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Simulation of noise barrier insertion loss using the boundary element method

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Within a project of the European Commission ("Calm Tracks & Routes") the performances of different styles of noise barriers were investigated. Additionally methods to increase absorption are tested. One goal of the project was to determine the mitigation of curved walls with high absorption coefficients, because studies made before the project gave the hint that noise barriers curved away from the source should give satisfying insertion losses. With such a curvature the view at the landscape behind the wall is hindered to a lesser degree compared to straight noise barriers. The modelling of the noise barriers is done using the Boundary Element method. An absorptive model for grassland is added and implemented into Green's functions. Due to the model used for grassland an application of the fast multipole method is not possible and the simulations are limited to the two-dimensional case. It becomes obvious that the distance of the source is important for the mitigation of curved noise barriers with respect to straight ones. Therefore different wall types and source positions are taken into account. The results of the numerical simulation are compared with measurements in situ and in a large anechoic chamber.

Introduction

Within the sixth framework of the European Union a project was financed that should determine whether Noise barrier walls with a curvature outside of the road, which provide a better view at the landscape behind the wall, provide satisfactory insertion losses. Also new materials should be tested and new designs for the noise barriers should be tested. Especially a new material that has a high durability should be used for absorption. In this paper we present a comparison of the insertion losses of different types of noise barriers (see Fig 1).

Curved Walls

Main object of the project was the investigation of the effectiveness of curved walls compared to straight walls. This comparison was done by actual tests as well and by simulations. The part of the Acoustics Research Institute of the Austrian Academy of Sciences was the numerical simulation and the psychoacoustic evaluation of the simulated sounds behind the walls.

1.1 Simulation of the levels behind the wall

With the simulation it is possible to generate spectra of the insertion loss behind the different walls compared to free field conditions. As a measure of the effectiveness of the different barriers we use the insertion loss defined as

$$\mathit{Insertionloss} = \frac{\text{pressure with barrier}}{\text{pressure without barrier}}$$

All calculations were done in the spectral domain for frequencies ranging from 25Hz to 10000Hz in steps of 25Hz. To visualize the results for all facoustics 08requencies, animations over the whole range were made. Also aurealizations were made for a specific point behind the different barriers using a signal of a passing train as source.

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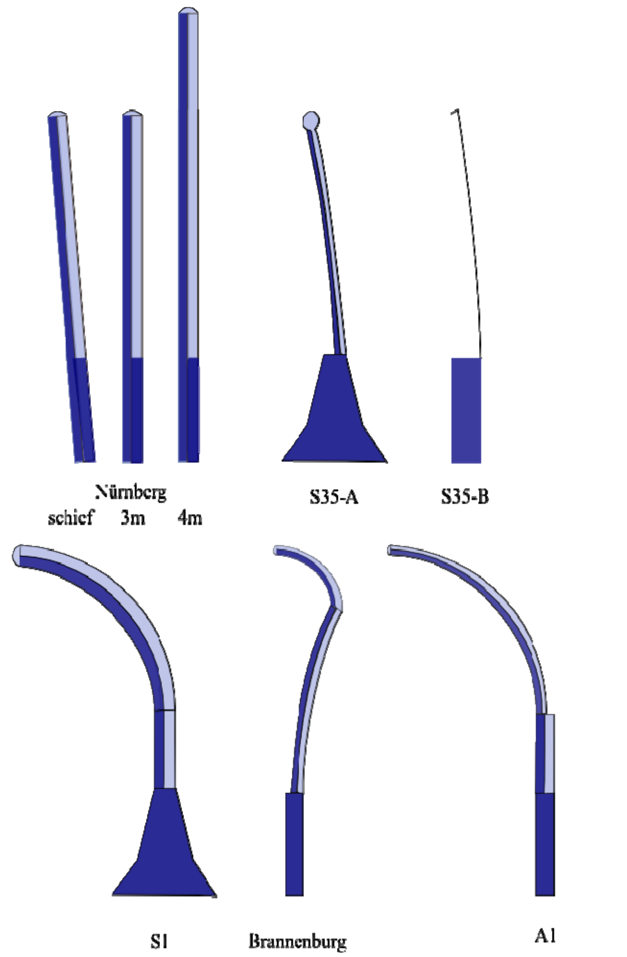

Fig 1: Noise barriers used in the simulation. Light blue parts are absorbing with a coefficient of 0.9.

To simulate the effect of the different barrier profiles the Boundary Element was used. A special adaption of the Greens function was made to simulate with grassland [1]. Special consideration of a reflecting road surface between sound source and noise barrier were taken, but the results did not show any significant difference to the case where only grassland was used (see Fig. 2).

The sound source itself was positioned at a height of 0.7m in different distances from the barrier (2m, 5m and 10m). As it can be seen in tables 1 and 2, is the effectiveness of the noise barrier very dependent on the position of the noise source from the barrier. For a source distance of 10m the form of the barrier hardly makes a difference anymore.

acoustics 08Since we were only interested in the differences between profiles it was sufficient to reduce our model to a 2D-case, neglecting influences by moving sources and different weather conditions, which certainly had some influence on the results.

1.2 Simulation of the mitigation at a reference position

For a given reference position behind the wall it is possible to investigate the reduction of noise. Originally this position was 25m behind the wall in a height of 2m. But it was found that the spectra vary if the reference position is changed a little bit (see for example Fig. 2)acoustics 08 because of interference patterns.

The main goal of the simulations was to determine whether curved walls allow for equal or even higher mitigation than straight walls of the same height.

Fig.1 shows the different forms of the simulated noise barriers. The different profiles are named in German with respect to the area where the noise barriers are or should be realized. Darker areas indicate acoustically hard reflecting surfaces, whereas a highly absorbing material (the absorption rate was set to 0.9) was assumed for the light blue areas. In our model absorbing material was modeled using appropriate impedance boundary conditions.

There are two straight walls Nürnberg 3m and 4m. The other walls are tilted (Nürnberg schief) with angle of 5 degrees or curved ones (S35-A, S35-B, S1,Brannenburg, A1). If not specified otherwise all walls are assumed to have a height of 3m. With respect to the regulations of the German railways absorption coefficient of 0.9 is used in the simulations for all barriers except S35B.

The wall S35B was assumed to be made of acrylic glass and therefore modeled as acoustically hard. For that barrier the simulation was made using middle face elements instead of boundary elements. The result is lower insertion loss relative to the other barriers. It is not clear, whether this effect is the result of the simulation or the reflecting surface.

The results are spectra with alternating minima and maxima caused by the interference effect behind the wall. The position of the maxima and minima in the spectrum is varying. Therefore a simple comparison at one fixed position is not possible.

1.3 Averaged insertion losses.

As our simulation is reduced to 2D, we cannot directly model the influence of a moving vehicle. In a first approach we simply try to address this fact by using the data from the simulation is an average about all positions behind the wall.

As the magnitude of the insertion loss is different for different positions behind the barrier due to interferences, the average of the insertion losses at several positions behind the wall was chosen (about 2000 positions in a 50m times 8m grid behind the barrier). Using these energetically averaged spectra the peaks are less dominant.

wall type	railway			road		
source distance	2.5m	5.0m	10m	2.5m	5.0m	10m
S1	21.2	18.8	15.9	21.3	18.0	14.4
A1	21.3	18.7	15.7	21.7	17.9	14.3
Brannenburg	20.5	18.1	15.6	21.2	17.6	14.2
S35-A	18.8	17.1	14.9	18.9	16.4	13.6
Nürnberg schief	18.5	16.8	14.7	18.7	16.0	13.3
Nürnberg 3m	18.7	16.8	14.8	19.1	16.2	13.3
Nürnberg 4m	21.5	19.3	17.7	22.4	19.2	16.3

Table 1 Average values of insertion loss in dB(A) behind the noise barriers

Our simulations showed that the 3m curved wall has an higher insertion loss than a 3m high straight wall. In table 2 the differences in dB(A) with respect to a 3m high straight wall are presented.

The results are:

- The insertion loss of a 3m high curved wall is nearly the same as that of a 4m high straight wall if the source is near to the wall.
- The effect becomes less significant, if the distance between wall and source increases.
- A tilt does not give an improvement. A large curvature is needed to improve the insertion loss.

wall type	railway			road		
source distance	2.5m	5.0m	10m	2.5m	5.0m	10m
S1	2.5	2.0	1.1	2.2	1.8	1.1
A1	2.6	1.9	0.9	2.6	1.7	1.0
Brannenburg	1.8	1.3	0.8	2.1	1.4	0.9
S35-A	0.1	0.3	0.1	-0.2	0.2	0.3
Nürnberg schief	-0.2	0.0	-0.1	-0.4	-0.2	0.0
Nürnberg 3m	0.0	0.0	0.0	0.0	0.0	0.0
Nürnberg 4m	2.8	2.5	2.9	3.3	3.0	3.0

Table 1 Average values of insertion loss in dB(A) behind the noise barriers relative to a 3m high straight wall

References

[1] K. Attenborough, Acoustical Impedance Models for Outdoor Ground Surfaces, Journal of Sound & Vibration, 99(4), 1985, pp. 521

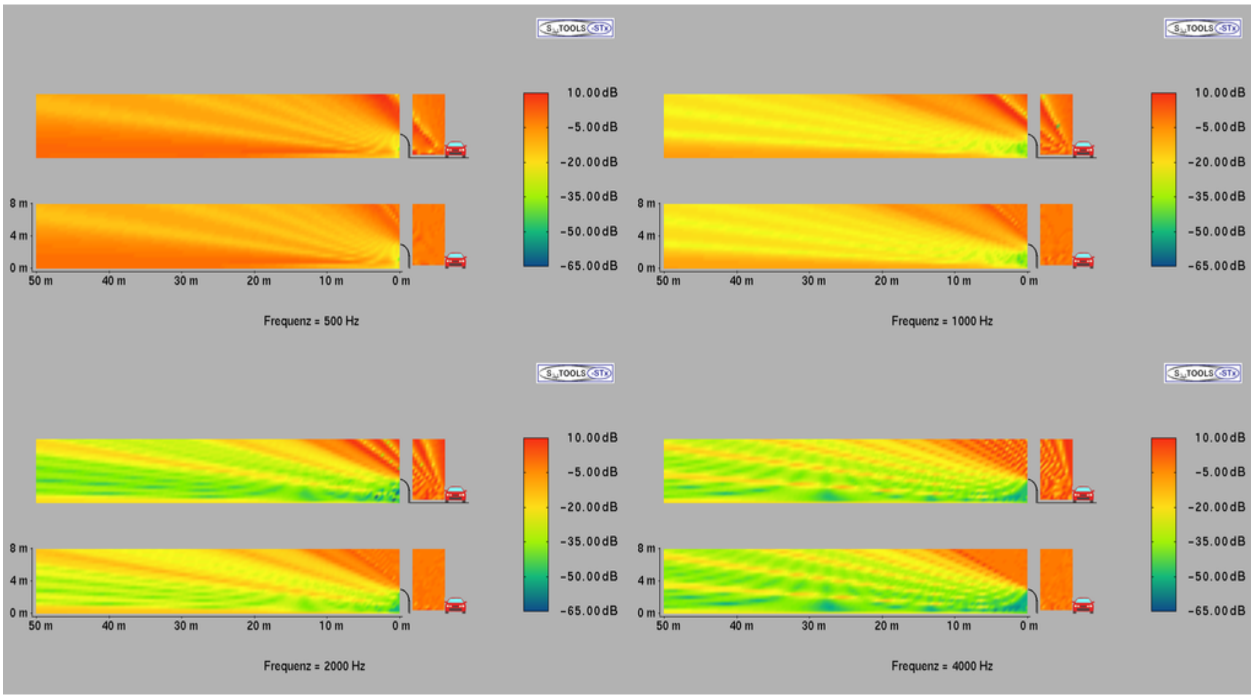

Fig 2: Insertion loss for a curved wall for different frequencies (500Hz, 1000Hz, 2000Hz and 4000Hz). The upper lines display results, where a road was simulated between the barrier and the sound source, in the lower lines the ground was assumed to be grassland everywhere.