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Journal of Sound and Vibration 293 (2006) 944–952

JOURNAL OF SOUND AND VIBRATION

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# The use of dynamic dampers on the rail to reduce the noise of steel railway bridges

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Accepted 26 August 2005
Available online 9 March 2006

**Abstract**

Even if all steel railway bridges are different, most of them produce more noise than ballasted track. If located in populated areas, steel bridges may generate annoyance for the population. Specific noise reduction solutions must be developed. A research programme has been started to deal with this problem. The vibroacoustic study of a reference steel bridge has been carried out over the whole frequency range from 5 to 5000 Hz using the finite element method (FEM) in the low-frequency range and statistical energy analysis (SEA) at higher frequencies. At higher frequencies, the rail appears to be the main acoustic source. This result is confirmed by an experimental characterization. The spatial decay rates of the rail vibration are very low, due to the rail fastening system. Then, noise reduction solutions dedicated to the rail are considered, especially dynamic dampers which have been specified. Two products have been selected and tested on the reference bridge. The experimental results are discussed.

## 1. Introduction

Most steel railway bridges produce much more noise than ballasted track. If located in populated areas, they may generate annoyance for the population. Steel bridges are often 100 years old but their replacement is not yet needed as they can be used for 20 or 30 more years. Then, noise reduction solutions must be developed without significant modifications to the bridge.

Noise amplification as the train passes over the bridge mainly depends on the rail fastening system. If the direct fastening system can be replaced by an elastic fastening with ballast, the noise reduction is significant and can reach 10 dB. In the other cases, specific noise reduction solutions must be developed.

A research programme has been started to deal with this problem. The aims of this project are to develop a methodology based on measurements and/or simulations to choose the best solution to reduce the noise of a given steel bridge, and to propose a database of noise reduction solutions.

All the measurements and computations carried out during the research project will be used to define an approach to select the best noise reduction solution. This methodology is useful for the infrastructure manager who must be able to take the most appropriate measures to reduce the noise of their network.

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doi:10.1016/j.jsv.2005.12.017

## 2. Bibliography

A lot of work has already been done concerning the noise reduction of steel railway bridges. Janssens and Thompson [1] present a complete model able to predict the sound pressure radiated by a steel railway bridge. The main input is the rail vibration that can be measured or obtained from a rolling noise prediction model such as TWINS [2]. A simplified model of the bridge (beam or simply supported baffled flat plate) is used to compute the radiation. An important conclusion of the paper is that in the frequency range up to 500 Hz, the noise radiated by the bridge is predominant, while for higher frequencies the noise radiated by the rail and the wheel takes over. Some recommendations are proposed for low-noise design of steel bridges like the lowering of the dynamic stiffness of the fastener system to increase the vibration isolation between the rail and the bridge, combined with rail dampers to reduce the noise radiated by the rail.

The result concerning the important contribution of the rolling noise is also presented in Ref. [3]. In the low-frequency band, an optimum choice of isolation of track to avoid coupling of vehicle modes with bridge modes is essential but, in addition, measures are needed to reduce the A-weighted sound pressure level (SPL).

To reduce the rolling noise on steel railway bridges, de Vos proposes the use of an embedded rail [4]. A reduction in A-weighted noise of 6 dB is achieved [5]. Other noise reduction solutions are tested and compared in the literature. Odebrant [6] proposes a number of solutions to lower the A-weighted sound level by 10 dB. This ambitious goal can be achieved using a combination of solutions acting on the rail and on the bridge structure.

Even if suppliers are able to promote their noise reduction solutions, the efficiency remains difficult to compare. The test of noise reduction solutions on the same bridge is the best way to compare their performances and provide a complete database of solutions.

## 3. The measurement campaign

The first step of the research programme concerned the selection of a test bridge. This one was chosen to be representative of the noisiest and more common structures from the French railway network. The Gavignot bridge in Enghien les Bains, 20 km from Paris, has been selected (see Fig. 1). The deck plate is 20.8 m long and supported by two longitudinal beams. The track supported by the bridge is composed by UIC60 rails and wooden sleepers directly fastened on the steel deck plate (see Fig. 2).

Fig. 1. The Gavignot bridge selected for the study.

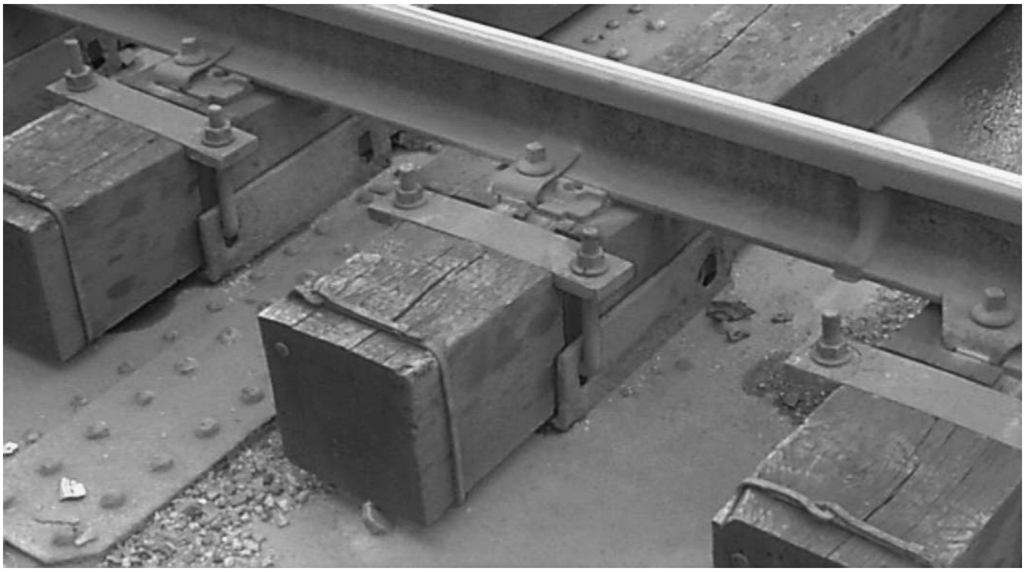

Fig. 2. Rail supported by wooden sleepers.

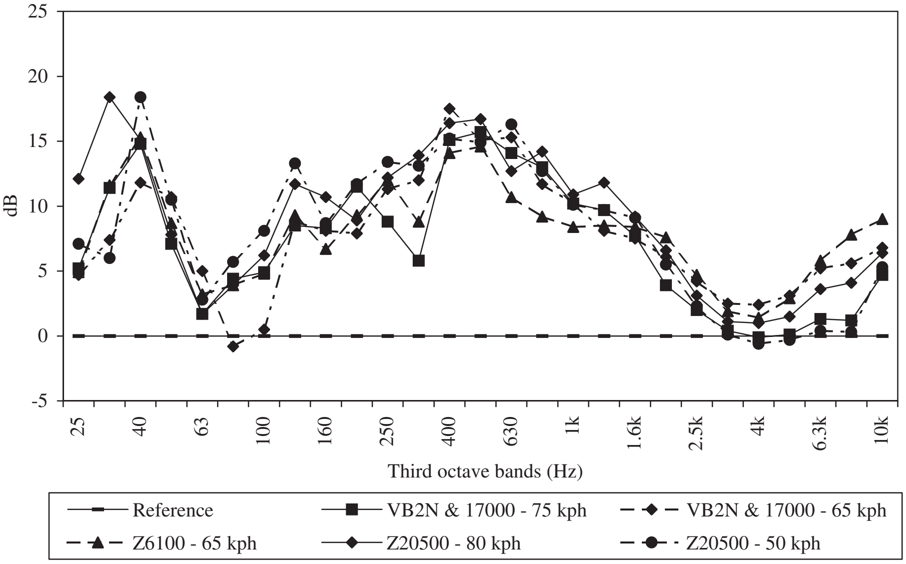

Fig. 3. Differences between the SPL measured in front of the bridge as well as a few hundred metres from the bridge on a ballasted track for each train (22 m far from the centre of the track, on the level of the top of rail). Z6100 and Z20500 are electric multiple units; VB2N and Corail are coaches pulled by 17 000 electric locomotives.

As a first step of the study, a measurement campaign was carried out to establish the SPL increase due to the bridge over the whole frequency range. The noise radiated by several passenger trains was measured in front of the bridge as well as a few hundred metres from the bridge on a ballasted track. For both measurements, the SPL was measured at 22 m from the centre of the track at the height of the top of rail. Suburban trains in normal operating conditions were recorded. Z6100 and Z20500 electric multiple units and VB2N and Corail coaches with 17 000 electric locomotives, compose the traffic. Their speeds range from 50 to 80 km/h. Differences between SPL are presented in Fig. 3. A value of 0 dB represents no difference between the SPL radiated by the train passing over the bridge and the ballasted track.

The increase in A-weighted SPL is between 10 and 14 dB.As shown in Fig. 3, the train speed and the rolling stock do not affect the increase in a given frequency band. Large differences appear around 40 and 400 Hz.The difference in A-weighted level is mainly due to the high-frequency energy. Nevertheless, the lower-frequency band generates annoyance too, for example, by causing windows to vibrate.

From this, it is clear that the understanding of the vibroacoustic behaviour of the bridge must be conducted over the whole frequency range. The finite element method (FEM) is used below 200 Hz [7]. The deck plate radiates the main part of the acoustic energy around 40 Hz. Solutions exist and will be tested on the Gavignot bridge in 2004–2005. Above 200 Hz, the vibroacoustic study and a noise reduction solution are presented in the next paragraphs.

## 4. The simulation of the vibroacoustic behaviour of the bridge above 200 Hz

Above 200 Hz, statistical energy analysis (SEA) has been used to predict the noise radiated by the bridge and identify parts of the structure which radiate the much more noise. The model is presented in Fig. 4. This three-dimensional view is built with 259 subsystems. Beams and plates are assembled to reproduce the elements of the structure. Two steel beams are used to model the rails and wooden beams for the sleepers. The software proposes internal loss factors. For the rail and the sleepers, a constant loss factor of 1% independent of frequency is chosen. Coupling loss factors are computed by the software according to the link (riveted, welded) defined between subsystems. A mass and an inertia are added along the link to take into account the small elements for which the modal density is too small to consider them as subsystems. The power input is computed by a dedicated toolbox of the software based on the theory of Remington [8,9]. The rail roughness is measured on the bridge itself and the geometry of the wheels is defined. Wheel roughness is selected in a database to be representative of the suburban train wheels.

The noise radiated at 22 m from the centre of the track is computed using this model and compared with measurement data in Fig. 5. The noise radiated by the rail and the propagation in the environment (image source) must be taken into account to reach the measured SPL.

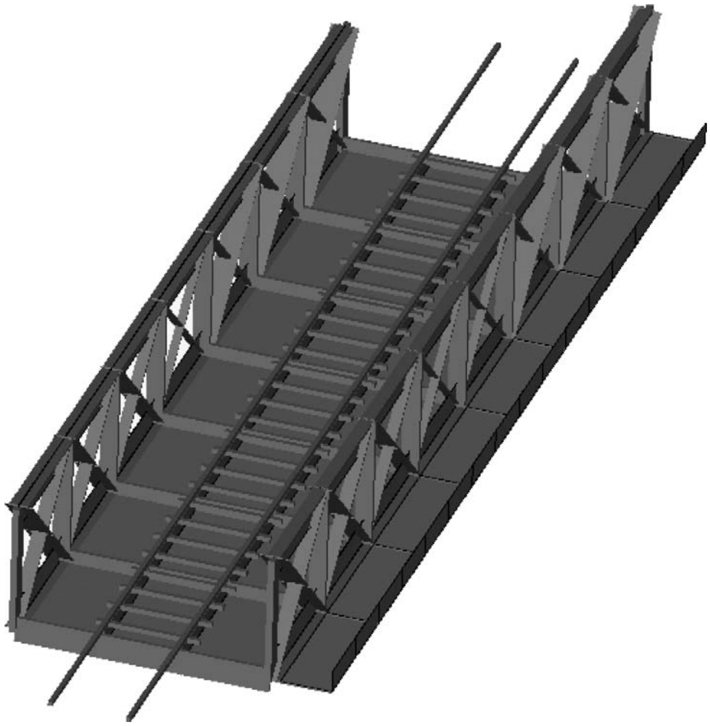

Fig. 4. View of the SEA model (AutoSEA software) of the Gavignot bridge. Each subsystem and link between subsystems are defined independently of the three-dimensional view.

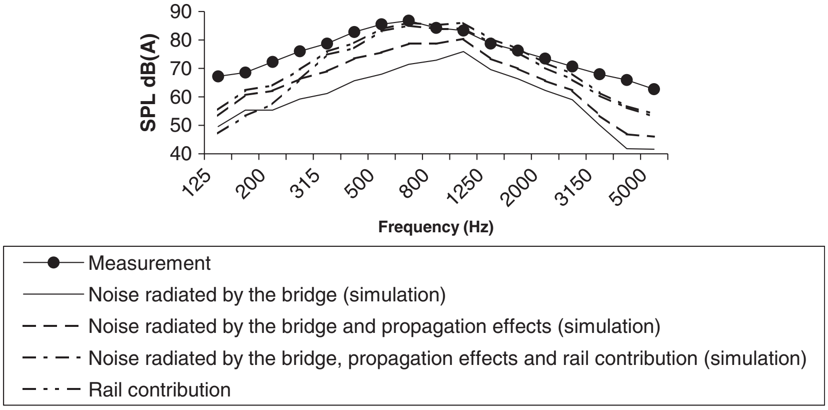

Fig. 5. A-weighted SPL measured ("measurement") and predicted ("noise radiated by the bridge, propagation effects and rail contribution" for a train (Corail) pass-by.

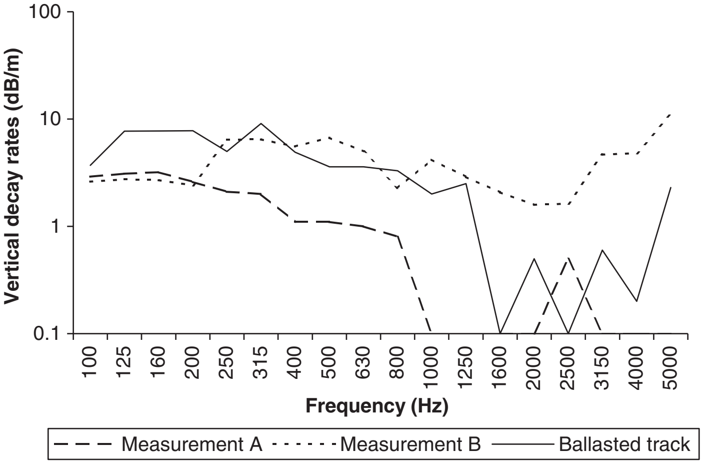

Fig. 6. Decay rates of the vertical energy in the rail in the middle of the test bridge ("measurement A"), at the extremity ("measurement B") and on the ballasted track.

To validate that the rail is the main acoustic source, the result of this model is compared with the result provided by a "reference model" for which the coupling loss factor between the rail and the sleepers is zero and the injected power is replaced by the energy of each subsystem measured during the field test. The comparison of the vibratory energy in the rail computed by both models show that the accuracy of the first one is better than 5 dB in each one-third octave band.

The large contribution of the rail to the increase in SPL is mainly due to the fastening system connecting the rail to the bridge. It can be characterized by the spatial decay rates of the vertical and lateral rail vibration. The SPL radiated by the rail is mainly linked to the vertical decay rates. As shown in Fig. 6, the vertical decay rates (measurements A and B) of the vibration in the rail depends on the place where the measurement is performed. Due to the limited length of the bridge (about 20 m), the decay rates seem to be low in the middle of the bridge and higher near the extremities. Track decay rates evolve continuously from the middle of the bridge, where they are very low, to the extremities of the bridge to join the track decay rates of the ballasted track.

## 5. The dynamic dampers

The decay rate of the vertical rail vibration is directly linked to the noise radiated by the rails as train wheels pass over them. Tuned dampers can be fitted to a variety of standard rail sections and tackle the noise at source. They consist in adding a mass–spring system to the rail and offer the possibility to enhance the track decay rates [10] and then reduce the noise.

In this case, the objective is to maintain over the whole frequency band a decay rate higher than 3 dB/m, especially around 1 kHz to reduce the A-weighted SPL. With such a specification, the noise reduction estimated using the SEA model is between 5 and 6 dB. This reduction is higher than the noise reduction estimated with rail dampers on a ballasted track [11] because of the low initial decay rate and high contribution of the rail to the SPL. Fig. 7 shows the predicted noise reduction as a function of frequency.

Then, an experiment has been carried out to test rail dampers in normal operating conditions on the test bridge. A rail damper was selected which conformed with the acoustic and infrastructure specifications. This is shown in Fig. 8. The tuned rail dampers can be installed directly on track onto rail that is already in service and this

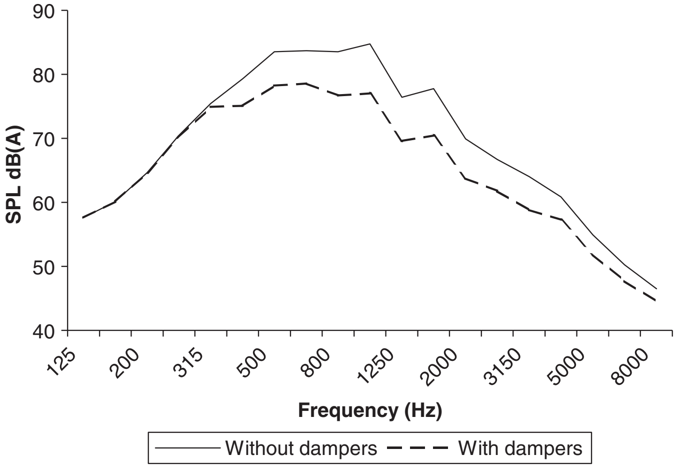

Fig. 7. SPL reduction estimated with the SEA model due to the use of rail dampers.

Fig. 8. Rail equipped with tuned absorbers on the Gavignot bridge.

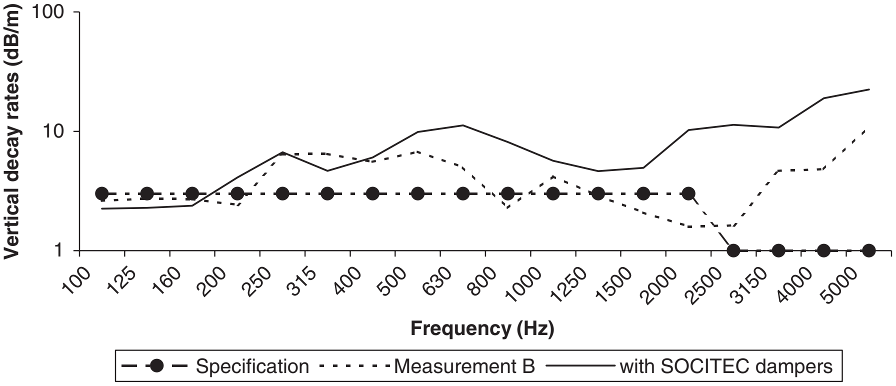

Fig. 9. Track decay rates of the Schrey and Veit (Socitec) tuned absorbers measured on the Gavignot bridge.

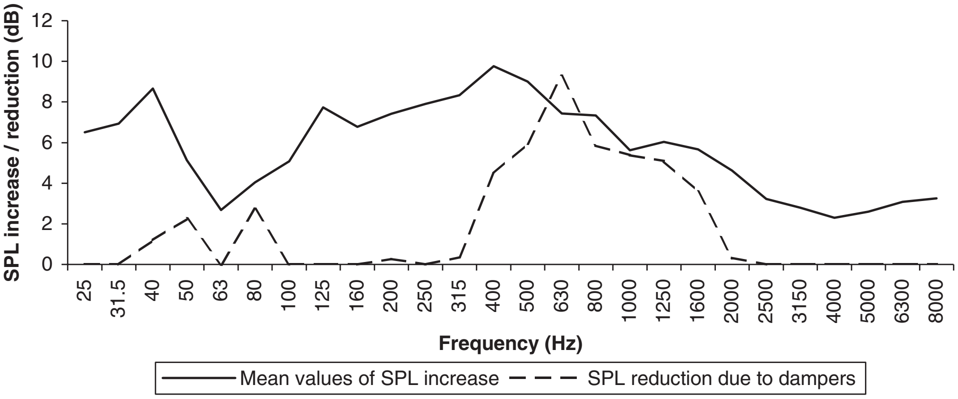

Fig. 10. SPL reduction according to the frequency compared with the SPL increase due to the bridge.

installation has been optimized to minimize possession times. Moreover the dampers must not require maintenance and must not produce effects on other elements of the rail infrastructure. Noise reduction was measured for service trains. The differences between the noise spectra of each train running on the ballasted track a few hundred metres from the bridge and the noise of the same train running on the bridge were computed. The increase in A-weighted SPL due to the bridge is reduced by 3–4 dB when the rail is equipped with tuned absorbers.

The operational efficiency is lower than the estimated one. Simulations have been carried out considering that the track decay rates are very low on the whole bridge. In fact, they evolve from the value of a ballasted track at the extremities to the considered value in the middle of the bridge. Fig. 9 confirms that the tuned absorbers improve the track decay rates much more than the specification over the whole frequency band. Nevertheless, a maximum of the track decay rates is reached around 800 Hz whereas the maximum SPL increase is located around 400 Hz.An improvement of the absorbers can be proposed to shift the maximum of the efficiency to the appropriate one-third octave band.

This proposal is confirmed Fig. 10 where the mean values of the SPL increase due to the bridge (mean value of the SPL increases presented in Fig. 3) and the mean value of SPL reduction due to dampers are plotted according to frequency. The maximum SPL reduction provided by the dampers is located in third octave band 800 Hz and the maximum SPL increase due to the bridge is in 400 Hz third octave band. Above 2 kHz, the contribution of the track decreases and wheels are likely to be the dominant source.

## 6. Another solution

Another solution intended to reduce the noise radiated by the rail is shown in Fig. 11. Like the tuned absorbers, this product is clipped on the rail. However, these blocks are made of a porous material. Because

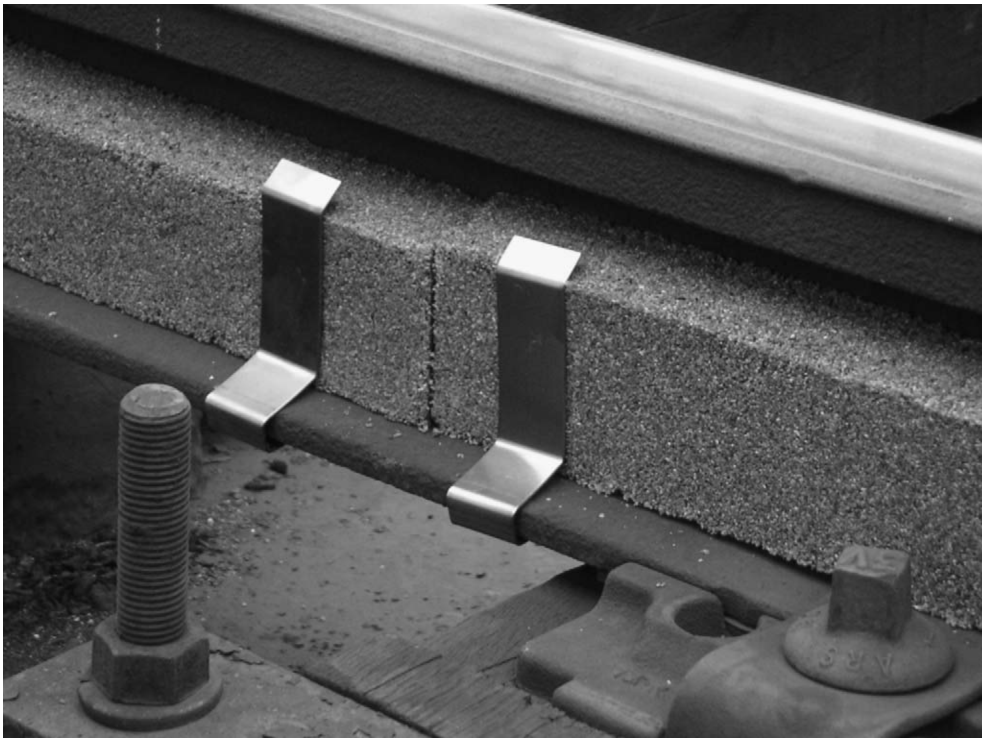

Fig. 11. Quietstone product clipped on the rail of the Gavignot bridge.

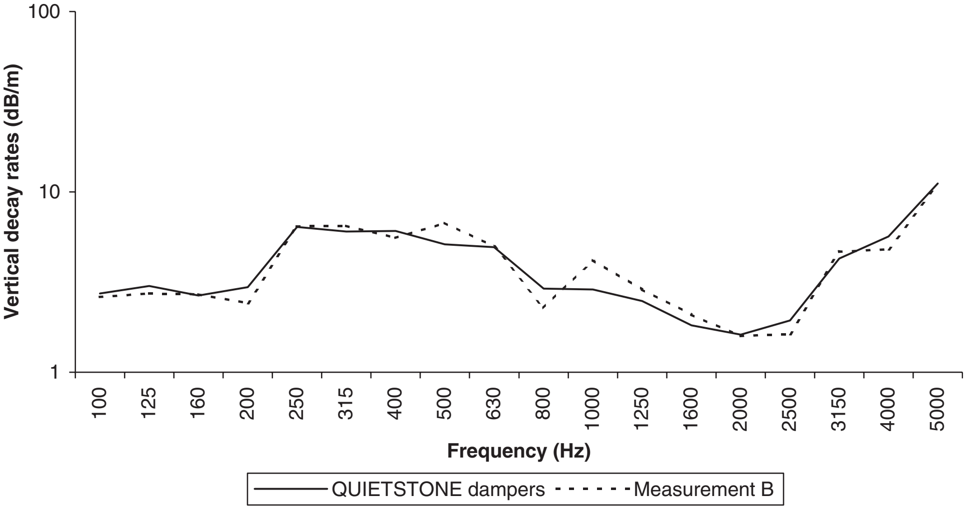

Fig. 12. Vertical decay rates of the vibratory energy in the rail equipped with Quietstone product.

they are not heavy, and do not contained a tuned mass–spring absorber system, the decay rates of the vertical rail vibration are not modified (see Fig. 12). The reduction in A-weighted SPL measured when the test bridge was equipped with this system was between 1 and 2 dB.This product reduces the SPL like a sound barrier very close to the rail.

## 7. Conclusions

According to measurements and numerical models, the rail is the major source of noise radiated by steel railway bridges above 100 Hz. Then, tuned absorbers for the rail are well suited to reduce the SPL. Some products exist and are able to enhance the spatial decay rates of the vertical rail vibration. The expected reduction in A-weighted SPL is between 5 and 6 dB according to the SEA approach. In practice, the reduction is measured as between 3 and 4 dB on a test bridge. A second product has been tested which acts like a sound barrier very close to the rail. The SPL reduction is between 1 and 2 dB in this case.

As the rail is the main component responsible for the increase in SPL above 100 Hz near a steel bridge with a direct fastening system, rail dampers become a standard solution to reduce the noise. Even though this solution is less efficient than a sound barrier, it is cheaper and is efficient in all directions of propagation.

## Acknowledgements

The research programme described is carried out by the French railway company SNCF for Réseau Ferré de France, the infrastructure manager. The noise reductions were measured by the test department of the SNCF. The rail dampers were supplied by Schrey and Veit (represented by Socitec in France) and Quietstone.

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