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DYNAMIC TESTS OF TWO LARGE-SPAN BRIDGES FOR SHM

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Abstract: *Experimental measurements were accomplished at the Port Bridge and the Slovak National Uprising Bridge, both across the Danube River in Bratislava, Slovakia. The Port Bridge is a road-rail steel truss bridge with four spans, length of main span is 205 m. The Slovak National Uprising Bridge is a cable-stayed bridge, length of main span is 303 m. Nowadays both bridges are overloaded, therefore monitoring campaign has already started. The measurements were based on National Instruments system using the accelerometers.*

Keywords: SHM, FEM model, dynamic response, bridge

1. Introduction

Structural health monitoring (SHM) of bridges structure is currently very well developed. Nowadays many scientific teams are working on this topic, e.g. Seo (2015), Colins (2014), Wenzel (2009) and Farrar (1997). The aim of this article is to describe the initial measurements on two bridges with a large expans across the Danube River in Bratislava, Slovakia - the Port Bridge and the Slovak National Uprising Bridge (the SNP Bridge). This research was carried out under the research program APVV No. 0236-12 granted by the Slovak Research and Development Agency entitled “Bridge Structural Health Monitoring via Repeated Dynamic Tests”.

2. Bridge structure

2.1 The Port Bridge

The Port Bridge is a road-rail steel truss bridge across the Danube situated near the port of Bratislava. The prepatory work began in 1977 and was fully operational in 1985. The bridge consists of the main bridge structure, motorway and railway estacades and pedestrian and cyclist footbridge. Length of the bridge is nearly 461m (Fig. 1b) and comprises of four spans with a range of 89.6 m, 64.0 m, 204.8 m and 102.4 m.

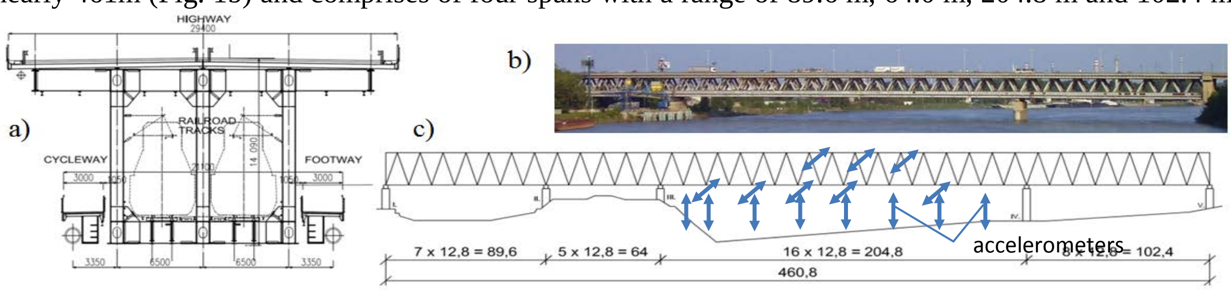

Fig. 1: The Port Bridge - a) cros- section, b) north view, c) side drawing (in m) with accelerometers.

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The structural system consists of a two-storey steel structure consisting of three 14m high steel beam trusses, which are 6.5 m apart (Fig. 1c). There is a part of D1 highway which connects Petržalka and Ružinov district on top of the bridge. There is a two-way railway line as well as console-mounted footbridges for cyclists and pedestrians at the bottom. There are engineering networks with heavy water pipe below these consoles. The bottom structure consists of five reinforced concrete pillars with a hexagon-shaped ground plan which are coniccaly expanded to the top.

2.2 The Slovak National Uprising Bridge

The SNP Bridge is road asymmetric cable-stayed steel bridge across the Danube situated under the Bratislava Castle. Construction was completed in 1972. The bridge is supported by cables from pylon. Total length of the bridge is almost 432 m (Fig. 2b) and consists of three spans, main span is 303 m long. There are three pairs of cables in the main span.

The bridge contains ortotropic 2-box beam which is 4.6 m high and 21.1 m wide (Fig. 2c). There are two lanes in both ways on the top deck. The same as the Port Bridge, there are two consoles for pedestrians and cyclists at the bottom level. Engineering networks are located inside the beam boxes.

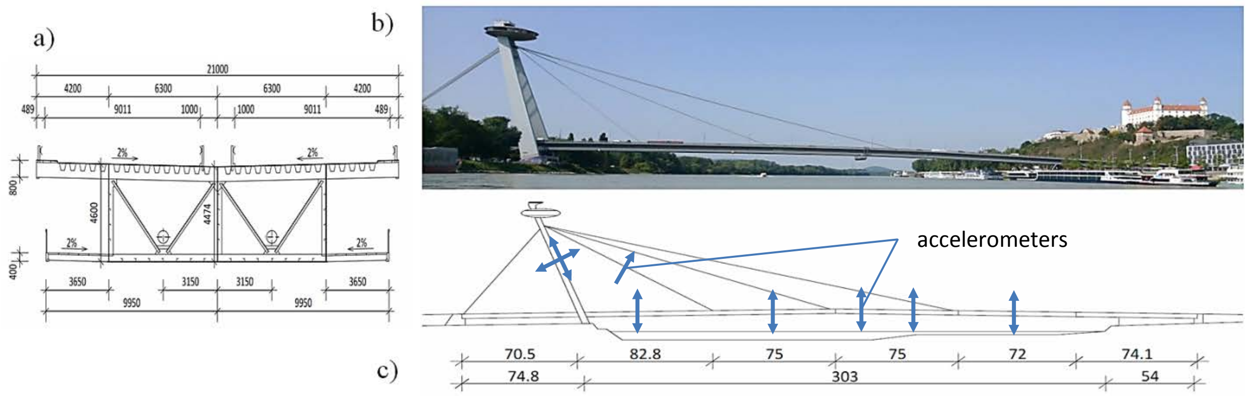

Fig. 2: The SNP Bridge - a) cross-section, b) south view, c) side drawing (in m) with accelerometers.

3. FEM model and analysis

FEM models were created for both bridges. The model of Port Bridge was created mainly from BEAM and SHELL elements. Mostly the same types of elements were also used in the case of the SNP Bridge. This model of bridge is little more complicated, because of pre-stressed cables and curvature of bridge deck. Models were created considering number of details from drawing documentation, e.g. curvature of the deck in vertical direction, box sections, cables, stiffeners, etc. The dimensions of model elements were also obtained from drawing documentation. Natural modes shapes and frequencies of the bridges have been calculated.

4. Measurement and modal analysis

A system with devices from National Instruments (cRIO 9067 and 9074 with 2+2 I/O modules NI 9234) and a program created in LabVIEW for data acquiring was used for the measurement. Two main measurement polygons were used, placed on the pavement benches. 29 accelerometers were used on the Port Bridge and similarly in case of the SNP Bridge (Fig. 1c and 2c). The traffic on the bridges during the tests was recorded by the camera.

5. Measurement results

5.1 The Port Bridge

The appropriate traffic pattern (Sokol, 2017) (when two trucks meet in the middle of the main span Fig. 3) has been chosen from the accelerometer record. Accelerometer E was located in the middle of main span on the front side, since accelerometer O on the back side. The record of accelerometer E is in Fig. 4a.

Fig. 3: Traffic pattern - two trucks meet in the middle of span.

Interesting time is between 202-203s (Fig. 4b), amplitude of E and O are in the opposite phases, it indicates torsion response.

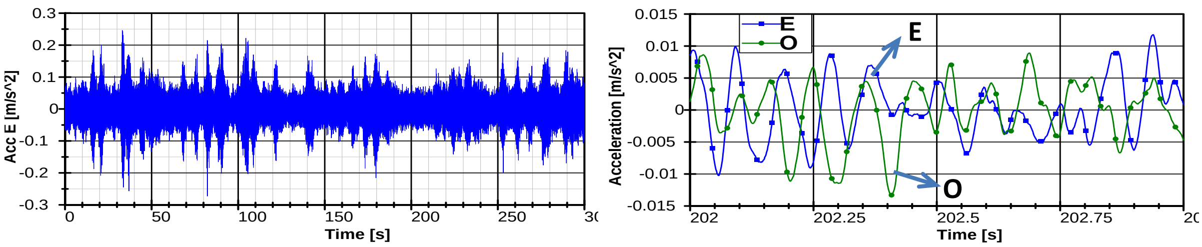

Fig. 4: Record of acceleration - a) total record 0-300s (not filtered), b) 202-23s record (low pass filter)

5.2 The Slovak National Uprising Bridge

The appropriate traffic pattern (when concrete truck and bus meet in the middle of the main span Fig. 5) has been chosen from the accelerometer record. Accelerometer M was located in the middle of main span on the front side, since accelerometer B on the back side. The record of accelerometer M is in Fig. 6a.

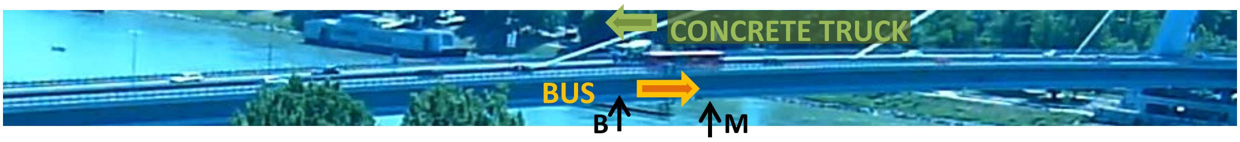

Fig. 5: Traffic pattern - concrete truck and bus meet in the middle of span.

Interesting time is between 87-88s (Fig. 6b), amplitude of B and M are in the opposite phases, it indicates torsion response.

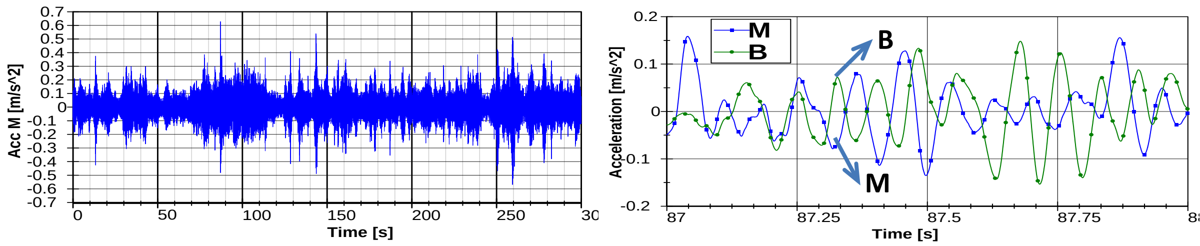

Fig. 6: Record of acceleration - a) total record 0-300s (not filtered), b) 87-88s record (low pass filter)

6. Amplitude spectrum (FFT)

The amplitude spectrum has been calculated from the acceleration values using the Fast Fourier Transformation (FTT). At least the first eigenvalues could be identified at the extremes. The Port Bridge $f_1 = 0.78$ Hz, $f_4 = 1.24$ Hz (Fig. 7), the SNP Bridge $f_1 = 0.43$ Hz, $f_5 = 1.33$ Hz, $f_6 = 1.53$ Hz (Fig. 8).

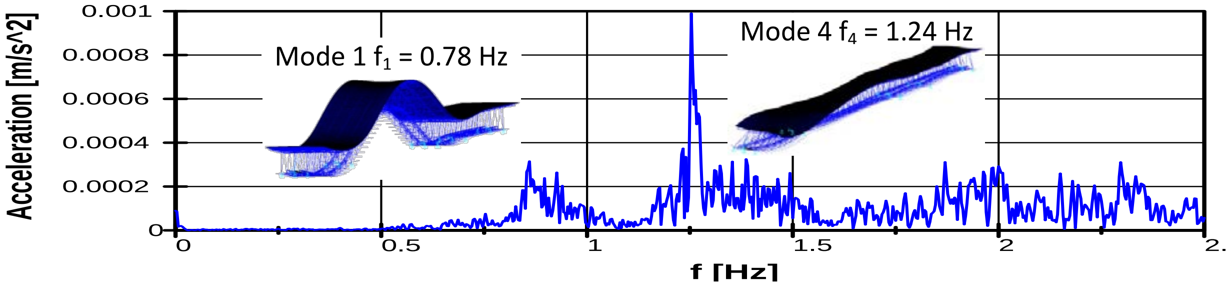

Fig. 7: Amplitude spectrum of the Port Bridge - E accelerometer(not filtered)

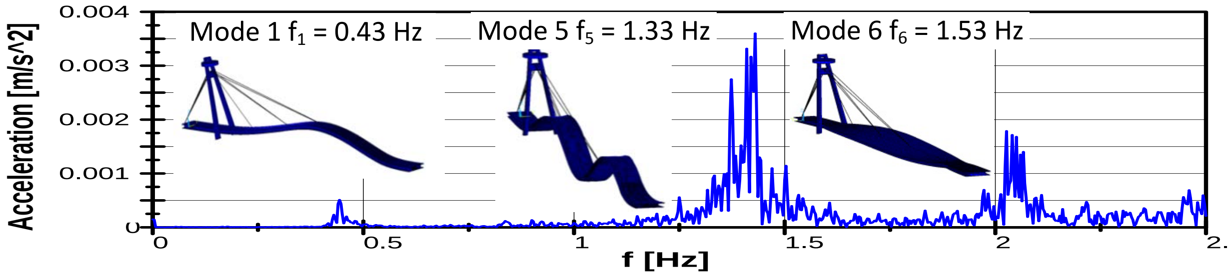

Fig. 8: Amplitude spectrum of the SNP Bridge - M accelerometer(not filtered)

The bridge response is starting to be evaluated also numerically. The preliminary results show good coincidence between measured and calculated data, at least concerning the extreme values of acceleration occurring with respect of time due dominating frequencies in the response.

7. Conclusions

This work presents the initial phase of testing and analyzing of dynamic response of large bridges subjected to traffic load. First results of comparison between experimental and numerical simulation are promising. Large bridges (like SNP and Port Bridge) can be excited by appropriate traffic situation that can be accurately identified torsional natural modes shapes (Port Bridge f_4 = 1.24 Hz, SNP Bridge f_6 = 1.53 Hz). Work on this research is still in progress, other results will be in additional publications.

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