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NOISE AND VIBRATION CONTROL OF THE SOUTH RAILWAY BRIDGE OF BUDAPEST

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Abstract

The paper reports on the noise and vibration control of a 451 m long steel railway bridge. The vibration and noise generation mechanisms were investigated first. Vibration of the rail fixture, sleeper, horizontal and main girders and the steel walking plates were measured, together with noise measurements in a number of measuring points both in the close vicinity of the bridge and at larger distances. The obtained vibration characteristics were compared to results of numerical calculations, enabling the identification of vibration propagation mechanisms. The noise radiation of the investigated bridge section was investigated by means of a combined experimental - numerical method. Eventually, both the horizontal steel walking plates and the main vertical girders were identified as major noise radiators. Based on the investigations a combined noise control package, including the vibration isolation system CDM ISOFERPONT and replacement of the steel walking plates by a composite plate structure, was developed and realized. The final measurements have shown that the average vibration and noise levels were reduced by 5 to 8 dB.

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INTRODUCTION

One of the main railway bridges of Hungary lies in the South of Budapest. The 451 m long, double-track riveted steel South Railway bridge is a major link between West and East Hungary, carrying heavy rail traffic day and night, 7 days a week. While it was far from the city center when originally built 130 years ago (and still it was between 1948 and 1953 when rebuilt after WW2), the recent construction of a new Millennium City Center has put some highly demanding cultural buildings in the close vicinity of the bridge, giving rise to a serious environmental problem. Therefore, the Hungarian Railway has decided to take serious noise control measures on the bridge.

Preliminary noise measurements and sound field mapping calculations have revealed that the noise of the bridge exceeds the overall environmental noise level by more than 10 dBA in the course of train pass-bys. Apart from the wooden sleepers, the bridge consists of steel elements only, without any vibration isolation or damping. It was for this reason quite obvious that some kind of vibration isolation between the rails and the steel structure is an inevitable must. Nevertheless, it was also clear from the beginning that certain elements of the bridge such as the 5 mm thick steel walking plates are major noise radiators too, even at relatively low vibration levels.

The paper reports on the acoustic tests and simulation calculations, aimed at pinpointing the major noise radiators of the bridge structure and the optimum places of vibration isolation. The noise control measures are also discussed and results of the verification measurements are shown.

NOISE AND VIBRATION MEASUREMENTS

The investigated bridge is a multi-part, framed steel structure, having lower support at the bankside parts and upper support at the riverbed sections. Being closer to the critical buildings, the bankside parts are more important from the noise exposure point of view, and this is why most of the measurements were performed in a (hypothetical) plane perpendicular to the main axis in the middle of that section.

Noise measurements of a number of trains at app. 20 m (or reference) distance from the side guard have revealed that the overall noise level averaged over the whole pass-by increases by 9dB per double speed. The noise spectrum of three typical trains are shown in Fig. 1. The dominant bands are nearly always centered around 500 Hz, determining the A-weighted SPL.

Fig. 2a. shows the structure of the bankside sections. From the purely geometrical point of view, both the (vertical) main girders and the horizontal walking plates can be conceived as predominant partial noise sources of the bridge. In order to reveal the noise generation and radiation mechanisms in more detail, extensive vibration and noise measurements were conducted. The vibration of all important bridge elements: rail, baseplate, wooden sleeper, main beams, girder spars and walking plates were measured and, simultaneously, near-field and far-field noise recorded. The (vibration) measuring points are summarized in Fig. 2b, and some of the most relevant spectra are compared in Fig. 3.

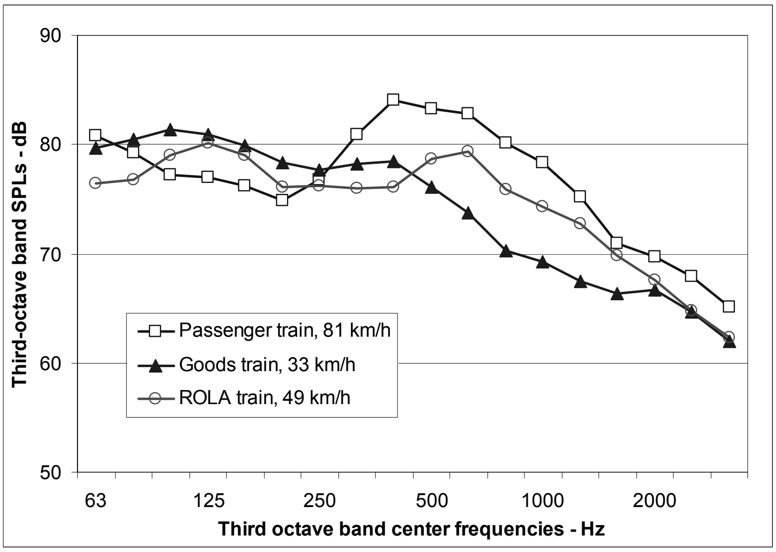

Fig. 1: Noise spectrum of three typical train pass-bys

Fig. 2a: Bottom view of the bankside part of the bridge

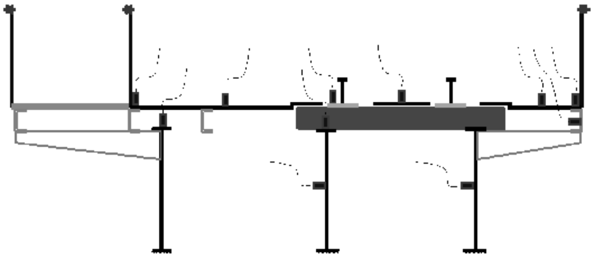

Fig 2b: Schematic cross section and vibration measuring points

The vibration spectra and their comparison to the farfield noise is not easy to interpret. It might seem at first sight that the dominant noise source is the walking plate, directly screwed to the sleepers in between the two rails. Nevertheless, as it will be shown later, due to its limited radiating surface its contribution is by far less than that of the larger walking plates and especially that of the girders.

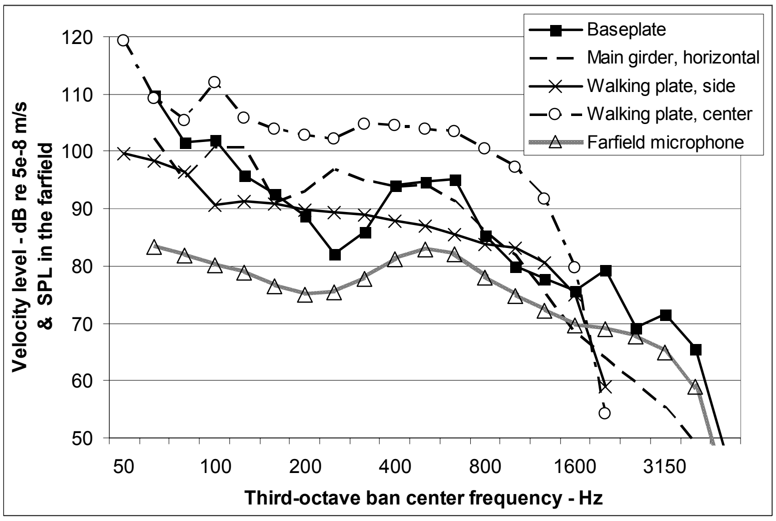

Fig. 3: Comparison of vibration spectra and the farfield noise

Comparing the spectrum shapes of the vibrations and noise, the main girder can perhaps be conceived to be an important radiator. This conclusion is further confirmed if one derives some kind of radiation efficiency curves, by subtracting the velocity levels measured along various potential radiator surfaces from the farfield noise spectrum, and the calculation is repeated for a number of different trains and pass-bys. The result is shown in Fig. 4. Unlike the other curve set, the relationship between the girder vibrations and noise levels (left figure) is practically identical for all trains, suggesting that the main girder acts as the major partial noise source into the farfield.

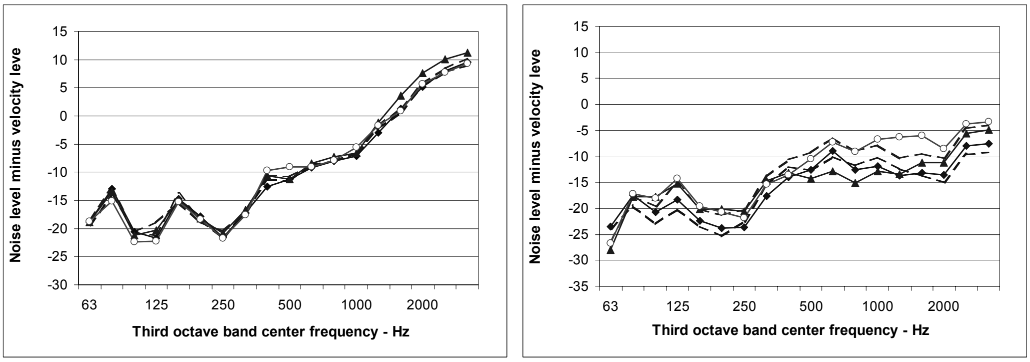

Fig. 4: “Radiation efficiency” curves (i.e., farfield noise minus vibration velocity spectra), calculated for a number of trains and pass-bys. Left curve set refer to main girder, right set to walking plate vibrations.

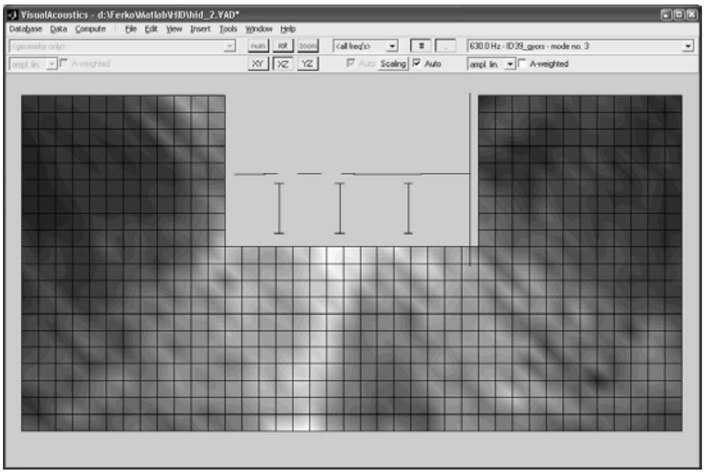

Fig. 5: Calculated sound field around along a visualization plane

Considering that the conclusions to be drawn from the investigations had serious financial implications, the spectrum analyses were complemented by numerical calculations as well. Structural FE simulation of the bridge structure was performed, and a simplified inverse Boundary Element technique developed. This method enables the analyst to calculate the sound field of a source with reasonable accuracy, even if very few information is available over the real vibration distribution along the source surfaces. A typical noise radiation pattern is depicted in Fig. 5; for more details of the technique see [1].

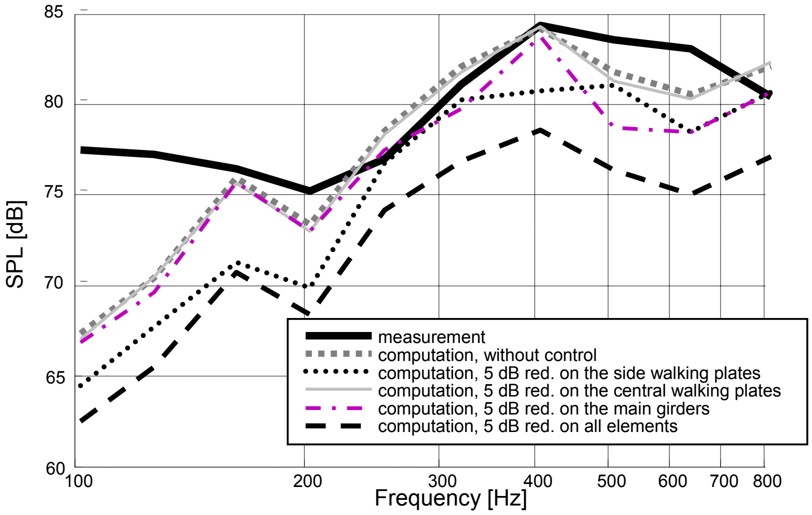

Fig. 6: Comparison of measured and computed noise spectra in the farfield reference microphone position, by assuming 5 dB vibration reduction along various potential radiating elements of the structure

The computations were performed for a simple model of the bridge, by assuming that 5 dB vibration reduction is achieved along the main girder, along the walking plates and along all important radiating elements, respectively. The results calculated for the reference microphone position are given in Fig. 6, from where one can draw somewhat different conclusion as discussed above: the side walking plate seems to be more important that the main girders.

The simulation calculations were verified by measurements on the bridge: in its original state, and also with the walking plates removed, see Fig. 7a. The result of this latter experiment is quite interesting: while the vibration is increased by some 1 dB in the relevant frequency range (obviously caused by less mechanical load on the primary vibrating elements), the total noise radiated to various noise measurement points is reduced by app. 2 dB. This end result has a very clear interpretation: half of the energy is radiated by the main girders and another half by the walking plate. This in turn implies that neither the vibration reduction of the girders, nor the essential improvement of the walking plate is sufficient to solve the problem entirely, but instead, both measures are necessary in order to achieve satisfactory noise control.

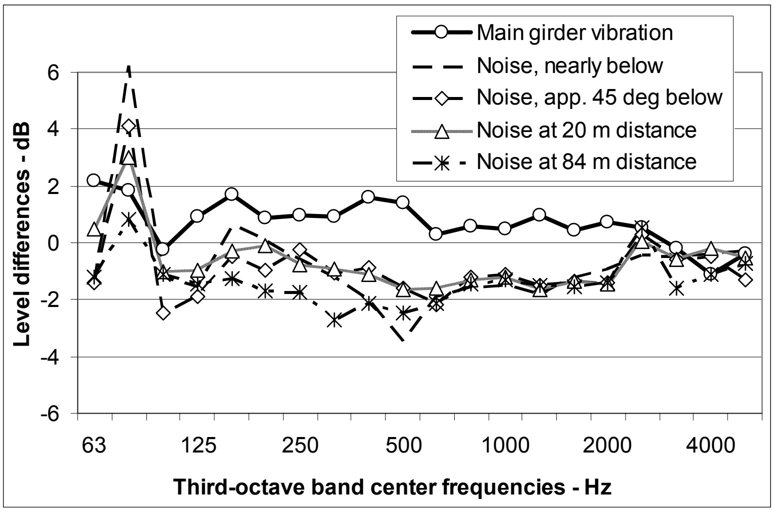

Fig. 7a and b: Removal of the walking plates and the resulting noise and vibration spectra.

NOISE AND VIBRATION CONTROL MEASURES

The design of vibration control of the rail fixture was based on a combination of a highly resilient pad and underslab. These elastic elements of the CDM FERPONT system are manufactured from natural rubber, corkelastomer composites and kevlar fibres and aim at reducing the vibration energy entering the bridge structure. As a consequence, the dynamic forces generated by the wheel/rail interaction put the rail into increased motion and therefore the rail can easily become an important airborne noise source. This noise component is to be reduced by a special tuned absorber (CDM ABSO-RAIL), fixed to the rail web.

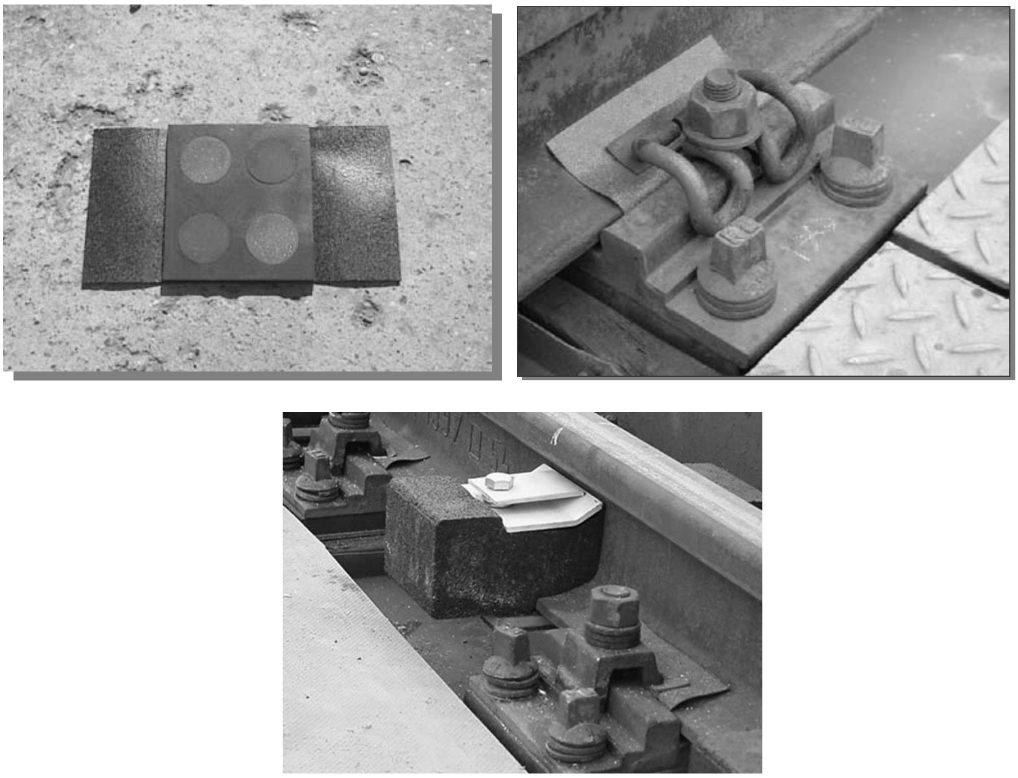

Fig.8: Elements of the CDM FERPONT system

The used elements selected for the given application were the CDM-DPHI-81010 resilient rail pad having statical stiffness value of K_{stat}= 30 to 35 kN/mm, adopted to K-clip and SKL12 rail fastener, see Fig. 8.

The noise radiation from the walking plates was treated by exchanging the steel plates for plates of a damped plastic composite material. This system was specially developed for general bridge applications, and its damping was optimized for the given case.

MEASUREMENT RESULTS

Fig. 9 shows the comparison of noise spectra, measured before and after the conversion works on the balcony of the new National Theatre, at app. 150 m distance from the bridge. Depending on the speed, load and other parameters of the trains, both the vibration and the noise level reduction ranges from 5 to 8 dB. In other words, this means that the train traffic along the bridge does no longer stand out from the general background noise of the area.

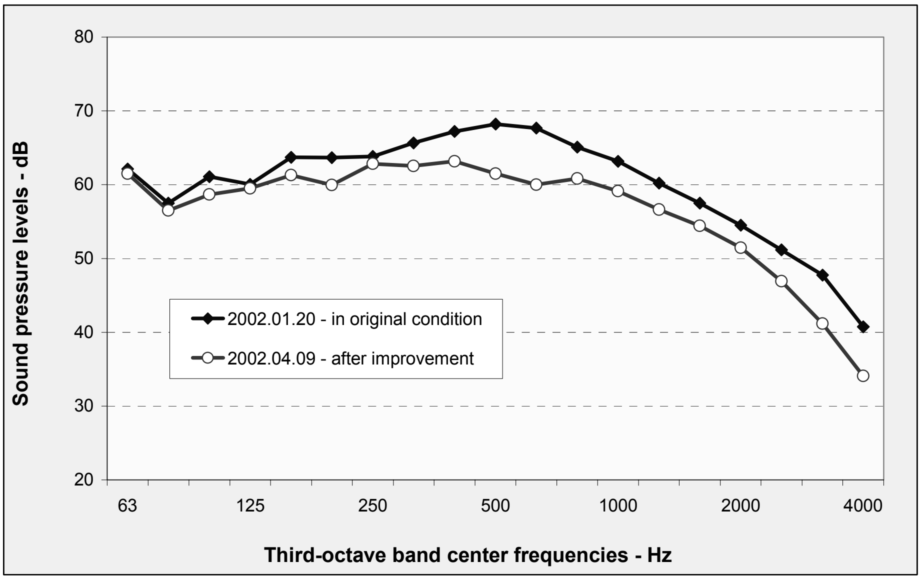

Fig. 9: Comparison of maximum noise spectra, measured for the pass-by of a passenger train

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