8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

DYNAMIC EFFECT OF HIGH-SPEED TRAIN AT THE BRIDGES

***J. Györgyi[1] and G. Szabó[2]**

[1] Budapest University of Technology and Economics
H-1521 Budapest, Műegyetem rkp. 3
gyorgyi@ep-mech.me.bme.hu

[2] Pont-TERV Ltd.
H-5000 Szolnok, Üstökös u. 4
hoeses @freemail.hu

Key Words: Train-bridge interaction, High-speed train effect, Quasi-modal analysis.

ABSTRACT

Railway bridges for high-speed trains can be under large dynamic loading in certain cases. If we want to calculate the dynamic effect of a moving vehicle during the test of a railway bridge we have some possibility to build up the model of the structure and the vehicle too.

It is very important to underline that the analytical methods can be applied in simpler cases only. If the structure is more complex than a simple supported beam or we want to model the train with more realistic models. In this study two different type bridges were considered. The first one is an arch bridge the second is a truss structure. The main goal is the investigation of the dynamic sensitivity of these two structures.

The investigated bridge structures are one track steel railway bridges with the span of 52.0 m. For the comparison of dynamic behaviour the dimensions of the structural elements are set to reach almost same vertical stiffness so the static behaviour can be considered the same in case of these two bridges. During the dynamic analysis we investigated the vertical displacements of the quarter point and the middle point of the main girders of the bridges.

We applied a Japanese express train as a dynamic load which is fictive in Hungary nowadays, but can be necessary to model really high speed moving loads. We can model these trains in three ways; as moving forces only, moving forces and mass points together, and as a whole dynamic system with springs and dampers.

The dynamic behaviour of the bridges due to a moving train we had to determine the mode shapes. If we compare the mode shapes we find that while the first shape of a truss bridge is symmetric in case of the arch bridge is asymmetric. Moreover the frequencies are much closer to each other in the case of the arch. Therefore the dynamic behaviour of a truss bridge and an arch bridge due to vehicle load are strongly different. By monitoring the vertical displacements of a certain point we find that for the same accuracy we need much more eigenvectors in case of the arch bridge. If we consider the bending moments or the shear forces of the girders we need even more eigenvectors in case of the arch. The deformation due to total loading is symmetric in both cases but due to asymmetric loading the deformation of the truss is almost symmetric in case of the arc bridge is mostly asymmetric. This type of behaviour will be sensed in the results.

During the travelling different number of the railcars is above the bridge, the degree of freedom of the system and size of the matrices and vectors is changing in time. We have to generate the systems at every time step. A practical method for generate the time dependent matrices was showed in [1]. During the analysis we have to generate only contact matrices every time step. The matrix differential equation of the vehicle-bridge system after that

$$(\mathbf{M}_C + \mathbf{M}_t(t))\ddot{\mathbf{u}} + (\mathbf{C}_C + \mathbf{C}_t(t))\dot{\mathbf{u}} + (\mathbf{K}_C + \mathbf{K}_t(t))\mathbf{u} = \mathbf{r}_t(t), \quad (1)$$

where $\mathbf{M}_C$, $\mathbf{C}_C$ and $\mathbf{K}_C$ are the constant matrices $\mathbf{M}_t(t)$, $\mathbf{C}_t(t)$ and $\mathbf{K}_t(t)$ are the time dependent matrices. If we generate some smallest eigenvectors orthonormal for mass matrix both for the structure and the vehicle and collect the eigenvectors in a hyperdiagonal matrix **V**, (the size of it depends from the railcar number above the bridge) we can use the technique of quasi-modal analysis. In practice we calculated all eigenvectors of the poor vehicle model and for the correct calculation of the displacements ten eigenvectors of the bridge were enough. [2].

Using the introduced computational methods we can calculate the motion of any point of the two bridge structures. If we collect the maximum values at the certain velocities we obtain the curves below. On Figure 1 the maximum displacements of the middle point of the truss bridge versus train velocities can be seen. We can see peak values at certain velocities where we get large dynamic effects. Three different curves represent the different train models. In case of using forces and mass points for modelling the train the critical velocity is lower than in case of forces only. The presence of the train as a dynamic system decreases the vibration amplitudes. The strong line represents the dynamic factor offered by the standard.

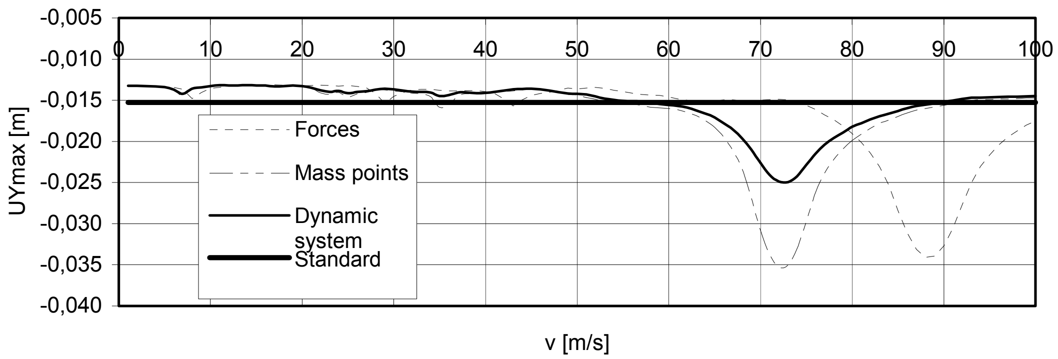

Figure 1. Maximum displacement versus train velocity curve of the truss bridge at middle point

Each case showed the significant role of the train modelling. The train can strongly decrease the dynamic effects as a vibrating dynamic system on the bridge structure. But the value of the critical velocity was different in case of different point of the structure.

REFERENCES

[1] J. Györgyi, "Calculation of vehicle-bridge system using quasi-modal analysis", *Proc. of the fourth European conference on structural dynamics-EURODYN'99,* Vol 2: 681-686, Rotterdam: Balkena. 1999.

[2] J. Györgyi and G. Szabó, "Dynamic train-bridge interaction at arc bridge in the case of a different model", *Slovak Journal of Civil Eengineering,* XIV(3-4):37-47. 2006.