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Experimental Verification of an Assumption

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Abstract. Within the process of solution of vehicle – bridge interaction problems various computing models of bridges are adopted. For example classical computing models especially discrete computing models with lumped masses give very good results. In such a case some assumptions must be adopted. The assumptions relate to the shape of deflection curve and the load distribution function. In such a case the experimental tests are advised to verify the validity of adopted assumptions. The presented paper describes the adopted assumptions and methodology of their experimental verification. It mutually compares the experimentally and numerically obtained results and makes findings for practical applications.

Introduction

Vehicle bridge interaction problem is an actual engineering problem analyzed by engineers all over the world. It can be followed in literature from the year 1849. It was induced by the collapse of Chester Rail Bridge in the year 1847 [1]. Also in the Czech and Slovak Republic important works arose in this field. In the area of railway bridges they were published by Frýba, L. [2] and in the area of highway bridges they were published by Melcer, J. [3]. Numerical modeling of the vehicle motion along bridge structure requires paying attention minimally to these facts: creation of computing models of vehicles, creation of computing models of bridges, creation of computing programs for the solution of the equations of motion and displaying of obtained results. The finite element method and Component element method are widely used nowadays. Also the classical computing models especially discrete computing models give very good results. Often some assumptions must be adopted in the process of creation of computing models especially within creation of bridge computing models. In such a case the experimental tests are needed to verify the validity of adopted assumptions. The presented paper describes the adopted assumptions and methodology of experimental tests. It mutually compared the experimentally and numerically obtained results and makes findings for practical applications.

Computing Model of a Bridge

For the bridge the beam computing model with lumped masses was adopted. Equation of motion are written in the form

$$[m]_D \cdot \{\ddot{v}(t)\} + 2 \cdot \omega_b \cdot [m]_D \cdot \{\dot{v}(t)\} + [k] \cdot \{v(t)\} = \{F(t)\}\,. \tag{1}$$

$[m]_D$ is diagonal mass matrix, $[k]$ is stiffness constant matrix, $\{F(t)\}$ forcing vector, $\{v(t)\}$ displacement vector and ω_b is damping circular frequency. The derivations with respect to time t are denoted by the dot above the symbol.

Let us assume the bridge computing model with one lumped mass in the middle of the span. In this case the assumption about the shape of deflection curve $v(x,t)$ and the shape of load distribution function $\Phi(x)$ can be adopted in the shape of sine function, Fig. 1.

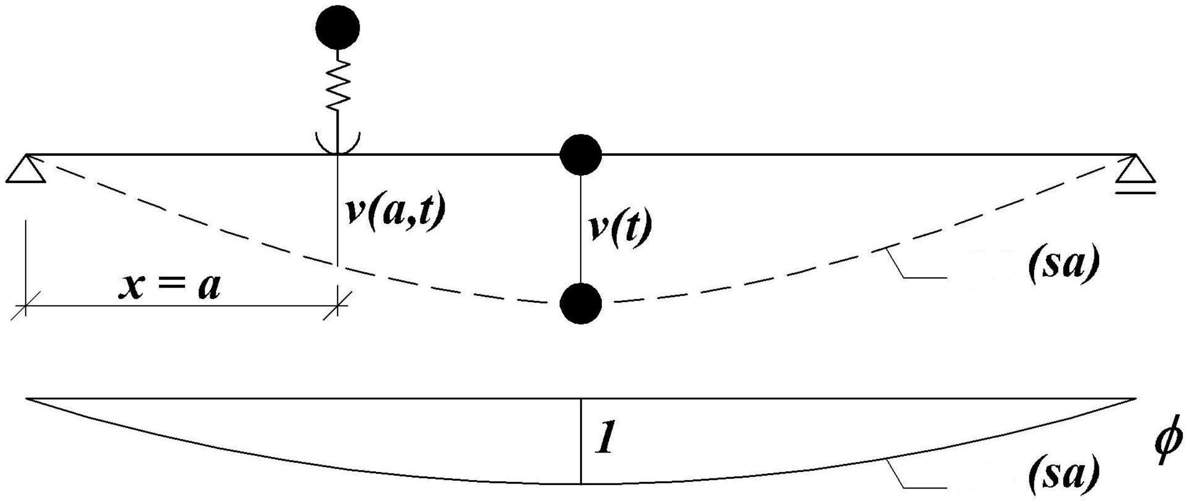

Fig. 1. Sine approximation.

Then

$$v(x,t) = \Phi(x) \cdot v(t) + h(x) \text{ eventually } v_x(t) = \Phi_x(t) \cdot v(t) + h(t)\,, \tag{2}$$

where

$$\Phi(x) = \sin(\pi \cdot x / l) \text{ eventually } \Phi_x(t) = \sin(\pi \cdot c \cdot t / l) = \sin(\omega \cdot t)\,,\ \omega = \pi \cdot c / l\,, \tag{3}$$

$$F(t) = F_{tire}(t) \cdot \Phi_x(t)\,. \tag{4}$$

The function $h(x)$, $h(t)$ represents the road profile, c speed of vehicle motion in [m/s], ω angular frequency.

Tests in Laboratory Conditions

To verify the validity of adopted assumptions the model of the bridge as two span continuous beam was made in laboratory conditions. The model was carried out on the principle of model similarity. It was steel beam with the spans $l_1 = l_2 = 1{,}45$ m and with cross section 12 x 18 mm. Special equipment providing the movement of the load was developed, Fig. 2. In front of the beam the speeding-up path and behind the beam the braking path were built up.

The inductive sensor IVR 99427 was used for the observation of mid-span vertical deflections, Fig. 3. The signal from the sensor was leaded via amplifier and A/D interface to the computer. Then the signal was analyzed by numerical way in the program system DAS16 or DISYS. The time of the load passage was registered by the use of two accelerometers BK 4508 situated at the beginning of the beam and at the beginning of the braking path, Fig. 4.

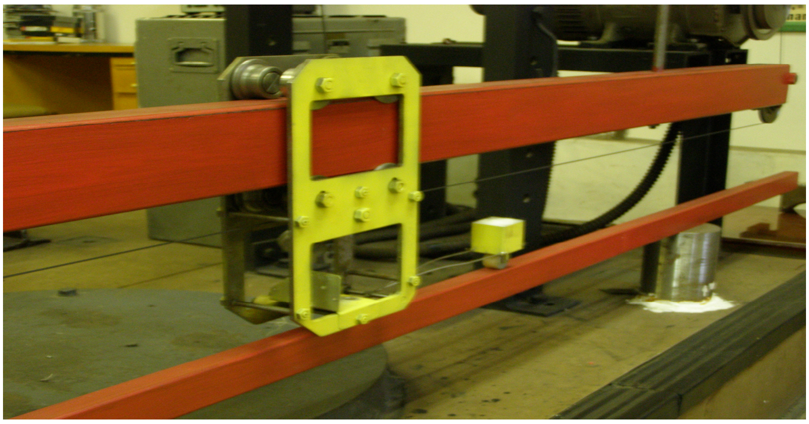

Fig. 2. Drawing unite with moving load and speeding-up path.

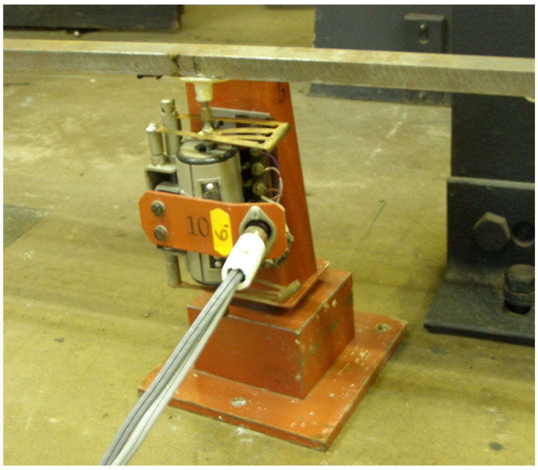

Fig. 3. Inductive sensor IVR 99427.

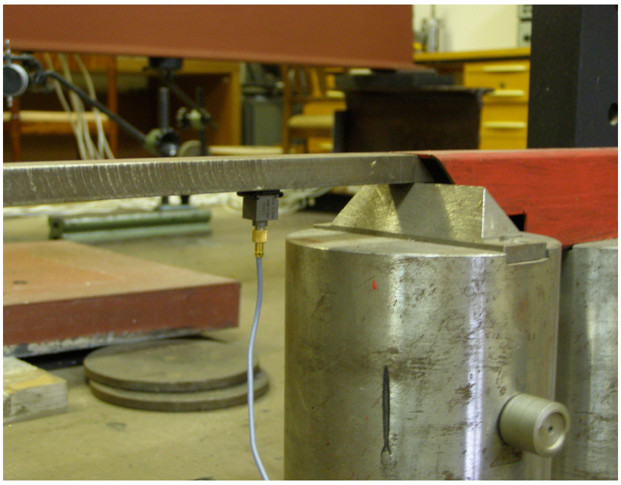

Fig. 4. Accelerometers BK 4508.

The time of the load passage was calculated as $t = t_e - t_b$. The average velocity of moving load was determined as $c = l/t$, Fig. 5.

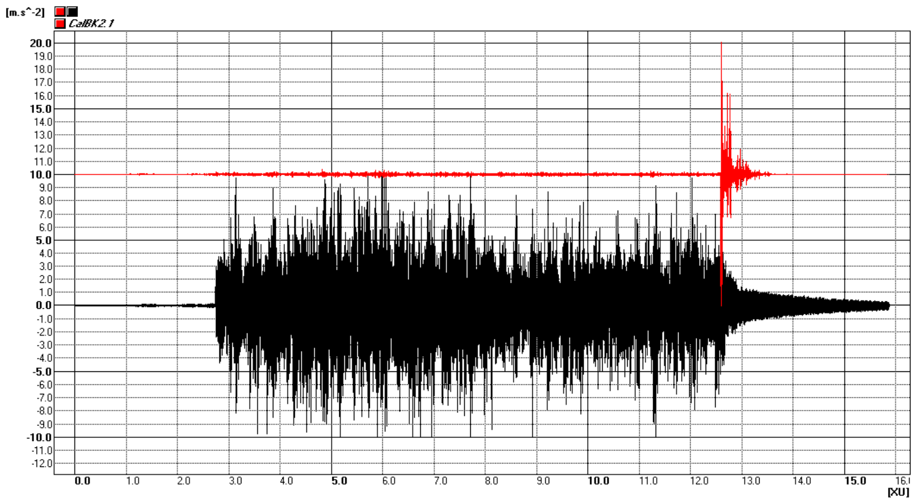

Fig. 5. Records of acceleration from 2 sensors for determination the time of load passage.

The mass of moving load was m_v = 413.75 g. The movement of the mass point m_v at various speeds was realized and response of the beam at mid-span was registered. The same process was modeled by numerical way. The numerically and experimentally obtained records were mutually compared.

Conclusions

For some type of bridges the beam computing model with lumped masses gives very good results. The assumption about the shape of deflection curve and the assumption about load distribution function must be adopted in this case. In case of single span beam or two span continuous beam with one lumped mass in the middle of the span the deflection curve and load distribution function can be approximated as sine function. The best way is to verify such assumptions by experimental test and to compare mutually the experimentally and numerically obtained results. As the example the comparison of numerically and experimentally obtained of mid-span beam vertical deflections at the speed of moving load 0,82857 m/s is plotted in the Fig. 6. On the basis of the obtained results we can say that adopted assumptions are in harmony with reality and the adopted assumptions can be used for the numerical solution of real engineering problems.

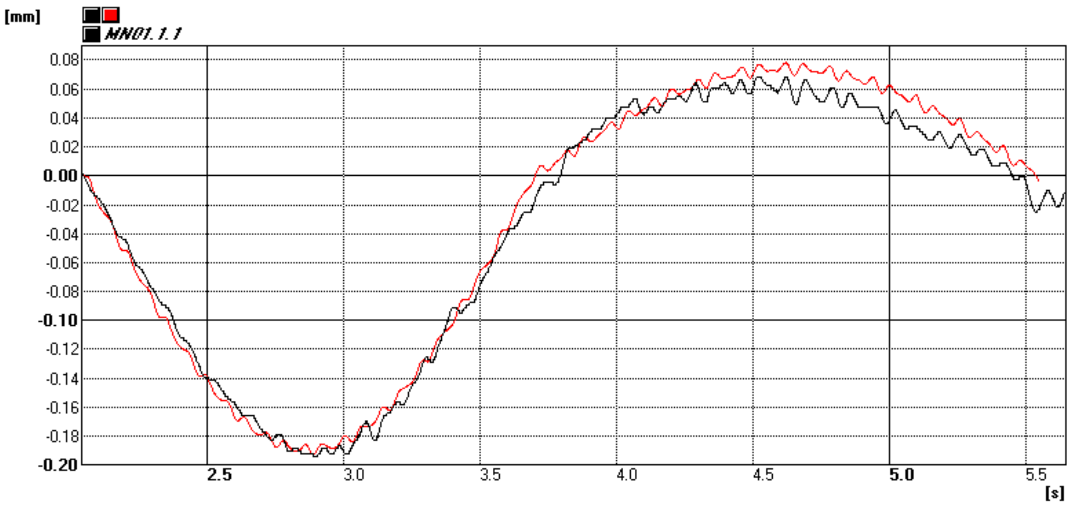

Fig. 6. Vertical mid-span deflection, numerical solution versus experiment, speed 0.82857 m/s.

References

[1] R. Willis, Appendix, Report of the Commissioners Appointed to Inquire into the Application of Iron to Railway Structures, Stationary Office, London, 1849.

[2] L. Frýba, Dynamics of railway bridges, ACADEMIA, Praha, 1992. (in Czech)

[3] J. Melcer, Dynamic calculation of highway bridges, EDIS, Žilinská univerzita v Žiline, Žilina, 1997. (in Slovak)