in the interval $f_{e(1)} = 4{,}042 \div 4{,}048$ Hz. This result very good corresponds to the frequency obtained by numerical way $f_{n(1)} = 4{,}035$ Hz.

Acknowledgements

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