EAN 2019
57th conference on experimental stress analysis

Using technical seismicity to identify some modal characteristics of a bridge

MELCER Jozef[1,a]

[1]Department of Structural Mechanics and Applied Mathematics, Faculty of Civil Engineering; University of Žilina; Univerzitná 8215/1, 010 26 Žilina, Slovak Republic

[a]jozef.melcer@fstav.uniza.sk

Keywords: Modal characteristics, Technical seismicity, Experimental test, Numerical modelling, Bridge structure

Abstract. There are characteristics which define the dynamical individuality of every structure from dynamical point of view. The knowledge of these characteristics is important especially in case of bridge structures. The presented paper is dedicated to the numerical simulation and experimental validation of some modal characteristics of a bridge structure. The random bridge response on the excitation due to technical seismicity from rail transport is analysed. The results of analyses of vibration records offer values suitable for verifying numerical procedures.

Introduction

Natural frequencies and natural modes represents the basic characteristics defining the dynamical individuality of all dynamical systems [1, 2]. In bridge construction, it is good to know the values of at least the basic natural frequencies [3]. These characteristics can be obtained by numerical or by experimental way. Currently, it is effective to use the FEM computational model and the required characteristics to obtain numerically [4]. However, the experiment is the only way to verify numerically obtained results. Therefore, the role of experiment in mechanics is indispensable. The present article describes one of the possibilities of experimental verification of some natural frequencies of a bridge.

Numerical solution

The subject of the analysis is the bridge construction with three fields. Each field acts statically as a single supported beam with a span of 29 m. Bridge width is 11.50 m. The bridge is made of prefabricated elements I73, Fig. 1.

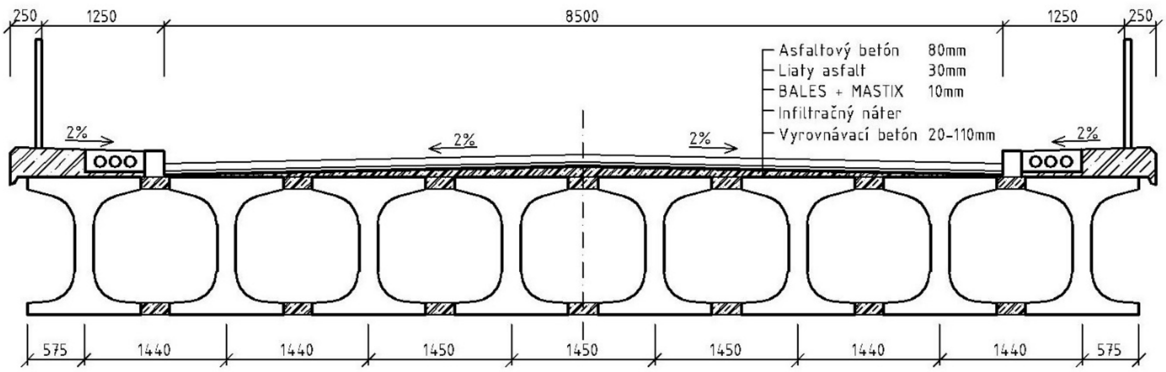
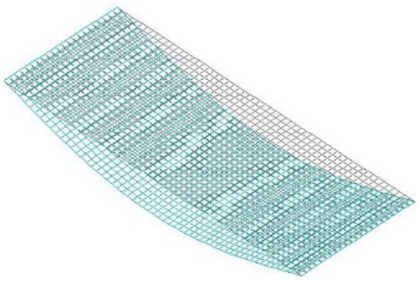
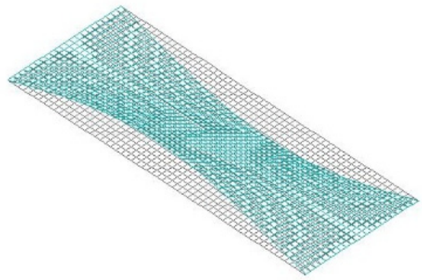


Fig. 1: Cross section of the analysed bridge

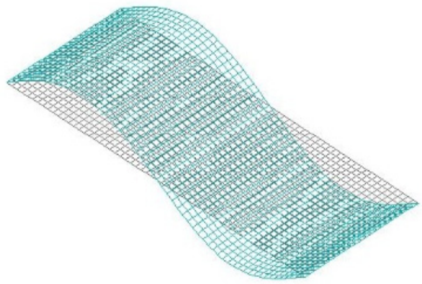
The FEM computational model using the deck-wall elements was created for the bridge. A quadrangular, eight nodal, Mindlinian element is used [4]. The element has nodes in the quadrilateral corners and at the centre of the sides. The centre nodes have like unknowns the components of displacement vector $\{\mathbf{u}\} = [u, v, w]^T$, the corner nodes have like unknowns the components of displacement vector $\{\mathbf{u}\} = [u, v, w]^T$ and the components of rotation vector $\{\boldsymbol{\varphi}\} = [\varphi_x, \varphi_y, \varphi_z]^T$. The model had 812 finite elements. On this computational model, natural frequencies and natural modes were calculated. As an example, Fig. 2 shows the first four natural modes and the corresponding natural frequencies.



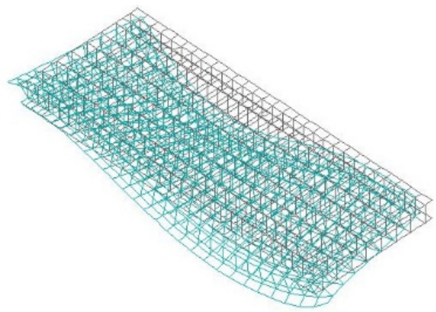
$j = 1,\ f_{(1)} = 4{,}04$ Hz



$j = 2,\ f_{(2)} = 10{,}59$ Hz



$j = 3,\ f_{(3)} = 14{,}89$ Hz



$j = 4,\ f_{(4)} = 19{,}44$ Hz

Fig. 2: The first four natural modes and the corresponding natural frequencies

Experimental test

To verify the results of numerical calculation the experimental test on the bridge structure was carried out. As a source of kinematic excitation, subsoil vibration caused by the passage of trains under the first bridge field was used. It is the analysis of the bridge's response to technical seismicity induced by rail transport. Acceleration sensorsVB12VD 150040 from MMF (Metra Mess Frerquenztechnik) were used to measure bridge vibration. The sensors operate linearly in the frequency range 0.15 - 260 Hz. The signal is amplified by the charge amplifier M68 (also from MMF), Fig. 3. The amplifier serves as an integrator and low-pass filter. The voltage signal is digitized in an analogue - digital converter and it inputs to the computer in digital form. The NI 9215 converter from the firm National Instruments was used, Fig. 4. The signal is stored and further processed by the computer, Fig. 5. DYSIS system was used to analyse the measured signals. The second bridge field was measured. The sensors were placed on the sidewalk in half and a quarter of the span, Fig. 5. The view of the tested bridge and the measuring centre located under the bridge is shown in Fig. 6 Comparison of numerically and experimentally obtain natural frequencies can be seen in Table 1.

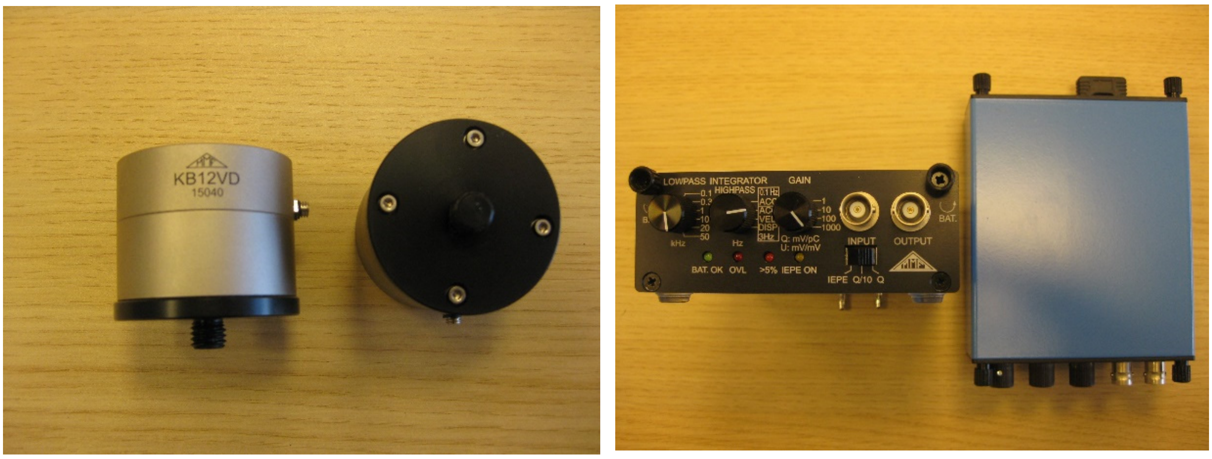


Fig. 3: Sensor VB12VD 150040 and charge amplifier M68

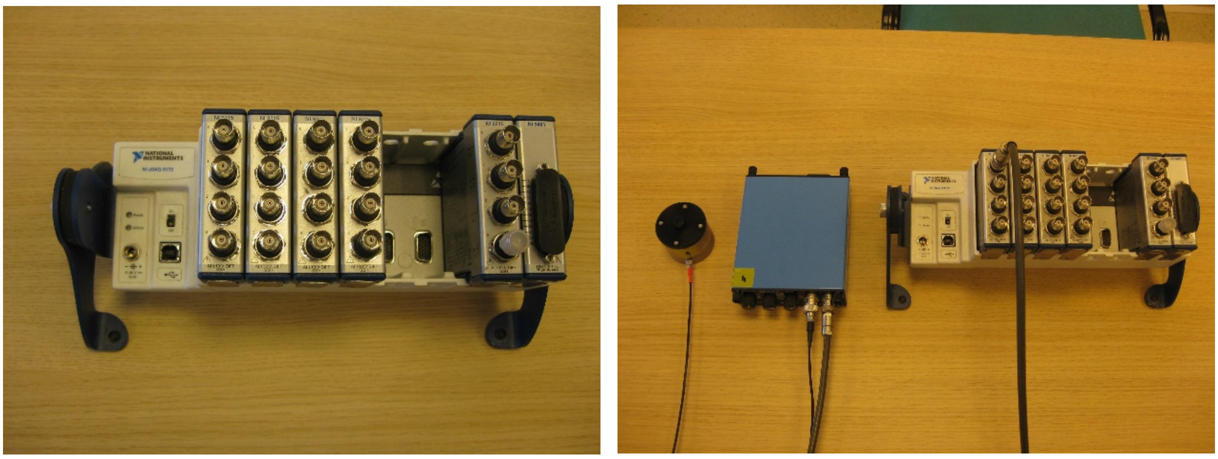


Fig. 4: A/D converter and complete assembly

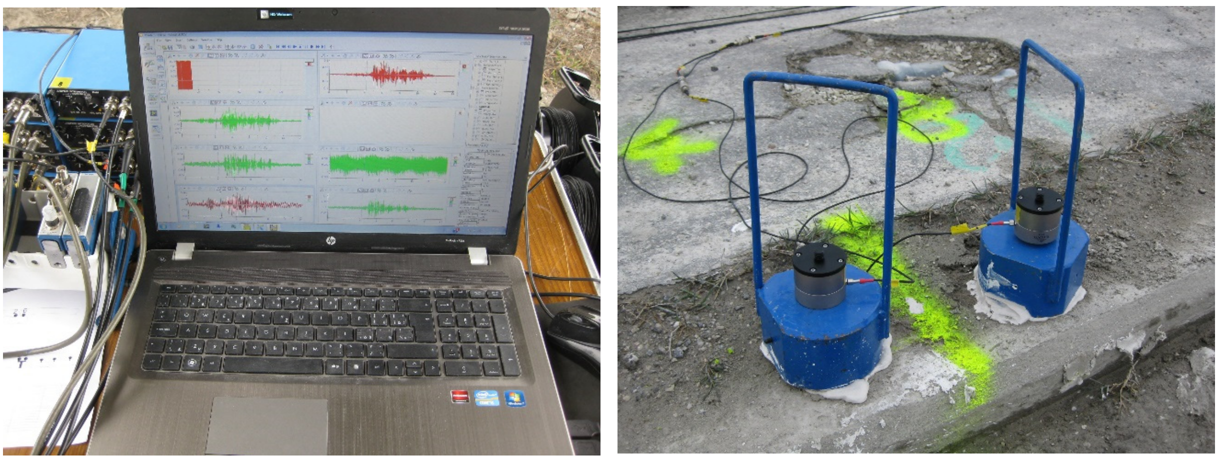


Fig. 5: Final stage – computer and placing sensors on the bridge

Fig. 6: View of the tested bridge and the measuring centre

Table 1: Comparison of numerically and experimentally obtain natural frequencies

Natural frequencies $f_{(j)}$ in [Hz]			
j	FEM model	Experiment	Difference Δf in [%]
1st bending	4.04	4.12	- 1.94
1st torsional	10.59	9.15	+ 15.74
2nd bending	14.89	14.29	+ 4.20
2nd torsional	19.44	19.38	+ 0.31

Conclusions

In the case of bridge structures, experimental verification of numerical results is needed. Some modal characteristics of the bridge can be verified, for example, by analysing the random vibration induced by the technical seismicity. As the results of experimental measurements show the harmony between calculation and experiment is good. The only difference is in the 1st torsional mode of the vibration. The reasons may be more. Their analysis goes beyond the possibilities of this article.

References

[1] D. Kuchárová, J. Melcer, Dynamic of structures (in Slovak), first ed., EDIS, University of Žilina, 2000.

[2] Jimin He, Zhi-Fang Fu, Modal analysis, first ed., Butterworth-Heinemann, Oxford, 2001.

[3] J. Melcer, et. all, Dynamic of transport structures (in Slovak), first ed., EDIS, University of Žilina, 2016.

[4] I. Němec et al., Finite element analysis of structures, principles and praxis, Shaker Verlag, Aachen, 2010.