Investigations for Simplified Consideration of Train-Bridge-Interaction based on Railjet High-Speed Train

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Introduction. The interaction between bridge structure and vehicle has an important effect on railway bridges. Numerous research studies of recent years have shown that especially for the majority of structures – varying from short to medium span (up to 30-35 meters) – the influence of this interaction can play a significant role on the dynamic behavior of the structure. To take this interaction effect into account, the Eurocode allows additional damping values when using the moving load model MLM.

This simplified consideration of the interaction by the so called additional damping method ADM, depends on the bridge span only. Numerous cases had been shown where the structure response to a detailed interaction model DIM - which is a more accurate calculation method including the interaction effects - differs up to 30 % from the results obtained by the ADM. An example can be seen in figure 1.

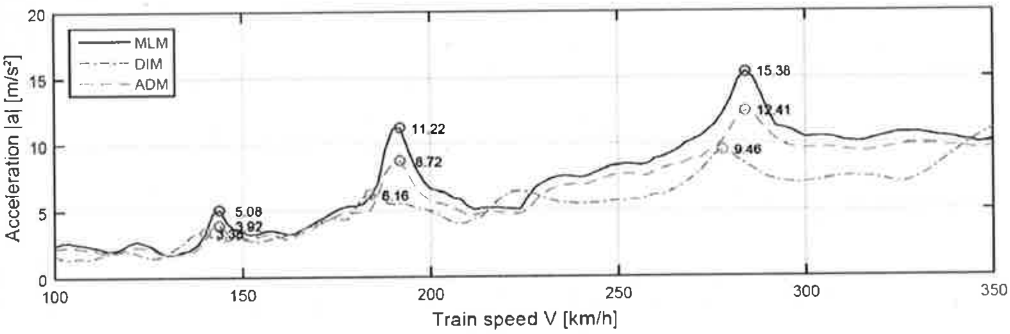

Fig. 1. System response of a bridge (L=15m, μ=5t/m and f_0=3Hz) to different load models of a Railjet High-Speed train

The reason for this big difference is that the complex mechanism of the vehicle-bridge interaction depends on the totality of factors, such as vehicle-bridge-mass ratio, vehicle-bridge-frequency ratio or vehicle-bridge-length ratio. By the bridge span alone, this mechanism is only restricted describable. Since dynamic analysis using DIM are very time consuming, especially if a large number of structures (e.g. all structures on a specific railway line) have to be examined, an alternative method to approximate the interaction effects becomes necessary.

Parametric study. As a basis for further investigations a parametric study has been performed. The goal was to determine the differences in the dynamic bridge response between a DIM and a MLM. The underlying train was the Railjet – High-Speed train of the Austrian Federal Railways. Detailed data of this train can be found in [1, 3]. The dynamic analysis of the train crossings were performed with a Matlab-Code developed at the Institute for Structural Engineering of the TU Wien [1]. The algorithm is based on modal analysis. Thereby the exact solution was approximated by using the first three eigenmodes of the structure. Bridges with a length from L=7 to 40m, a mass of μ=5 to 30t/m and a first natural frequency f_0 between 3 and 12Hz were investigated.

The parametric study confirms that the vehicle - bridge interaction has the greatest effect on lightweight structures with a first natural bending frequency close to the primary bogie frequency. Even for structures with a length of 40m, a relative error in the acceleration peaks of about 20% can be detected in a realistic mass range. In some cases, the use of the DIM can ledad to larger accelerations than the use of the MLM. Vehicle-bridge interaction is also effecting the dynamic behavior of the structure by changing the natural frequency of the system while the train is on the bridge. The frequency errors determined in this study are in a quantitative range of about 4 %.

Approximation method. The idea for a simplified method to capture the vehicle-bridge interaction was abstracted from Museros [2]. With the aid of impact factors κ_{approx} and reference deviation R_{ref} the results of a calculation with the MLM are approximated to the results of the DIM.

$$a_{DIM,approx}(\lambda^*, \mu, f_0) = a_{MLM}(\lambda^*, \mu) \cdot \left(1 - \kappa_{approx,a}(\mu, f_0) \cdot \frac{R_{ref,a}(\lambda^*)}{100\,\%}\right) \qquad \left[m/s^2\right]$$

Figure 2 shows the example of a 17m span bridge with a first natural frequency of 6,5Hz and a mass of 6000kg/m. As reference, the results of a 15 and a 20m bridge were used. The approximation of the DIM results was done for both references and interpolated afterwards. Although the difference between the lengths of the reference structures is very large, the approximation $DIM_{approx,in}$ is still in a reasonable range. As can be seen in the figure below the results of the ADM are much worse.

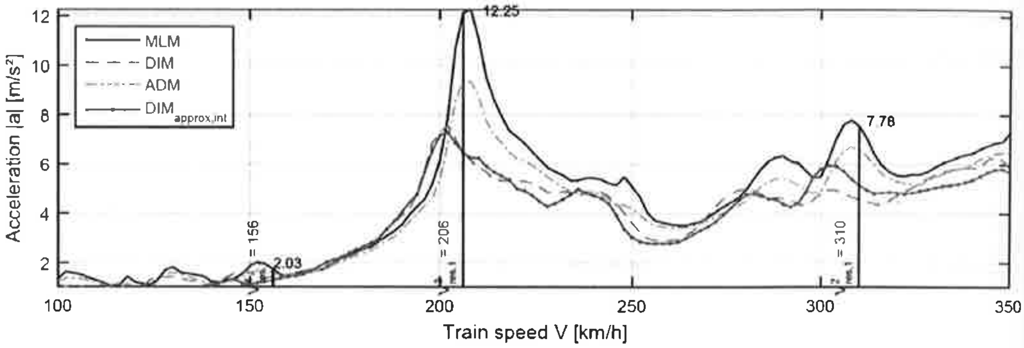

Fig. 2. Example of a 17m bridge (μ = 6t/m, f0 = 6,5Hz), interpolation between the references of a 15 and a 20m bridge.

Conclusions. The presented method produces an approximation of the peak values as well as of the entire graph shape. The quality of these adjustment is mainly based on the discretization of the reference calculations. It was shown in an example that even for a relatively rough grid of references reasonable results can be obtained.

References

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