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DYNAMIC MODELLING AND TESTING OF NEW BRIDGE CROSSING DANUBE IN BRATISLAVA

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Abstract: *The cable–stayed bridges are usually built for long span and are subjected to dead and moving loads, seismic motions of supports to wind forces, temperature and many other forces. The dynamic study of the suspended and cable–stayed bridges was initiated by collapse of the well–known Tacoma Bridge in the USA. The paper deals with the vibration of suspended bridge subjected to the action of moving loads during the regular dynamic tests of the bridge and to point out on the discrepancy that may occur between finite element modelling (FEM) and on–site strain and displacements and acceleration amplitude measurements.*

Keywords: ***Structural response, structures dynamic diagnostics, FEM analysis, bridge dynamic loading tests, natural frequencies and modes.***

1. Introduction

The aim of the paper is based on practical experience from the assessment of the New Bridge crossing Danube in Bratislava, Slovakia, a 431.8 m long with skew pylon 90 m high. The length of the main span crossing Danube is 303.0 m and total width of the bridge deck is 21.0 m. The FE modelling is described and typical problems are outlined. From the regular tests of the bridge results it follows that the assessment results in the ultimate limit state and especially in the fatigue limit state are very sensitive to precise finite element modelling, see the papers (Baťa et al., 1994; Benčat, 2008; Benčat, 2009; Benčat et al., 2009; Ozakan et al., 2003; Troitsky, 1988). Also, a reliable FE–model is a necessary basis for applying more advances assessments such as plastic analysis, fracture mechanic, seismic analysis, etc.

2. FEM analysis

The relevant combination of a detailed and comprehensive finite element modelling, sensitivity analysis, on–site measurements and model updating is crucial for the assessment in order to provide a solid decision basis for the necessary actions to be taken. Despite both the complex structural layout of the bridge (Fig. 1) and simplifying assumptions of the FE model *IDA Nexis* software (Fig. 2), results showed good agreement for all identified frequencies in the basic frequency range 0 – 5 Hz (Fig. 4).

3. Bridge dynamic loading test

The dynamic response tested two spans of the bridge was induced by passing load vehicle *SCANIA* with weight of 15 900 kg in the both directions with various speed. The operating dynamic loading test (DLT) started with a load speed of c = 5 km/h (crawling speed) which increased up to the maximum achievable speed c = 62 km/h.

<u>*A computer – based measurement system*</u> (CBMS) was used to record the dynamic response of the bridge excitations induced by testing vehicle over DLT period. The investigated vibration acceleration amplitudes were recorded at selected points with maximum calculated deflection in each of the investigated two spans (Fig. 1).

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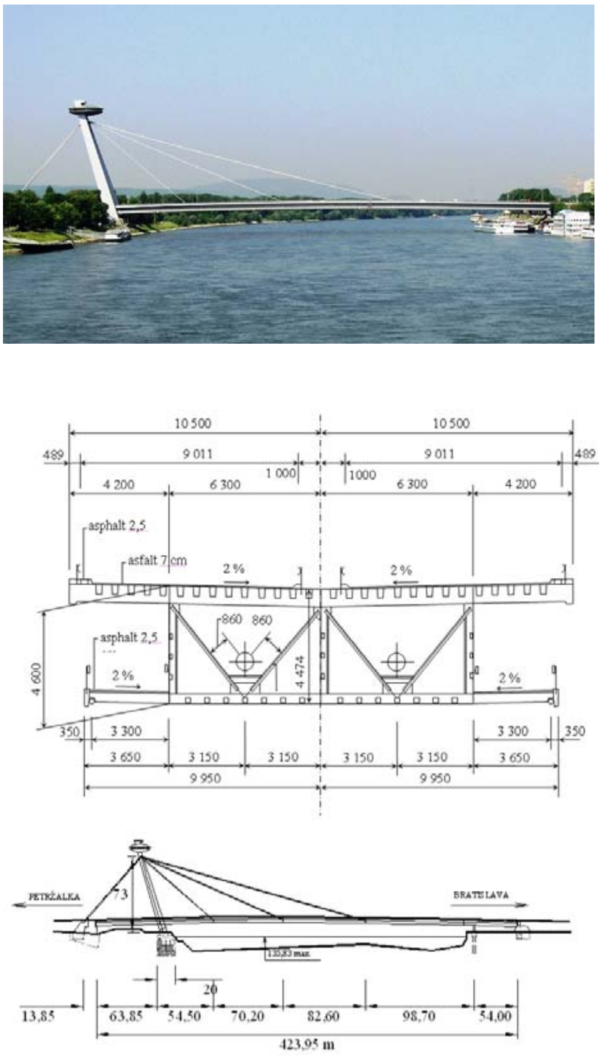

Fig. 1: New Bridge over the Danube in Bratislava.

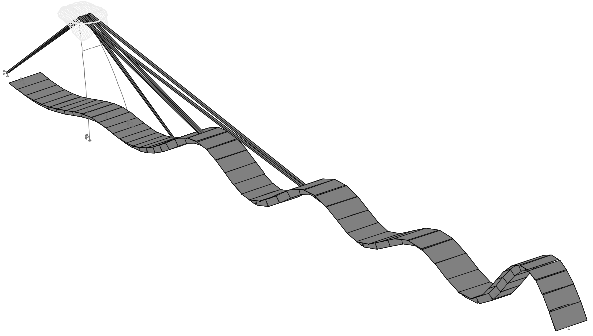

Fig. 2: Natural mode example.

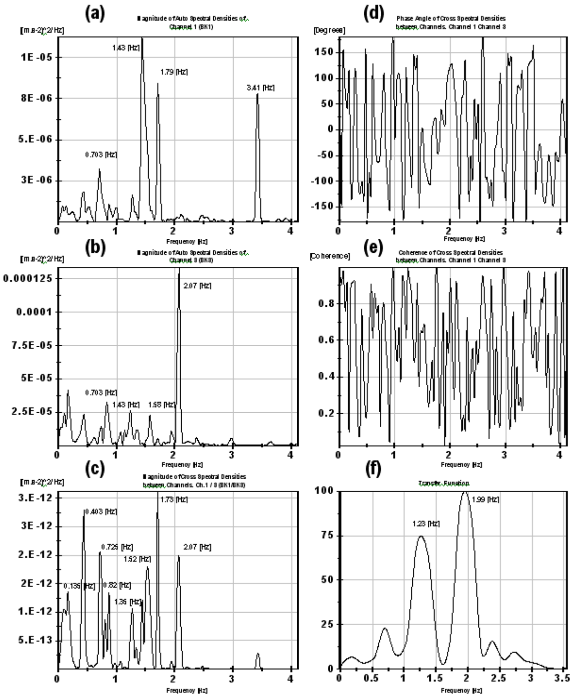

Fig. 3: Spectral analysis procedure functions.

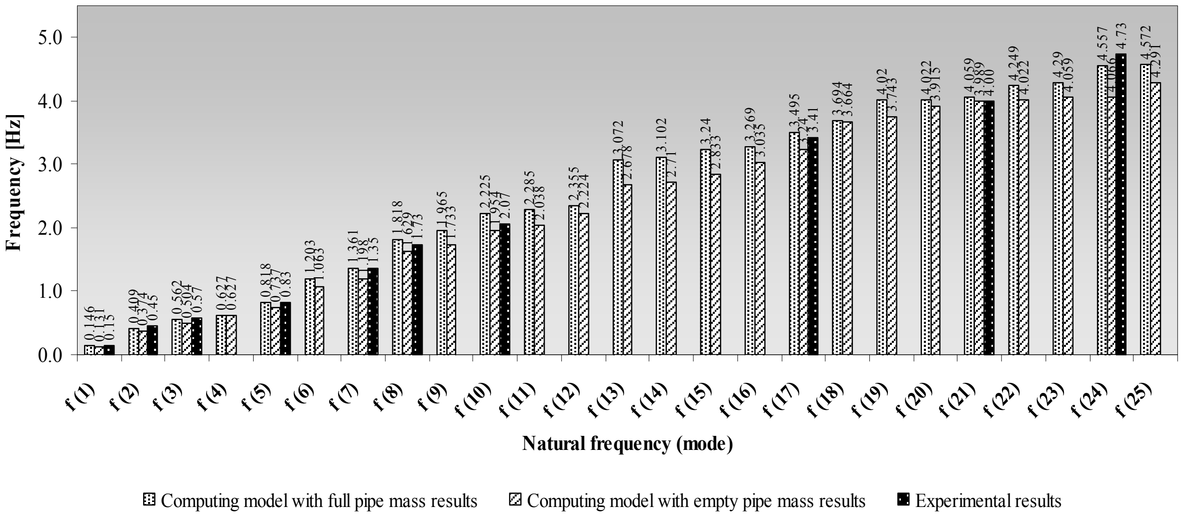

Fig. 4: Calculated and experimental natural bridge frequencies comparison.

In the same points the vibration amplitudes in both vertical and horizontal direction respectively were recorded, by accelerometers *Brüel-Kjaer BK 8306 (BK1…BK4)* with the amplifiers *BK 2635*. In the same points were installed the tensometers *Kistler 9232A* with the amplifiers *Kistler 5011 (K1, BK2)* and in the 1st span of the bridge inductive displacement transducers (relative sensors) *Bosh (R1…R4)* were installed, too. Output signals from the all sensors (accelerometers, tensometers and transducers) were preamplified and recorded on two PC facilities with A/D converters of the software packages *NI LabVIEW* and *DISYS* in the central measuring station *KSM – UZ*.

4. The off - line experimental analysis

Analysis has been carried out in the *Laboratory of the Department of Structural Mechanics, University of Žilina*. *Natural frequencies* were obtained using spectral analysis of the recorded bridge response dynamic components of the structure vibration, which are considered ergodic and stationary. The vibration *ambient ability* has been investigated by means of the correlation and spectral analysis in order to obtain *cross correlation functions* $R_{xy}(t)$ and *coherence function* $\gamma_{xy}^2(f)$. *Spectral analysis*, for example paper (Bendat et al., 1993; Brownjohn et al., 2008; Brownjohn et al., 2010), was performed via *National Instruments* software package *NI LabVIEW*. As an example, Fig. 3 shows a part of the spectral analysis procedure results of the dynamic vertical components structure vibration from the bridge DLT.

The experimental analysis of the bridge dynamic response caused by moving load made it possible to *identify eight basic modes of bridge vibration*. These frequencies have been received by analysis of small amplitude vibration and so the analysis corresponds to linear vibration. From the tests vibration time histories it was possible to predict the *damping characteristics* according to test and monitoring results (Benčat, 2008; Benčat, 2009) by using logarithmic decrement – υ. The evaluation of the *logarithmic decrement* has been done using the bridge free vibration records due to the vehicle moving after their bridge passing. The logarithmic decrement corresponding to the *first* and *second* modes of the bridge vibrations varies in range $\upsilon = 0.024 \div 0.049$.

5. Conclusions

Theoretical and experimental investigation dynamic response of the *New Bridge* over the *Danube in Bratislava* is described in the paper. The following conclusions can be drawn:

- The predicted dynamic behavior of the bridge by a simplified *FEM* analysis calculation was compared to the measured one. Despite both the complex structural layout of the bridge (Fig. 1) and simplifying assumptions of the model (Fig. 4), results showed good agreement for all identified frequencies in the basic frequency range 0 – 5 Hz.
- The experimental analysis of the bridge dynamic response caused by moving load made it possible to identify 8 *basic modes of bridge vibration*. These frequencies have been received by analysis of small amplitude vibration and so the analysis corresponds to linear vibration.
- The experimentally achieved *dynamic load factor (DLF)* shows that real stiffness of structure is fully comparable with the corresponding value for $\delta \approx 1{,}10$ obtained by computation according to *Slovak standard* prescriptions.
- Many different formulas were suggested to evaluate the *DLF* from the experimental data obtained under traffic loading. More recently, researchers have used the ratio of *maximum dynamic response over the maximum filtered response* (used in this analysis) as a definition of the *DLF*. A response range approach was also suggested for *fatigue considerations*.
- Filtering techniques used to extract the static component from displacement or strain signals, obtained from dynamic testing under traffic loading, can have a considerable influence on the *DLF*. Proper filter characteristic should be used, and the static component should be compared with crawling speed test or static deflection from *SLT*, which was performed before *DLT* in this tests.
- This computational model will be applied for the bridge fatigue and seismic analysis before starting a decision making process regarding to the bridge strengthening.
- The results of the correlation and spectral analysis of the time histories of the bridge dynamic response proved ambient ability of the bridge vibration.

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