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# Experimental Characterisation of the Acoustic Performance of Railway Components

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## Abstract

To the end of developing novel rail pads with improved noise performance and ballast protection, an iterative loop was put in place. Design and simulations were performed numerically, and promising designs were made into prototypes that were tested experimentally. To this end, a test setup comprising of a three-sleeper railway segment was used. The setup was excited with white noise fed through a shaker, and the noise emissions were evaluated using intensimetry measurements.

Many rail pad designs were tested, and the results show that adapting the rail pads can improve noise emissions by as much as 3dB. These results were corroborated by sound pressure measurement performed on an 18-sleeper railway segment at the Technical University of Munich (TUM). The effect of under-sleeper pads was also evaluated and no significant influence on noise emissions could be found. This could be a limitation of the setup in its present form, as it doesn't have an actual rock ballast. In a parallel project titled Study of rail clamps preload influence on ballast solicitation and acoustic emissions, also commissioned by the swiss Federal Office for the Environment (FOEN), the effect of rail clamp preload on noise emissions was investigated and was found to be negligible.

The different measurements performed on the three-sleeper setup allowed to evaluate the influence of various track components on noise emissions. These show that rail pads are one of the components (excluding rolling stock) that have the most significant influence on railway noise emissions. The results seem to translate well to longer railway segments. Using a real rock ballast is the main element that could

improve the fidelity of the three-sleeper cell. Even without it, the three-sleeper cell delivered promising results, while offering great flexibility on a reduced-scale setup that can fit in a lab.

**Keywords:** railway, rail pad, experimental, noise.

# 1 Introduction

The project *Novel Rail Pads for Improved Noise Reduction and Reduced Track Maintenance*, commissioned by the swiss Federal Office for the Environment (FOEN) and carried out by the Swiss Federal Institute of Technology in Lausanne (EPFL), the School of Engineering and Management (HEIG-VD/HES-SO) and the Swiss Federal Laboratories for materials science and technology (Empa), aimed at developing novel rail pads with improved noise performance and ballast protection. To this end, a numerical finite element (FE) model of a three-sleeper section of railway was developed and calibrated using a real identical twin. The FE model was then used to explore pad designs, the most promising ones being made into prototypes, whose vibro-acoustic performances were finally assessed on the real three-sleeper cell, the whole forming an iterative loop. The goal of the unit-cell is to provide an experimental framework allowing for comparative and repeatable measurements. It was also used to characterise its behaviour in order to develop various simulation models.

The unit-cell has also been used to study other railway components, as for example, under-sleeper pads, or rail clamps, as in the parallel project, *Study of rail clamps preload influence on ballast solicitation and acoustic emissions*, also commissioned by the FOEN as well as the Federal Office of Transports (FOT) and carried out by the HEIG-VD/HES-SO.

The present paper is focused on the experimental noise measurements that were performed on the three-sleeper cell.

# 2 Methods

The three-sleeper cell visible in Figure 1 consists of:

- three B91 sleepers
- two 1.80m 60E1 rail segments
- twelve Vossloh W 14 clamping system
- a ballast substitute of 10cm-thick wooden beams

Compared to an actual railway track, some rail vibration modes present on the unit-cell are not present on continuous tracks. The free ends of the rail segments, being less constrained, also induce different vibration modes and additional noise emissions. The absence of actual ballast also affects the noise emissions of the sleepers.

The unit-cell is excited by an electromagnetic shaker attached at the end of a rail at an angle of 5.7° (relative to the vertical, pointing outward) or 45° (pointing inward) as shown in Figure 2. This shaker is fed a white noise signal.

The noise emissions are measured using a method called intensimetry. Using a pair of phase-matched microphones, the sound intensity is measured at discrete points evenly spaced on a surface (represented in Figure 3) enclosing a sound source, and then integrated over the surface area of the enclosing surface, to obtain the acoustic power emitted by the sound source [1]. This method allows suppression of steady background noise.

Figure 1 - The three-sleeper unit cell and the gantry for the intensimetry measurements

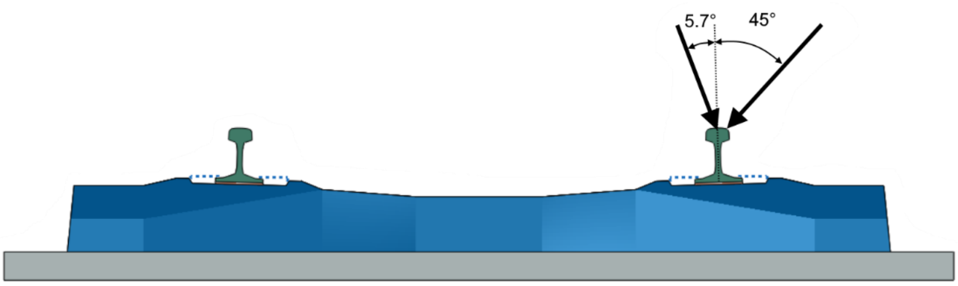


Figure 2 - The two different angles of excitation

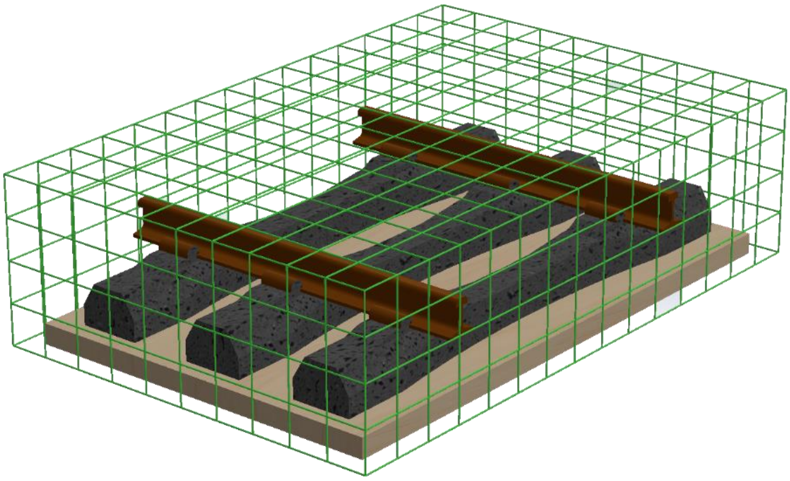

Figure 3 - The enclosing measurement surface.

The 3-axis gantry visible in Figure 1 was used to move the microphones in a repeatable way along the measurement points. The measurements are normalised by the square of the exciting force and are expressed in watts per Newton squared (W/N2), or dB of W/N2. The results are analysed in the spectral domain, over the 300-1500Hz frequency range.

The coherence of the acquired data, the reproducibility of the measurements and the rejection of foreign noises were evaluated to assess the reliability of the measurements and were found to be very good. Care was also taken during the measurements to assure quality of the acquired data.

In the *Novel Rail Pads for Improved Noise Reduction and Reduced Track Maintenance* research project, the acoustic properties of several rail pad prototypes were measured against reference EVA pads from the Swiss Federal Railways (SBB) in order to find quieter alternatives.

In the project *Study of rail clamps preload influence on ballast solicitation and acoustic emissions*, the variation of noise levels induced by different rail clamps preloads have been investigated.

## 3 Results

Figure 4 and Figure 5 show that different rail pads can affect noise emissions by as much as 3dB. The frequency range of interest is 500Hz-1120Hz, as results below 500Hz tend to be more random, and the peak around 1400Hz is not relevant to continuous railway tracks.

These results were corroborated by measurements performed at the Technical University of Munich (TUM) on a setup comprising 18 sleepers. Sound pressure measurements presented in

Figure 6 showed similar contrast between the hybrid prototypes and the reference hard pad.

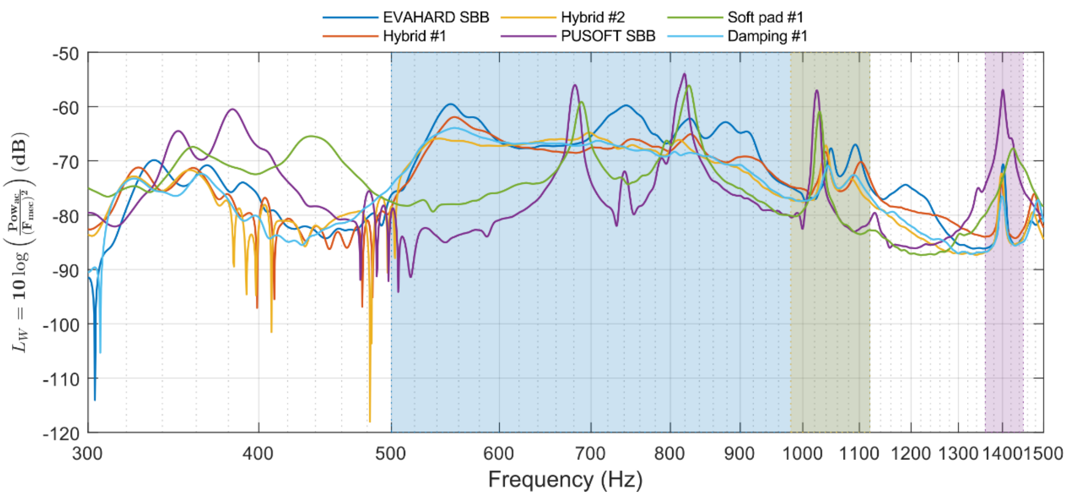


Figure 4 - Normalised acoustic power spectrum for different types of rail pads (5.7° excitation).

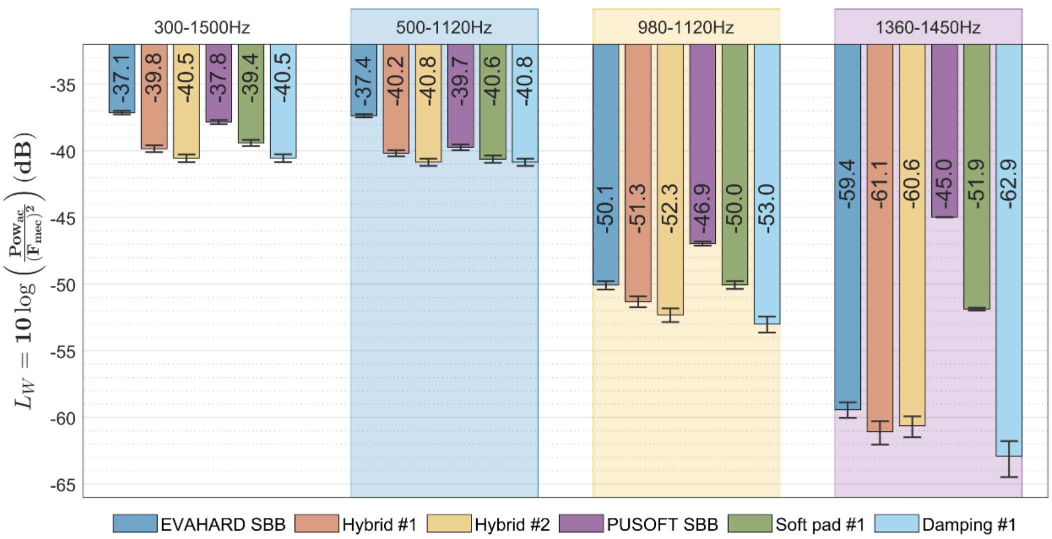


Figure 5 - Normalised acoustic power for different types of rail pads, for the frequency bands of interest illustrated in Figure 4 (5.7° excitation).

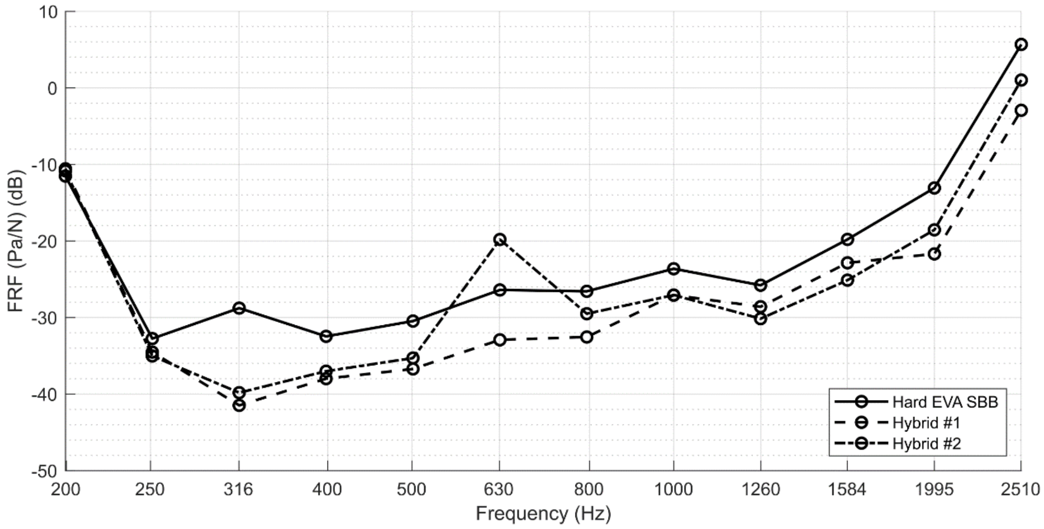


Figure 6 - Sound pressure measurements performed on a 18-sleeper track, for different types of rail pads (5.7° excitation).

The influence of under-sleeper pads (USP) was also investigated and can be seen in Figure 7 and Figure 8. No significant influence could be found. This could also illustrate a limitation of the three-sleeper cell in its present form. Without a real ballast, the interaction between the sleepers, the USPs and the rocks of an actual ballast cannot be properly replicated. Also, the aim USPs is mainly to protect the ballast and not so much to reduce noise.

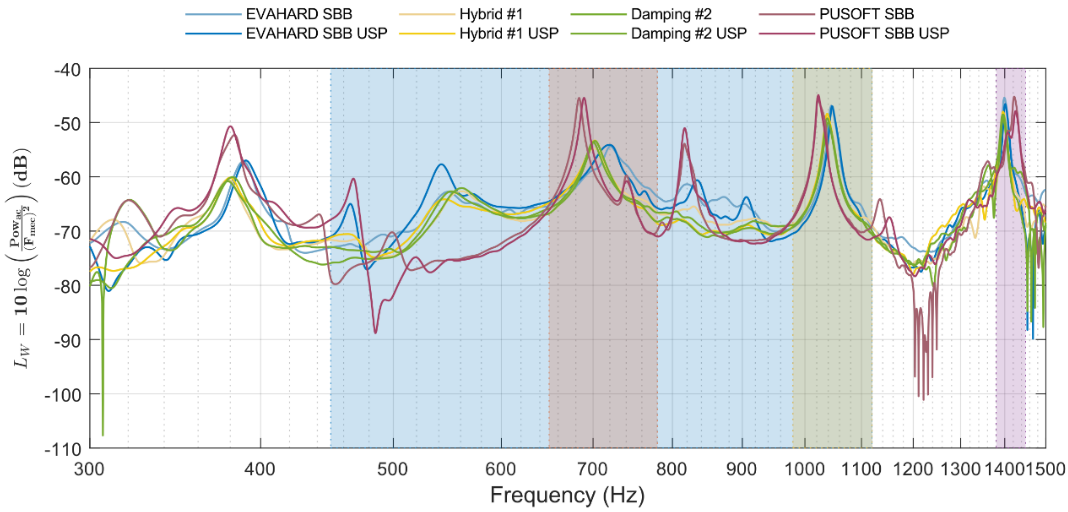


Figure 7 - Normalised acoustic power spectrum for different types of rail pads, with and without USPs (45° excitation).

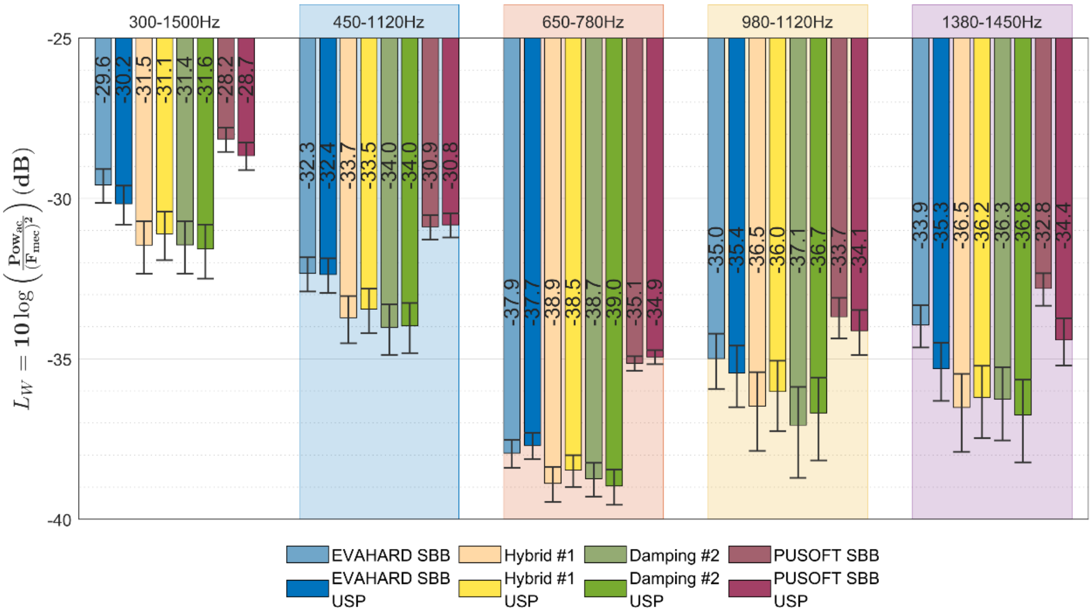


Figure 8 - Normalised acoustic power for different types of rail pads, for the frequency bands of interest illustrated in Figure 7 (45° excitation).

In *Study of rail clamps preload influence on ballast solicitation and acoustic emissions*, two cases were studied:

- All clamps (6) loaded at 100, 75, 50, 25 and 0% of the nominal preload
- 1, 2 and 4 clamps (8, 16, 33%) on the central sleeper loaded at 50% of the nominal preload.

In the first case, shown in Figure 9, noise emissions increased only when the clamps were completely untightened.

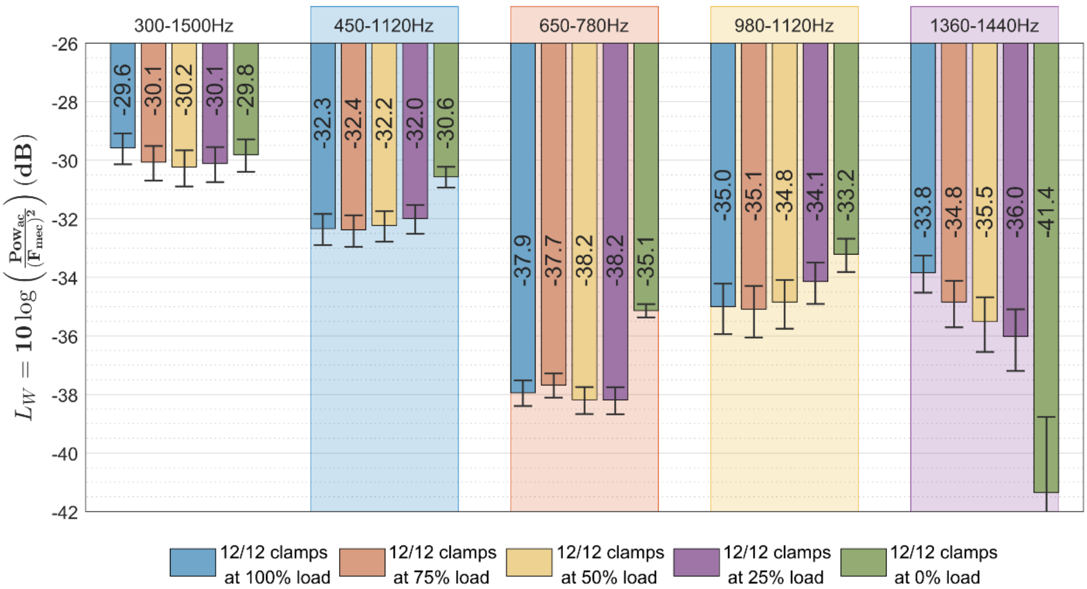


Figure 9 - Normalised acoustic power for different preload levels applied to all twelve clamps, integrated over the frequency bands of interest (45° excitation).

In the second case, shown in Figure 10, no significant influence on noise could be found.

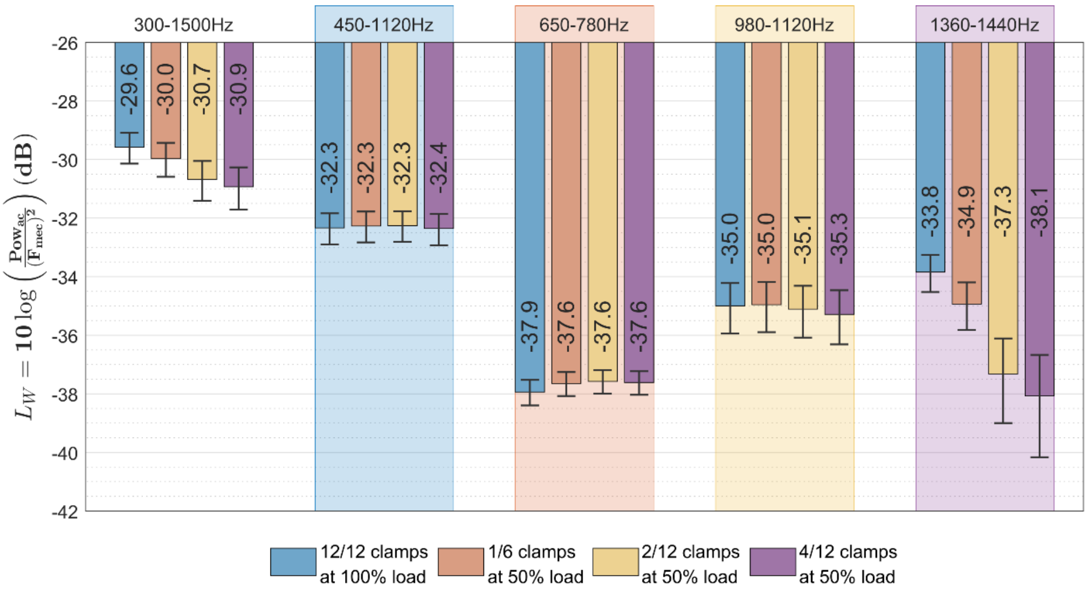


Figure 10 - Normalised acoustic power for a 50% preload applied to a various number of clamps, for the frequency bands of interest (45° excitation).

## 4 Conclusions and Contributions

The different intensimetry measurements performed on the unit-cell allowed to evaluate the influence of various track components on noise emissions in a fast and reproducible manner. Despite the small size of the setup, which induces vibration modes that are not 100% representative of a continuous track, the three-sleeper setup provided similar contrasts between pads than what could be measured on a long track with real ballast. Notably, it was found that it is possible to reduce noise emissions by about 3dB by adapting the rail pads. It was also found that clamps tightening, on stiff EVA pad, had no significant effect on noise, except if they were to be all completely untightened. No significant influence on noise emissions could be found when under-sleeper pads were used, although this could be linked to the absence of an actual rock ballast and thus limitations of the test setup.

Using a real rock ballast is the main point that could improve the fidelity of the three-sleeper cell. Even without it, the three-sleeper cell delivered promising results, while offering great flexibility on a reduced-scale setup that can fit in a lab. It also showed that rail pads are one of the components (excluding rolling stock) that have the most significant influence on railway noise emissions.

## Acknowledgements

The projects *Novel Rail Pads for Improved Noise Reduction and Reduced Track Maintenance* and *Study of Rail Clamps Preload Influence on Ballast Solicitation and Acoustic Emission* are funded by the Swiss Federal Office for the Environment (FOEN) and the Swiss Federal Office of Transport (FOT).

## References

[1] EN ISO 9614-1:2009 Acoustics. Determination of sound power levels of noise sources using sound intensity Measurement at discrete points.