CHALMERS

Prediction of performance improvement using BEM for a low-height finite-thickness noise barrier with an acoustically-soft surface compared with an acoustically-hard surface

Project: Good sound environment in station communities
(God ljudmiljö i stationssamhällen)

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Report
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INTRODUCTION

The Boundary Element Method (BEM) is used here to predict the improvement in noise barrier insertion loss when the barrier is given an acoustically-soft surface compared with an acoustically-hard (infinite impedance) surface. The cases predicted concern rail traffic noise and include various thicknesses of a low-height barrier, for a set of point sources and receivers within a range of azimuthal angles (see further details below.) For this purpose, a so-called 2.5-dimensional (2.5 D) BEM implementation is used, i.e. allowing for modelling point sources in an otherwise two-dimensional domain.

The accuracy offered by using boundary element modelling, thanks to its wave-based essence, together with its applicability to the 2.5-dimensional calculation domain of interest here, at the same time as the calculation costs are reasonable, makes it an attractive choice. A ray-based method could provide lower calculation costs, but with a too low resulting accuracy. On the other end, a more complete wave-based model, e.g. using a finite-element (FE) approach or a finite-difference time-domain (FDTD) modelling, would demand a higher computational cost. The benefit with the latter type of models would be that they allow for sound propagation within an acoustically-soft barrier material, whereas by using BEM only the surface impedance is prescribed. Hence, by realising the here predicted effects in constructed noise barriers, the layer of the acoustically-soft barrier material may need to be compartmentalised, e.g. by using sound-blocking, massive plates within the soft material, oriented perpendicularly to the barrier surface. In addition, the body of the train is not modelled here, whereby possibly deteriorating reflections between the train body and the side of the barrier facing the train are not considered. Therefore, realised noise barriers should have a highly absorptive surface toward the train in order to approach the predicted insertion losses.

METHOD

A description of the implemented BEM as used here can be found in a previous publication [1]. The additional parts that need to be defined contain the general geometry, the modelling of the acoustically-soft barrier surface material and the extraction of insertion loss improvement.

The general geometry is shown in Figure 1. To model the effect of an acoustically-soft surface material, it is assumed to be of the same material as the ballast, which is implemented using the model by Hamet, according to Ref. [2], with the thickness parameter set to 0.3 m. (The flow resistivity of the ballast is set to 3000 Ns/m^4, the porosity to 0.3 and the structure constant to 3 [2].) It could be noted that, even though this material choice is somewhat unrealistic, the results are assumed to give a good indication of what improvements could be possible by using acoustically-soft materials on noise barriers instead of only acoustically-hard materials.

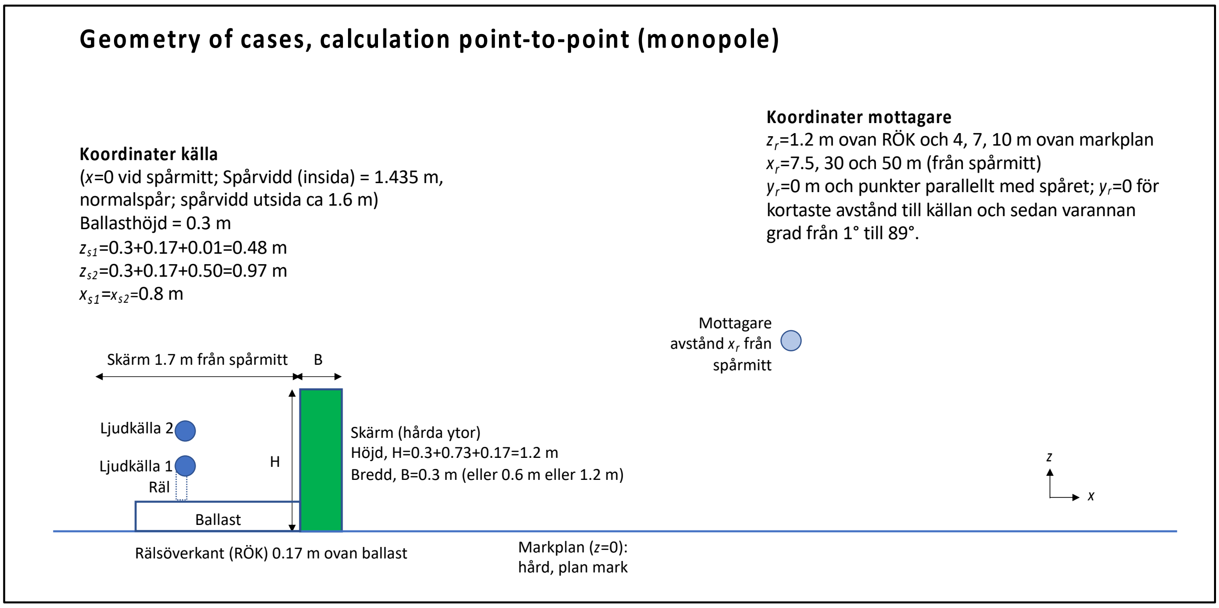

Figure 1. Geometrical set-up of the rail traffic noise situation.

Since the predictions use idealised propagation conditions (e.g. hard and flat ground and regularly shaped volumes of ballast and barrier), the interference pattern is exaggerated compared with real situations. Therefore, the results have been averaged (energy-wise) over five receiver heights, separated by 0.2 m, to provide the result for each nominal receiver height. Even though this choice is somewhat arbitrary, it can be argued that the final result is preferable and relevant.

The frequency range of the calculations covers the third octave bands 25 – 5000 Hz, using three frequencies per band before calculating the energy average of each band.

RESULTS

The sources, being at different heights, are also linked with different insertion losses. The insertion loss data are given as function of frequency as well as of translation in space along the rail track compared with the receiver (Δy). Concerning discretization in y-direction in the BEM calculations, a fixed angular step size of 2 degrees is used (from 1 to 89 degrees), from which an interpolation is made to a step size of Δy=1 m.

In Figures 2–7 the calculated improvements in insertion loss (ΔIL, in dB) are plotted for the two lowest source heights (1 and 50 cm above railhead) and the three barrier widths of 30, 60 and 120 cm. The receiver is at 7.5 m range from the track centre. It can be noted that the insertion loss improvement increases with angle. This shows the wanted benefit of a soft barrier surface, which is of particular interest since for an ordinary, acoustically-hard, barrier the insertion loss decreases with angle. Also, the insertion loss improvement increases with barrier width, as expected.

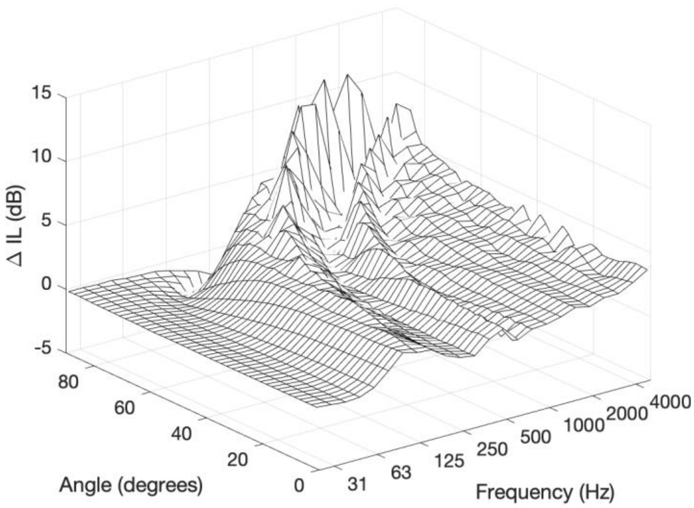

Figure 2. Improvement in insertion loss by using a soft surface on a 30 cm wide barrier (low source position).

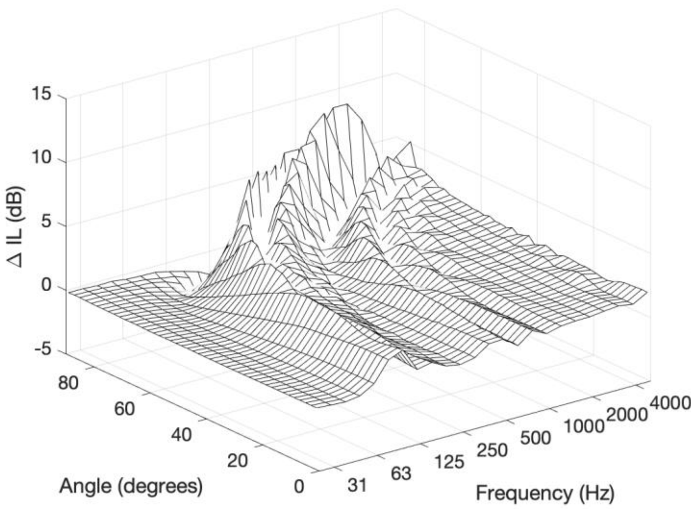

Figure 3. Improvement in insertion loss by using a soft surface on a 30 cm wide barrier (mid source position).

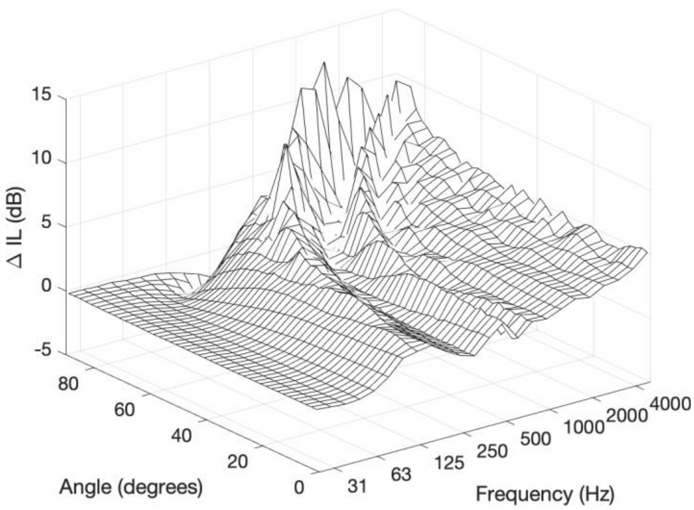

Figure 4. Improvement in insertion loss by using a soft surface on a 60 cm wide barrier (low source position).

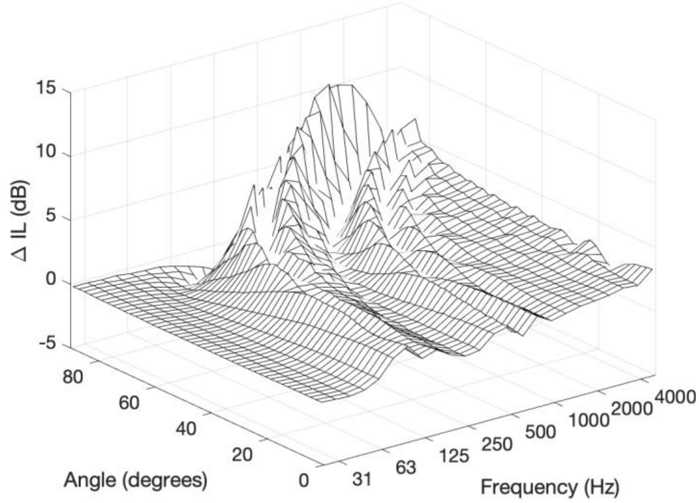

Figure 5. Improvement in insertion loss by using a soft surface on a 60 cm wide barrier (mid source position).

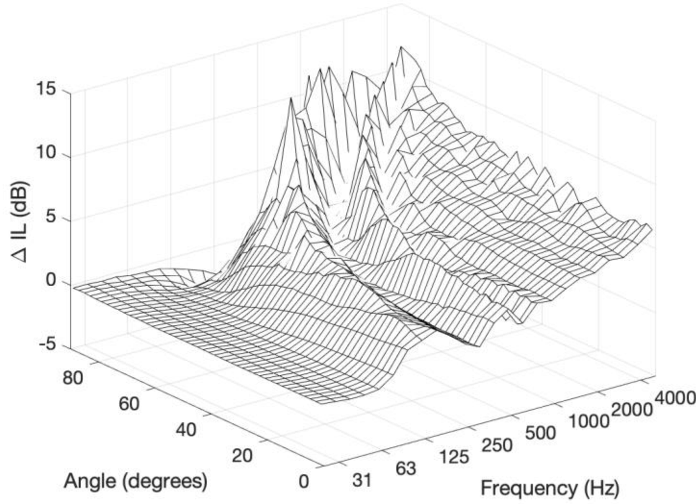

Figure 6. Improvement in insertion loss by using a soft surface on a 120 cm wide barrier (low source position).

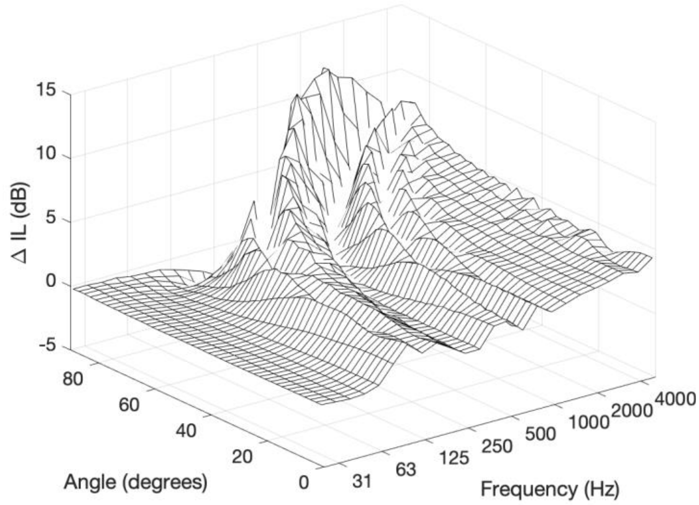

Figure 7. Improvement in insertion loss by using a soft surface on a 120 cm wide barrier (mid source position).

REFERENCES

[1] van der Aa, B. and Forssén, J. (2015), "The 2.5D MST for sound propagation through an array of acoustically rigid cylinders perpendicular to an impedance surface", Journal of Physics D: Applied Physics, 48(29), p. 295501. doi: 10.1088/0022-3727/48/29/295501.

[2] J. Defrance, E. Salomons, I. Noordhoek, D. Heimann, B. Plovsing, G. Watts, H. Jonasson, X. Zhang, E. Premat, I. Schmich, F. Aballea, M. Baulac, and F. de Roo, "Outdoor sound propagation reference model developed in the European Harmonoise project", Acust. Acta Acust. 93, 213–227 (2007).