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# SOLUTIONS FOR ACOUSTICAL PROBLEMS WITH BALLASTLESS TRACK

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Ballastless track has higher sound emissions compared to ballasted track due to the reduced connecting impedance for the rail, the reduced vibration decay rates along the rail and the reduced absorption. A study using a simulation tool for the prediction of sound for trains led to a proposal for an acoustical innovative ballastless track design (AIFF). This concept introduces a damped and booted sleeper. A prototype sleeper has been developed. Results from laboratory experiments on a single sleeper and on a short-track section consisting of 10 sleepers showed promising results.

## 1. INTRODUCTION

Rolling noise is the predominant source of noise emission of railroads over a wide range of train speeds. For typical vehicle and track configurations without noise barriers this range extends from 60 to 280 km/h. As the majority of passenger traffic and all freight traffic operates within this speed range, rolling noise is the major noise source of concern for railways.

This applies both to ballasted track and ballastless track (FF), which will be the standard track type for newly constructed lines of Deutsche Bahn AG (DB AG, German Federal Railways). Compared to ballasted track, ballastless track has the disadvantage of increased noise emission (see Figure 1), where at present sound absorbing layers are added to the construction as a counter measure. A short overview of the measures necessary to reduce noise is given in section 2.

The traditional approach to noise control would have been to study the generating mechanism before deciding which secondary absorption or shielding measures to apply. The approach taken to investigate primary measures and the preliminary results achieved within a project for the development of an "acoustically innovative ballastless track" (AIFF) are presented in Section 3.

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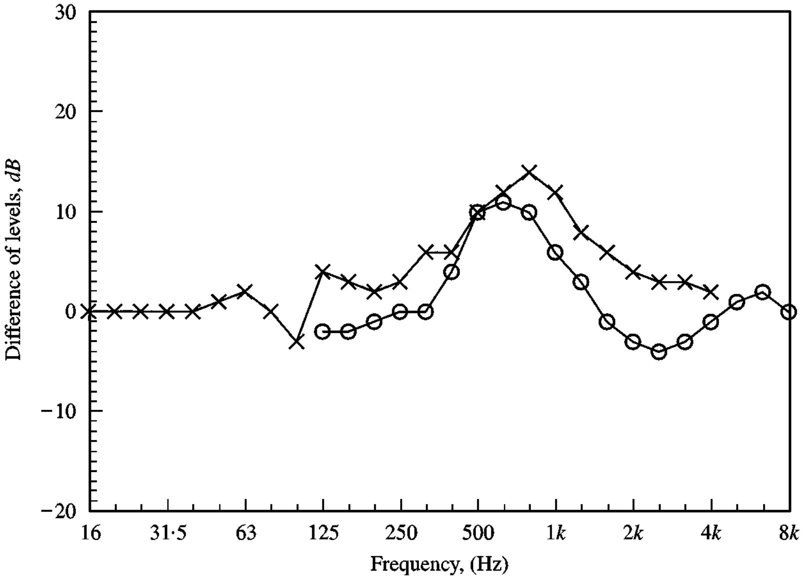

Figure 1. Difference of levels comparing ballasted and ballastless track for vehicle interior noise (×) and structure borne sound on the rail (○).

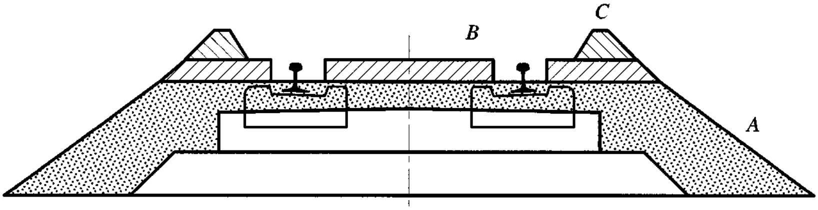

Figure 2. Cross-section of ballastless test track with absorption: absorbing layer (A), add-on to shield the rail (B) and mini barrier (C).

## 2. SECONDARY NOISE REDUCTION MEASURES

In 1993, when DB decided to build ballastless track in a larger scale, a series of tests was undertaken with the aim of showing that absorbent ballastless track can be acoustically equal to, or even better than, ballasted track [1]. In order to achieve this objective three mechanisms were taken into account:

- *absorption of the rolling noise which is radiated downwards*: the absorption layer should be as thick as possible, reaching out to the side as far as possible.
- *inhibiting the radiation of the rail*: this can be achieved by covering as much of the rail as possible with the absorbing material.
- atenuating the radiation of sound between vehicle underside and absorption by installing small barriers.

Figure 2 shows an example of a typical cross-section constructed using rubber granulate to test the importance of the three mechanisms described and the effect of the countermeasures. The combination for all three mechanisms showed level reductions of approximately 6 dB; omitting the small barriers (C) reduced this effect to around 4·5 dB, whereas leaving out the shielding of the rail (B) led to only a marginal reduction. Using simple absorption alone (A) gave around 3 dB reduction.

These values were achieved with newly applied materials. A degradation of the effects has to be expected due to wear caused by weather, pass-by of trains and dirt deposit in the cavities.

## 3. PRIMARY NOISE REDUCTION MEASURES

### 3.1. MODEL CALCULATIONS

The rolling noise generation model RIM [2], based on the ideas first put together into a model by Remington [3] was developed for DB AG. This impedance model of wheel, rail and contact zone, excited by the combined roughness of the running surfaces, can be used to predict structure- and airborne sound from the various components of the wheel/track system, similar to ERRIs TWINS package [4]. A validation [5] conducted for passenger trains on ballasted track showed good agreement between calculated and measured results.

A comparison of the predicted spectra for train pass-bys on ballastless and ballasted tracks, as presented in Figure 3, shows that the higher pass-by levels are caused predominantly by higher radiation of the rails in the frequency range between 500 and 1500 Hz.

Inspection of the respective spectra of the structure-borne sound on the rails shows that rail vibration levels in that frequency range are higher and that the damping of the vibration along the rail is substantially lower for ballastless track; furthermore, the input impedance in the relevant frequency range of a ballastless track is significantly lower when compared to a ballasted track.

These effects are caused by the fact, that for standard ballasted track, the rail is fixed quite rigidly to the sleeper via a stiff rail pad in the fastening. For ballastless track the rail fastening includes a comparatively soft baseplate pad, thus decoupling the rail from the slab. As the baseplate itself is rather lightweight it does not have a great influence on the connecting impedance of the rail. Apart from the mass effect, the embedded sleeper of the ballasted track acts as an absorber through its damped resonances.

In order to study thoroughly the effects of various types of track construction parameters such as the dynamic properties of rail, the pads, and the sleepers were investigated. This study lead to the proposal described in the next Section.

### 3.2. PROPOSAL FOR AN ACOUSTICAL INNOVATIVE BALLASTLESS TRACK

The parameter study showed that the basic principle of construction of standard ballastless track is acoustically problematic. The low connection impedance of the rail in the important frequency range, caused by the baseplate in combination with

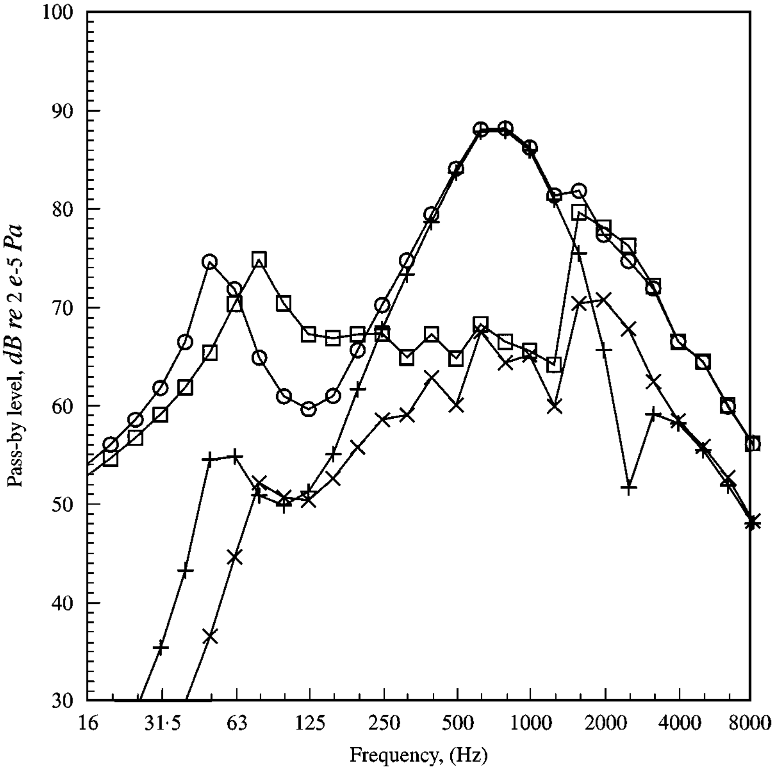

Figure 3. Comparison of predicted one-third-octave band spectra of pass-by sound of a passenger train at 25 m distance, total (○, □) and the respective contributions of the rail only ( + , × ) on ballastless (○, + ) and ballasted track (□, × ).

the soft pad, must be avoided. In addition, this pad has a low loss factor leading to low damping of the rail.

In order to optimize ballastless track, it is therefore proposed to introduce a booted sleeper. The necessary elasticity is placed under the sleeper, thus providing a rigid connection between the rail and the sleeper. However, the theoretical results and prior experience with the Modurail system [6] showed, that without additional damping, high sleeper vibration is to be expected. It is therefore proposed to design a sleeper with internal damping, to act as a vibration absorber for the rail.

### 3.3. THE DAMPED SLEEPER

The booted damped sleeper will have the same effect on the rail as a sleeper embedded in ballast. In order to prove this effect, the loss factor of a freely suspended sleeper was measured in the laboratory and compared with the loss factor of a sleeper embedded in ballast, but decoupled from the rail. This decoupling was realized by dismantling the rail fastening and taking out the rail pad.

Figure 4 shows the results of this experiment for a concrete sleeper type B 70 W. The loss factor of the free sleeper is below $\eta = 0{\cdot}02$, whereas the embedded sleeper shows values of $\eta > 0{\cdot}1$ for the relevant frequency range from 300 to 2000 Hz.

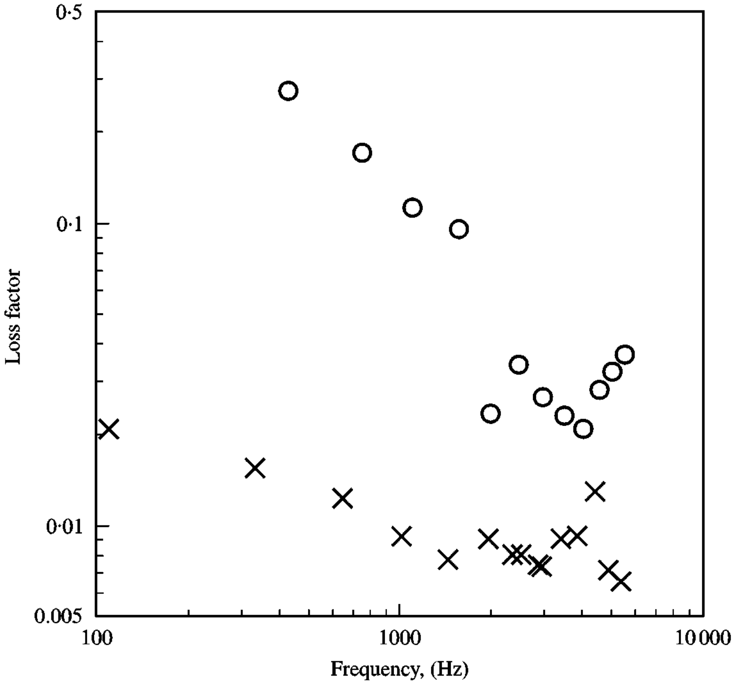

Figure 4. Comparison of loss factors for a free (○) and an embedded (×) concrete sleeper type B 70 W.

### 3.3.1. *Development of a damped sleeper*

In order to achieve damping in the construction of a sleeper, the application of a constrained layer appeared to be the most promising method. Basically, the sleeper is cut horizontally into layers and reassembled using a visco-elastic damping material between the layers. Optimum values for the loss factor of the assembly are to be expected for two equally thick outer layers with a thin damping layer connecting them.

### 3.3.2. *Model experiments*

As a damped concrete construction is not generally normally used currently, experiments for the determination of optimized material combinations for the relevant temperature range were conducted. In order to reduce the costs, concrete beams of size $1600 \times 125 \times 125\,\text{mm}^3$, cut in half and glued together using the damping materials, were used.

In order to determine the loss factor of the concrete beam, transfer impedances were measured with hammer excitation; the loss factors were estimated for all relevant modes using a modal analysis tool. As the properties of these visco-elastic materials are highly temperature dependent, the model sleeper was heated and cooled to cover the temperature range from approximately — 20°C to 40°C.

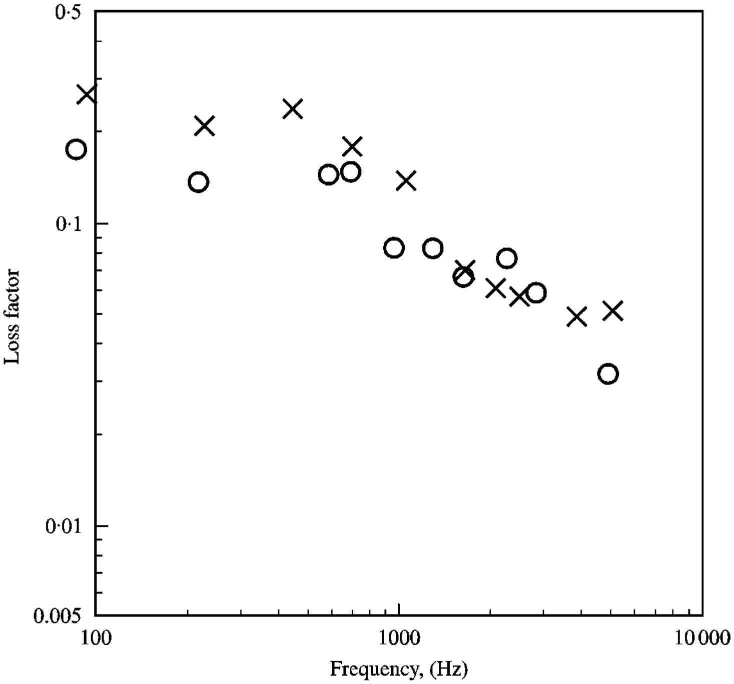

Figure 5. Loss factor of a prototype sleeper with damping material PVAC (Mowilith) depending on temperature: 20°C (×), 35°C (○).

### 3.3.3. *Development of a prototype sleeper*

In collaboration with Pfleiderer*, a manufacturer of concrete sleepers, different possible constructions of a damped concrete sleeper were discussed. Apart from the simple cross-section (cutting the sleeper horizontally) various other configurations were designed, where the pay load would not be transferred via the damping layer. In order to estimate the resulting loss factor of these constructions FE-calculations were made. An optimum sleeper should have a number of highly damped resonances in the relevant frequency range.

Due to construction problems, the concept of separating the damping layer from the load was abandoned, and sleepers with a simple cross-section were built. Dynamic and static tests showed that the construction can easily bear the loads and the sleepers passed the standard tests.

Figure 5 shows the measured loss factors of such a prototype for two temperatures.

### 3.3.4. *Experiments on a short prototype track section*

In order to evaluate the predicted structure-borne noise benefit of the proposed ballastless track, a short test section consisting of 10 damped sleepers was built.

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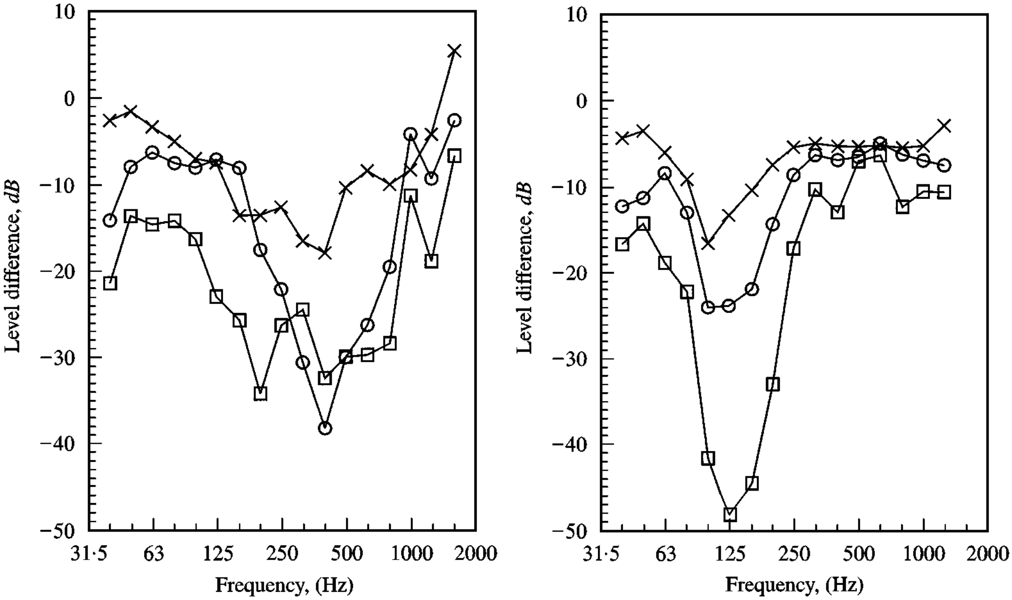

Figure 6. Reduction of the vibration propagating on the rails of AIFF (left) and standard ballastless track (right). Differences of vibration levels between the excitation point at one end of the rail and response points at the respective distances of 2 (×), 4 (○) and 8 sleepers (□).

The sleepers were laid on a ballast mat provided by Getzner[†] which was put on a concrete slab. The static supporting stiffness for the sleepers was set to approximately 22·5MN/m per support. The sleepers were cast in the mold of a sleeper type B 320 which is used for ballastless track; in addition, the horizontal damping layer was inserted during the production process. This sleeper uses the type Ioarv 300 rail fastening, which includes a baseplate pad. In order to achieve the stiff coupling of rail and sleeper necessary for AIFF, the baseplate pads were replaced by steel plates for one rail, whereas the other rail was fixed in the standard fastening with the soft baseplate pad decoupling the rail from the sleeper as is common practice for ballastless track. The rail ends were covered with a pile of sand in order to add damping to one end of the rails and thus reducing reflecting waves.

Figure 6 shows the results derived from input and transfer impedance measurements on the two rails of the test section. It can be clearly seen that for ballastless track the decay rate is very low in the frequency range between 315 and 1500 Hz compared with the AIFF. These results show that the proposed design achieves the predicted vibration characteristics.

## 4. OUTLOOK

The AIFF was designed according to acoustical principles, but is now undergoing a process of redesign in order to fulfil all requirements of DB AG's

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[†] Getzner Werkstoffe GmbH, Grünwald, Germany.

track department and the Eisenbahnbundesamt (EBA, Federal Railway Authority) so that a test section can be constructed in order to evaluate the performance under operational conditions.

A cost estimate showed that the additional costs necessary for the elastomer under the sleeper and inclusion of the damping layer can probably be covered by the cost savings achieved by moving the simpler rail fastening system and by the fact that the absorption layer has now become redundant.

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