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NUMERICAL AND EXPERIMENTAL ANALYSIS OF A BRIDGE

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Abstract: The bridge represents the important structure on the transport way. Moving vehicles represent the most important component of the load. The effect of moving vehicles can be followed by numerical and experimental way. The combination of both advances represents the most effective approach. The methods of numerical simulation of vehicle motion along bridge structure are presented in the submitted paper. The results of numerical results are compared with the results of experimental ones.

Key words: Bridge, moving load, experiment, numerical simulation.

1. INTRODUCTION

Bridges represent the structures subjected mainly to the effect of moving vehicles. It is important to know the dynamic response of bridges on the effect of moving load from the point of view of fatigue analysis and from the point of analysis of lifetime and reliability of the structure [1]. The mutual combination of numerical and experimental approaches is the best way for achieving of this goal. Contemporary state of computing technique enables to carry out the numerical simulations of various processes in real time. Experiment is needed because it represents the only way of verification of numerical advances.

2. COMPUTING MODELS OF THE VEHICLE AND THE BRIDGE

For the purpose of numerical simulation of vehicle motion along bridge structure the plane computing model of vehicle was adopted, Fig. 1. The model can represent a heavy vehicle for example the vehicle of Czecho-Slovak production TATRA 815. The computing model of vehicle has 5 degrees of freedom and the equations of motion are derived as ordinary the 2^{nd} order differential equations (1).

For the single span bridge the plane computing model with continuously distributed mass was adopted, fig. 2. The equation of motion is the 4^{th} order partial differential equation (2). By the adopting the assumption about the shape of dynamic deflection curve the partial differential equation can be transformed on the ordinary differential equation with coefficients dependant on the time t, (3).

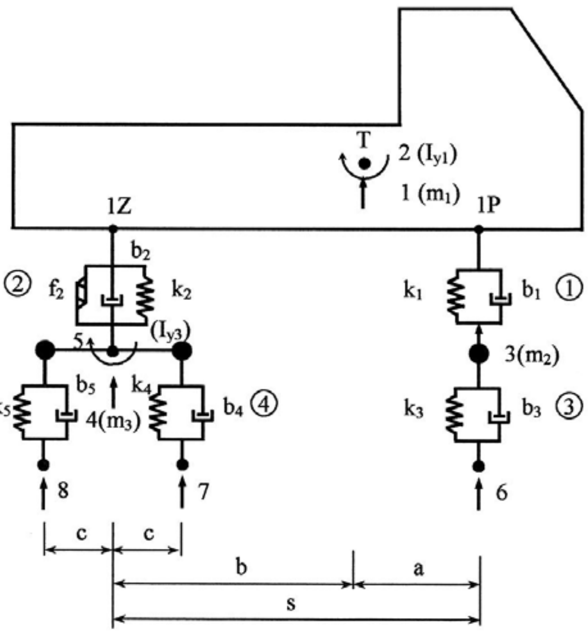

Fig. 1 Plane computing model of the lorry TATRA 815

$$\begin{aligned}
\ddot{r}_1(t) &= -\{k_1 \cdot d_1(t) + b_1 \cdot \dot{d}_1(t) + k_2 \cdot d_2(t) + b_2 \cdot \dot{d}_2(t) + f_2 \cdot \dot{d}_2(t)/\dot{d}_c\}/m_1, \\
\ddot{r}_2(t) &= -\{-a \cdot k_1 \cdot d_1(t) - a \cdot b_1 \cdot \dot{d}_1(t) + b \cdot k_2 \cdot d_2(t) + b \cdot b_2 \cdot \dot{d}_2(t) + f_2 \cdot \dot{d}_2(t)/\dot{d}_c\}/I_{y1}, \\
\ddot{r}_3(t) &= -\{-k_1 \cdot d_1(t) - b_1 \cdot \dot{d}_1(t) + k_3 \cdot d_3(t) + b_3 \cdot \dot{d}_3(t)\}/m_2, \\
\ddot{r}_4(t) &= -\{-k_2 \cdot d_2(t) - b_2 \cdot \dot{d}_2(t) - f_2 \cdot \dot{d}_2(t)/\dot{d}_c + k_4 \cdot d_4(t) + b_4 \cdot \dot{d}_4(t) + k_5 \cdot d_5(t) + b_5 \cdot \dot{d}_5(t)\}/m_3, \\
\ddot{r}_5(t) &= -\{-c \cdot k_4 \cdot d_4(t) - c \cdot b_4 \cdot \dot{d}_4(t) + c \cdot k_5 \cdot d_5(t) + c \cdot b_5 \cdot \dot{d}_5(t)\}/I_{y3}
\end{aligned} \tag{1}$$

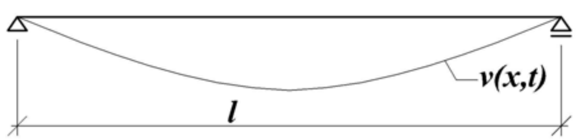

Fig. 2 Plane computing model of the bridge

$$E \cdot I \cdot \frac{\partial^4 y(x,t)}{\partial x^4} + \mu \cdot \frac{\partial^2 y(x,t)}{\partial t^2} + 2 \cdot \mu \cdot \omega_b \cdot \frac{\partial y(x,t)}{\partial t} = p(x,t)\,. \tag{2}$$

$$\begin{aligned}
\ddot{q}(t) = \{&-(\mu \cdot l \cdot \omega_b) \cdot \dot{q}(t) - (E \cdot I \cdot \frac{l}{2} \cdot \frac{\pi^4}{l^4} + \varepsilon_1 \cdot k_v \cdot \sin^2(\frac{\pi \cdot x_1}{l})) \cdot q(t) + (\varepsilon_1 \cdot k_v \cdot \sin(\frac{\pi \cdot x_1}{l})) \cdot r(t) + \\
&+ \varepsilon_1 \cdot G \cdot \sin(\frac{\pi \cdot x_1}{l}) - \varepsilon_1 \cdot h(t) \cdot k_v \cdot \sin(\frac{\pi \cdot x_1}{l})\}/(\frac{1}{2} \cdot \mu \cdot l)\,,
\end{aligned} \tag{3}$$

The equations of motion were solved numerically in the environment of the program system MATLAB. The 4th order Runge-Kutta integration method was adopted for numerical integration. The micro-profile on the bridge pavement was modeled as random numbers in certain interval.

3. EXPERIMETAL TECHNIQUE

The vertical mid-span deflection was observed on the bridge during experiment. The inductive sensors BOSH were used for its registration. The view on the sensor and view on the in situ installation is on the Fig. 3. The signal from sensor was lead by means of coaxial cables to measuring central. The measuring line is composed from these components: sensor, amplifier, signal cable, analogical – digital interface and operating computer. The lorry TATRA 815 was used as moving load during the test. The response of the on passing vehicle at various speeds was registered.

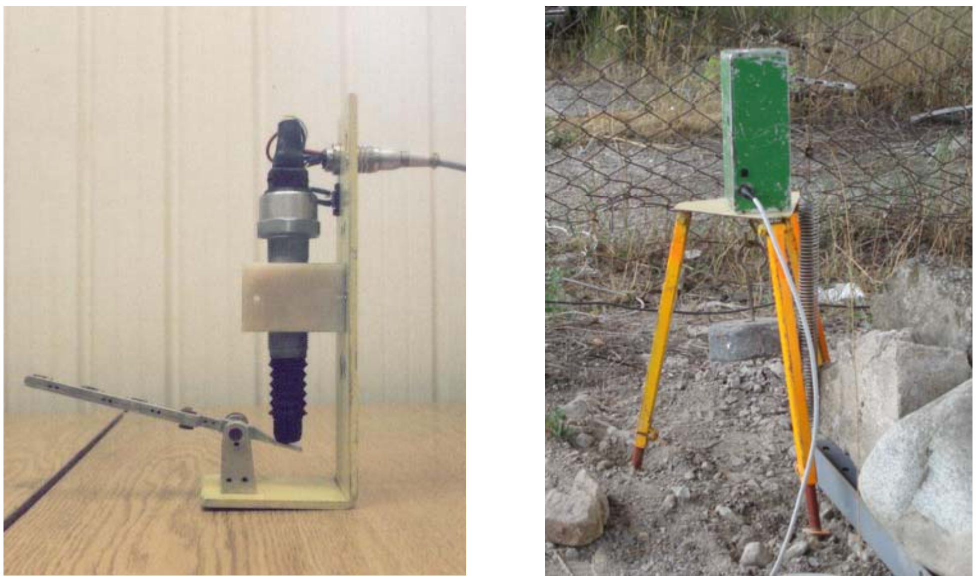

Fig. 3 Inductive sensor BOSH

4. RESULTS OF NUMERICAL AND EXPERIMETAL ANALYSIS

The process of dynamic loading test of the bridge was numerically simulated. The 12 runs of vehicle TATRA 815 were realised during the test. The vehicle passed the bridge in both directions at various speeds. The interval of speeds was from 6,4 km/h to 28,4 km/h. The results were worked up in graphical and numerical form. In numerical form the dynamic coefficients Delta were mutually compared. The results are put into Table 1. The dynamic coefficient Delta is defined as the ratio of maximal dynamic deflection and maximal static deflection by the equation (4).

$$Delta = \frac{v_{\mathrm{dyn,max}}}{v_{stat,\max}} \tag{4}$$

In graphical form the time histories of vertical mid-span deflections obtained by experimental and numerical way were mutually compared. As the example some results of mutual comparison are presented on the Fig. 4 (black – experiment, red – calculation). We can say to the end that the method of numerical simulation can be successfully applied for the solution of numerical modelling of vehicle motion along the bridge structure.

Table 1 Dynamical coefficients Delta obtained by numerical and experimental way

No.	Direction	Speed V [km/h]	Dyn. coeff. - calculated	Dyn. coeff. - experiment
1	V-M	6,420822	1,0147	1,0360
2	M-V	7,981041	1,0263	1,0180
3	V-M	15,019638	1,0196	1,0317
4	M-V	14,232935	1,0249	1,0355
5	V-M	17,227154	1,0347	1,0355
6	M-V	25,711119	1,0769	1,1068
7	V-M	20,195377	1,0977	1,1060
8	M-V	27,803670	1,0939	1,0936
9	V-M	28,456947	1,0845	1,1099
10	V-M	22,305309	1,0389	1,0214
11	M-V	27,295545	1,0361	1,0857
12	V-M	24,600014	1,0347	1,0947

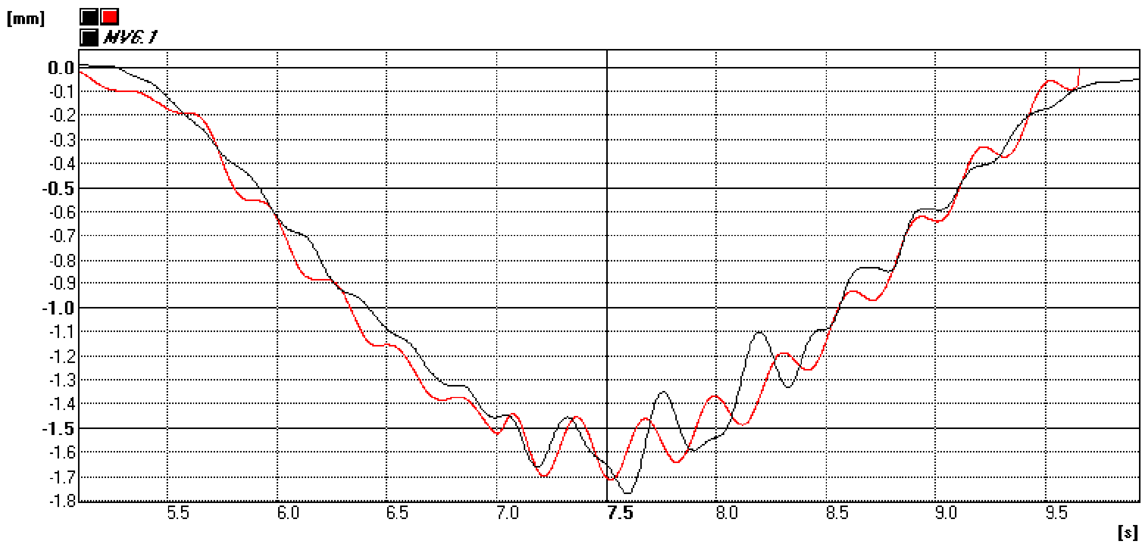

Fig. 4 Vertical mid-span deflection, experiment versus calculation, V = 25,71 km/h

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