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MODELING MULTIPLE REFLECTIONS BETWEEN TRAINS AND NOISE BARRIERS IN THE EUROPEAN NOISE PREDICTION APPROACH

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ABSTRACT

Transparent noise barrier panels are typically sound hard. In case of hard reflecting sidewalls of railway vehicles multiple reflections occur which lower the effect of noise barriers. Main factors influencing the insertion loss are height and vertical positioning of such reflecting elements as well as the distance between barrier and train. An important question is how such partially reflecting barriers can be considered accurately in standardized noise calculations methods. This study aimed on investigating the effect of such transparent/reflecting panels by means of extensive computational simulations with the 2.5D boundary element method which were previously validated using pass-by measurements. These calculations were used as a basis for comparison with the multiple reflection approach of the ÖAL 28 calculation model which is the Austrian implementation of the calculation scheme introduced by the directive (EU) 2021/1226 in order to identify possible shortcomings and find potential solutions. Major findings were, that simply using the vertical profile of absorption coefficients of the noise barrier causes strong discontinuities which can be avoided by modeling the reflections using Fresnel-zones. Furthermore, lowering the source to the top of the rail and shifting the vertical plane close to real positions yielded an improvement compared to the reference calculations.

Keywords: *Sound hard noise barriers,European noise directive,multiple reflections*

1. INTRODUCTION

Noise barriers along railway lines are usually highly absorbing as sound hard or highly reflecting surfaces oriented towards the track lead to reflections between train and barrier which may diminish the barrier's shielding effect (see e.g. [1–4]). The ÖAL 28 [5], which is the Austrian implementation of the propagation of the European prediction model [6] provides a calculations scheme for estimating the effect of multiple reflections between full-surface reflecting noise barriers and railway vehicles. The effect of multiple reflections is determined using a ray based approach also including partial reflections near the upper edge of the barrier. Commonly used barriers combining highly absorbing and transparent and thus highly reflecting elements are, however, not covered. Furthermore, the vehicle body is assumed to be vertical, flat, infinitely high and positioned above the near rail position.

The main aim of the work presented here was to investigate the effects of absorption coefficients varying over the height of the barrier, a way to incorporate these effects into the existing calculation method, and the potential limitations of such an approach. The basis for this investigations will be a set of 2.5D boundary element method reference calculations (BEM, [7, 8]). The calculation method was validated using extensive measurements along a double-track line equipped with a 2 m high and highly absorbing noise barrier which was modified using differently positioned reflecting panels [4].

2. METHODS

2.1 Noise prediction model

The approach for multiple reflections in the ÖAL 28 is ray based and is subject ot a number of simplifications.

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First, instead of a full 3-dimensional propagation path, for oblique paths only the vertical plane between the source and the receiver is considered. Furthermore, the vertical reflecting plane defining the vehicle's body is assumed to be positioned at the rail nearer to the noise barrier. The sound power portions of all image sources are subsumed to a single equivalent source, located above the head of the nearer rail at 0.5 m above the top of the rail. For each partial source, correcting terms are applied describing the difference between image source and equivalent source in spherical divergence, diffraction by the top of the barrier, absorption of the vehicle body and the barrier, and finite height of the barrier. The correction term for the barrier absorption of the n-th multiple reflection is taken to be the n-th power of the barrier's reflection coefficient.

To extend the calculation scheme for barriers with reflecting elements, the power term is changed to a multiplication of the locally reflection coefficients of each of the reflection points on the barrier. For discrete material changes the purely ray-based approach leads to discontinuities in the sound field behind the barrier. For that reason, λ/4 Fresnel zones describing a more realistic reflection behavior were introduced (c.f. [9]).

Furthermore, as the geometric positions of the equivalent source and the vehicles body plane according to the prediction model provide significant deviations of main propagation directions from BEM results, the source position was lowered to the top of the rail and the reflecting plane was shifted to a typical vehicle extension of 1.41 m from the middle of the track, which yields steeper and better matching propagation paths of reflections. Only results with these adaptions will be shown in this article.

2.2 Reference calculations

A 2.5D BEM approach was used to produce a set of reference calculations. For details of the model and the comparison to measurements please refer to [4]. Briefly, in order to determine the effects of reflecting panels the noise barrier was modified by temporarily attaching wooden formliners to the side facing the track. Four different variants of the noise barrier composition were recorded: the highly absorbing ground state, a 1 m high strip attached at the top as well as 0.5 m below the top of the barrier, and, using the latter vertical position, a fourth variant with only every other panel attached. A second cross-section in the immediate vicinity of the barrier served as a reference for determining the rolling noise. The measurements showed considerable effects of the reflecting panels which depend on the barrier variant as well as the type of rolling stock passing by.

The measurements were used to validate a 2.5D boundary element calculation model which was used as a reference for calculations using the ÖAL 28 model. The main focus for the reference model was to derive a suitable source model. Placing the source on top of the near rail lead to a good agreement between measurements and calculations with deviations mostly in the range of 1 dB and rarely more than 2 dB. The effects of the rolling stock were also partially reproduced in the calculations although for vehicles with more complex superstructures slightly higher deviations were observed.

Using this calculation model a number of different settings was calculated using heights of 2, 3, and 4 m. Here, only the 3 m high barrier and the close rail position will be considered. 1 m high sound-hard panels were placed at the top of the barrier and 1 m below the top of the barrier. As a reference a highly absorbing wall was used. The absorption material was determined as an average from the measurements in [10]. Three different track positions were also considered: 4.5 and 8.5 m distance between barrier and the near rail as well as a distance of 5 times the barrier height from the closest track.

3. RESULTS

The left column in Fig. 1 shows the reduction in insertion loss of adding a 1 m high panel placed immediately below the top of a 3 m high barrier. The upper left subfigure shows the ÖAL 28 calculation results when material changes are treated as discrete. Clearly, strong discontinuities occur in the field behind the barrier and the separate three reflections can be cleary distinguished starting from the first reflection at the top. Applying Fresnel zones leads to a much smoother effect of the reflecting surface (middle left subfigure). In comparison, the BEM calculation (bottom image) shows a qualitatively similar picture, however the calculated reduction exhibits up to a 2 dB higher change. In addition, two other differences can be observed. First, the change in barrier configuration leads to more extended effects in the regions close to the ground for the BEM results. This is not an effect of the reflections themselves and can not be obtained by increasing the number of reflections. The left subfigure in Fig. 2 shows the ÖAL calculation using two additional reflections (i.e. five in total). Virtually no change is observable which is due to the increased number of reflections in the absorbing portions of the barrier for higher order reflec-

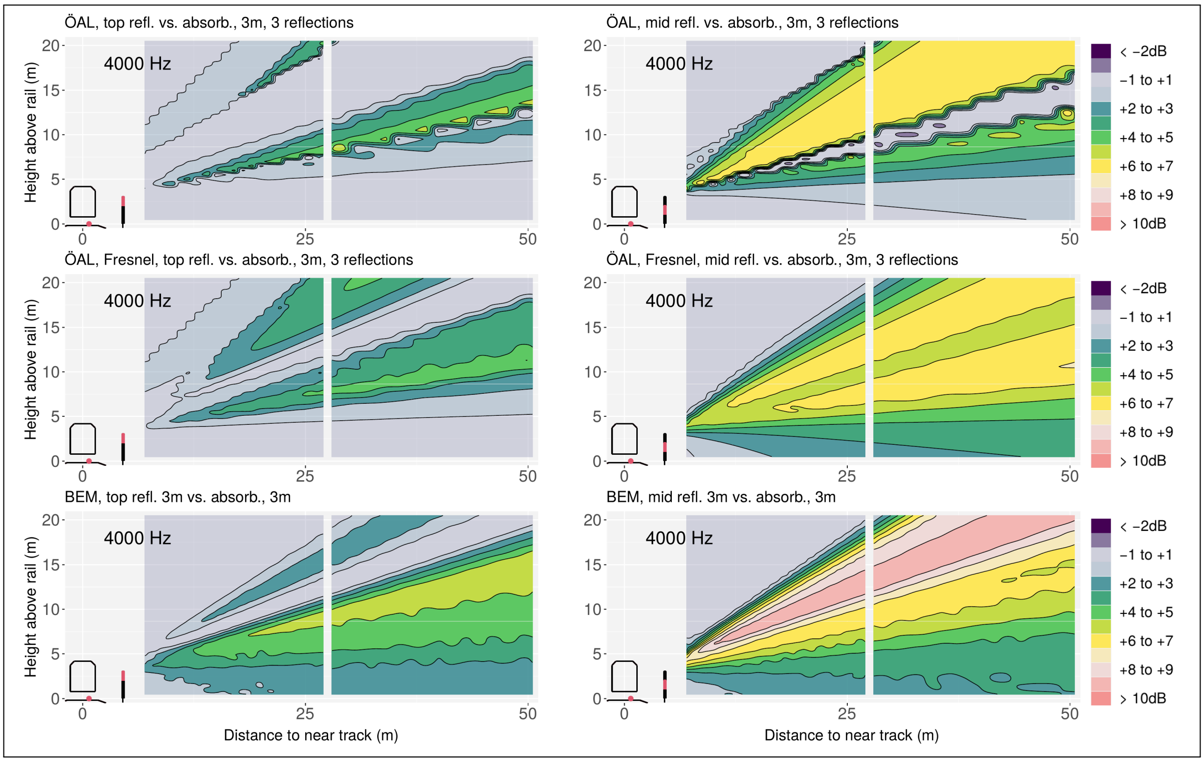

Figure 1. Effect of reflecting elements. Reduction in insertion loss at 4000 Hz due to a reflecting 1 m high panel placed at the top of a 3 m (left column) and 1 m below the top of the barrier (right column). Upper subfigures show results for the ÖAL 28 using 3 reflections and discrete material changes. Middle subfigures show the results when Frenesl zones are included. Lower subfigures show results for the BEM calculations.

tion paths. Instead of reflections, a possible reason for the extended effect in the BEM may be the reflecting material at the diffraction edge of the barrier. The ÖAL 28 uses a diffraction model which is solely based on the path length difference and does not take into account the material at the diffraction edge.

The second main difference between the middle left and lower left subfigures is, that for the ÖAL the effect of the first reflection extends to higher altitudes than for the BEM. The reason for this difference is most likely the assumption of an infinitely high vehicle body in the ÖAL whereas in the BEM the upper edge of the vehicle starts to affect the first reflection in this case.

Placing the panel 1 m below the edge leads to similar results concerning the effect of the Fresnel zones (right column Fig. 1, upper and middle subfigures). The affected regions are almost identical to the BEM calculations (lower right subfigure) as the reflections are flatter for the middle panel position and the diffraction edge is absorbing the middle reflecting and the absorbing reference barrier. The BEM leads to a higher effect in more elevated regions, i.e. for the earlier reflections, but a slightly lower effect in the middle range. Again, including higher order reflections does not add any significant changes (right subfigure in Fig. 2). Furthermore, using more than five reflections for a 3 m high barrier leads to paths that might pass under the vehicle for realistic vehicle bodies.

4. SUMMARY

The possibility to calculate the effect of reflecting portions of a noise barrier using the current approach for multiple reflections within the ÖAL 28, i.e. the national implementation of the calculation scheme introduced by the directive (EU) 2021/1226, was assessed using 2.5D

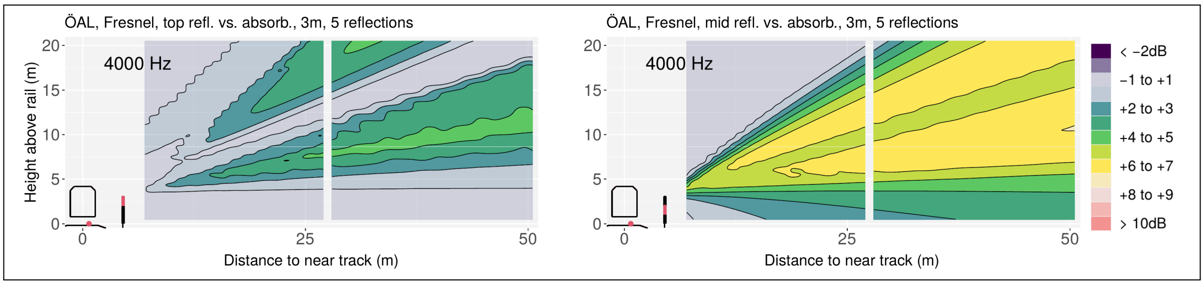

Figure 2. Effect of five reflections. Results as in the middle row in Fig. 1 including five reflections.

BEM reference calculations as a basis. Besides changes of the source position and the vehicle body the calculation scheme needed to be adjusted to incorporate varying material properties. In addition to simply defining an absorption coefficient that varies in height, Fresnel zones had to be introduced to avoid discontinuities in the reflection and thus achieve realistic sound field. Overall, the agreement with the reference BEM model is good, although some differences occur, partially due to the infinitely high vehicle body and, second, the effect of reflecting material at the diffraction edge. Still, some differences in the distribution in space of the changes occured, for which the reason is not clear. As was shown, too high a number of reflections does not add to the result but increases computation time. Thus, a limit of reflections needs to be set, e.g. such that rays would not pass under the vehicle body.

5. ACKNOWLEDGMENTS

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