Silent Railway Bridges

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Introduction

In Germany, about 32.000 railway bridges do exist. Because a large part is situated in urban areas, bridge noise is an important subject. When a train passes a bridge, vibrations are generated at the wheel-rail contact leading to rolling noise that may be different compared to the plain track. In addition, vibrations are transmitted into the bridge structure. The vibrating bridge parts radiate sound that is particularly distinct in the range of low frequencies. Both components, the rolling noise on the bridge and the noise radiated by the bridge structure, contribute to the bridge noise.

Up to now, the noise problems associated with railway bridges have been dealt mainly by empirical and experimental methods. Although a large amount of money has been spent in the development, the known measures to reduce bridge noise are in some cases not sufficient. In addition, there are hardly any specifications for the construction of low-noise-bridge structures.

Particularly in view of the large variety of bridge designs, the approach adopted by DB of an effective and cost-efficient combination of experimental investigation with simulations to produce low-noise bridges will be presented.

Bridge Noise

Bridge noise is known to vary with the construction type. Especially steel bridges with rails fastened directly to the bridge structure are known to be rather noisy. But also steel bridges with a ballasted track and even concrete bridges may lead to noise problems.

Figure 1 shows spectra of the sound pressure level measured beside a steel and beside a concrete hollow box bridge during the pass-by of a train [1]. When considering the not-

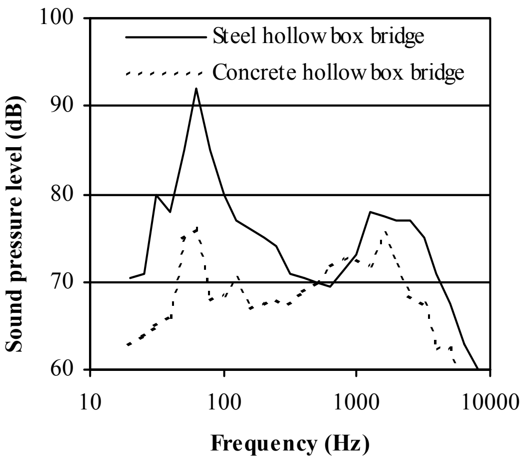

Figure 1: The sound pressure levels measured in a distance of 25 m beside a steel hollow box bridge and a concrete hollow box bridge.

weighted sound pressure levels, two main peaks are observed. At the given train velocity, the maximum at 63 Hz can be associated with the sleeper passing frequency. The maximum between 1 and 2 kHz is caused by the rolling noise and by vibrations initiated by the rail and wheel roughness. Differences in the spectra of the steel and the concrete bridge are observed mainly in the low-frequency region. Because natural vibration modes of steel bridge parts are in the same frequency range as the excitation of the bridge, the sound-pressure level of the steel bridge is much higher. The contribution at low frequencies and with it the annoyance of the residents is only represented when considering the not-weighted level.

In order to reduce the bridge noise, resilient elements are included between the rail and the bridge structure to minimize the transmission of vibrations [1]. Therefore, ballast mats are inserted into the ballasted track and resilient rail fixations in the case of direct fastening of the rail to the bridge structure. As an alternative to ballast mats, under sleeper pads have been proposed in the last years [2].

Although its efficiency to reduce bridge noise has been proofed by different measurements, resilient elements can have a serious disadvantage: Considering the efficiency as a function of frequency, the curve is nearly constant for high frequencies but dips can occur at low frequencies. In the case, the excitation frequencies of the bridge correspond to the frequency of a dip, the total efficiency of the measure is only small.

As an alternative to the application of resilient elements, construction measures have been shown to be very efficient to reduce the noise of steel hollow box bridges [3].

As the best solution to realize low-noise bridges, a combination of an optimised track and a low-noise bridge construction is proposed. Due to the large number of different bridge designs, the optimisation of measures is only possible by using a combination of experimental investigations and simulations.

Project “Leise Brücke”

As shown above, a model for the prediction of the sound radiation of any bridge is needed for the optimisation of measures. Therefore the DB-internal project “Leise Brücke” which means “Low-noise bridge” was started in May 2003.

Cost-Benefit Analysis

To describe the present situation, data on the distribution of bridge types in Germany, the typical sound radiation of those bridge types and the efficiency and costs of noise-reduction measures were collected. The analysis of the data led to the conclusion that the optimisation of direct and retrospective noise-reduction measures for steel and in some cases also for concrete bridges is efficient concerning costs and benefit. In detail, the analysis led to the following results:

1. Construction measures have a very good cost-benefit ratio for the noise reduction of newly build steel bridges.
2. Under sleeper pads can be a cheap and efficient solution as direct and retrospective noise-reduction measure.
3. The known measures as ballast mats and resilient rail fixations will also be important in the future.

Assessment of Data and Models

Because the effort to develop new models should be as low as possible, the collection of existing data and models is very important. Especially experimental data have been collected which can be used for a first test of models.

Experimental investigation

In addition to the test of models using existing experimental data, a new experimental investigation is planned. The aim is to measure data on the vibration and sound radiation for three steel bridges (two with and one without ballasted track) and one concrete bridge with ballasted track. For the investigation, typical bridge types will be considered. In addition, the efficiency of three different resilient elements introduced into the track-bed structure of steel bridges will be measured. At the end, a reasonable large amount of data will be available for the validation of the models.

Development of a Simulation Concept

The next step concerns the development and validation of the simulation concept. Figure 2 shows the modelling approach.

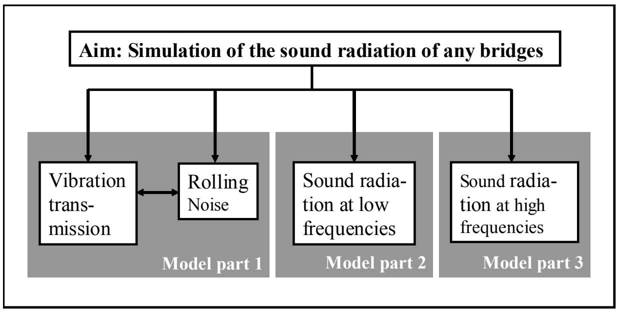

Figure 2: The model for the simulation of bridge noise is divided into three parts, the vibration transmission and the rolling noise as well as the sound radiation at low and high frequencies.

To model the rolling noise as well as the transmission of vibrations into the bridge structure, an impedance model as RIM [4] will be used. The different components of the track-bed structure are considered in the model. The influence of the bridge on the rolling noise and on the vibration transmission is considered by the input impedance of the bridge construction.

In the low-frequency region, the vibration and the sound radiation of the bridge are calculated by using the finite elements method (FEM) [5]. For the modelling, the bridge structure is divided into thousands of finite elements. For the nodes of the finite elements, the motion equations are set up and solved. For steel bridges, the simulation of the vibration up to some hundred Hz can be done by FEM. For the calculation of the sound, the radiation of the vibrating bridge parts has to be considered by an additional simulation tool.

For the simulations of the vibrations and the sound radiation of the bridge at high frequencies, the statistical energy analysis (SEA) will be used [6]. In this approach, the bridge is represented by a relatively small number of subsystems. Instead of the moving equations, equations for the energy flux from one to another subsystem are considered. Simulations of the sound radiation can be performed up to some thousand Hz.

Combining the three model parts, the sound radiation will be calculated for all bridges that are considered in the experimental investigation. Because the validation will be done for both, steel and concrete bridge types, the predictability of the simulation concept can be ensured.

Application of the Simulation Concept

After the development and the validation, the modelling concept will be applied to relevant questions. The optimisation of special bridge types is planned.

Summary

Bridge noise is a well-known effect that has been investigated since many years. For the reduction of bridge noise, mainly resilient elements introduced into the track are used today. Because of the serious disadvantages of these measures, optimised measures have to be developed. The cost-benefit analysis performed has shown that especially construction measures have a very good cost-benefit-ratio. In addition, optimised measures to be applied in the track are needed. Due to the variety of bridge types, the optimisation of measures requires the combination of experimental investigations and simulations. Therefore, a simulation concept will be developed that is able to predict the sound radiation of any bridge. After validation, the simulation concept will be applied within the project to relevant questions.

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