Impact of an Edge Sound Reducer Built into the Upper Edge of the Acoustic Screen on the Distribution of Acoustic Field on the Receiver’s Side

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Abstract. The article presents the problem of acoustic shielding, allowing for the influence of edge sound reducers built into the upper surface of acoustic screens. The impact of the analyzed solutions was evaluated on the basis of model tests carried out in laboratory conditions. For the needs of the planned tests, a reverberation chamber was appropriately modified, ensuring in it the so-called free field conditions. On such a research stand, the propagation of sound wave was investigated as a function of distance, at different heights, for situations without the acoustic screen and after its installation, testing various solutions on its upper edge. On the basis of the conducted tests, the shielding effectiveness of the analyzed test samples was determined. In the second part of the article, a computational model was made, which corresponded to laboratory conditions so that it was possible to carry out the simulation of acoustic field distribution in the same configuration as in the laboratory tests. In the final part of the article, the results were compared and the effectiveness of acoustic screens containing an edge sound reducer was evaluated.

1. Introduction
The reduction of noise in the environment is very often effected by the application of acoustic screens [1]. Acoustic panels used in road screens should meet relevant requirements for sound absorption. In general, the requirements involve sound absorption [2, 3]. The said parameter may undergo changes during the operation of acoustic screens in the natural environment [4]. The acoustic efficiency of the screen is greatly dependent on the dispersion of sound waves on the edge of such a screen [5]. Due to the effect of scattering on the edges of the screen, different edge shapes are being considered. The T-shaped screen [6] is one of possible options. The research studies on different shapes of screen edges were primarily carried out by Okubo [7]. And laboratory tests with the application of screen scaling methods were carried out by Voropayev [8]. Apart from laboratory tests or in situ measurements in the real environment, computer simulations are applied as a frequent method for testing the effectiveness of acoustic screens [9]. Therefore, the authors of this work carried out research studies on the influence of the edge sound reducer built into the upper edge of the screen on the acoustic field distribution on the receiver’s side. The tests were carried out in an acoustic laboratory adapted to this purpose. Similar studies were conducted by means of computer simulations in the SoundPlan program.
2. Research methodology

2.1. Laboratory tests

The tests were carried out in an adapted reverberation chamber. The adaptation of the reverberation room consisted in covering the floor, ceiling and walls with a sound absorbing material having the sound absorption coefficient close to 1.0. This way, the laboratory had the parameters similar to those in the anechoic chamber, i.e. close to free field conditions as in the environment. Using such an approach, it was possible to simulate free sound propagation, as it happens in an open environment. In such a laboratory, an acoustic screen was built. The measurement methodology was adopted in accordance with the standard [10]. The view of the test chamber and the cross section through the chamber together with the measuring points and the selected sample are shown in Figure 1.

![Figure 1. a) Reverberation chamber with the measurement points, sound barrier and sound source – cross-section b) Reverberation chamber with the sound source](image)

According to the standard [10], the method used to determine the effectiveness of acoustic screens consists in measuring the sound pressure before and after the installation of the tested device. Then, the efficiency \( \Delta L_E \) of the screen is determined based on the formula (1).

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\Delta L_E = L_{rA} - L_{rB} \quad [\text{dB}]
\]

where:
- \( L_{rB} \) - sound pressure level "before" the installation at the reception point,
- \( L_{rA} \) - sound pressure level "after" the installation at the reception point.

As shown in Figures 1a and 1b, there were 4 measuring points in the laboratory, spaced every 1 m from the acoustic screen. At each point, measurements were carried out in measurement cross-sections, respectively for the height range from 1.0 m to 3.5 m with a step of 0.5 m. The grid of points created in this way allowed us to determine the levels of sound distribution behind the sound screen. The sound source was located at the distance of 1.25 m away from the screen at the height of 0.5 m. In order to estimate the measurement uncertainty, each measurement at a given point and in the measurement cross-section was repeated six times.

The measurement set involving the transmission part consisted of a loudspeaker sphere with omnidirectional sound propagation characteristics and a pink noise generator. The reception part was made up by a Class I integrating meter with two sets of microphones.

The development of the laboratory for the test sample is shown in Figure 2.
According to the guidelines of the standard [10], the obtained spectrum in the one-third ranges was limited to the interval from 50 Hz to 5000 Hz.

2.2. Computer simulations

The computer simulation was carried out using the SoundPlan software for modelling geometrical acoustics layouts, Figure 3, applied for the calculations of acoustic field distribution. The computational model was made on the basis of digital geometric data obtained from the test chamber inventory. The model was fed with data specifying the acoustic properties of baffles limiting the test chamber. The omnidirectional sound source was installed, allowing for its acoustic parameters, as well as point sound receivers located in the same way as in the measurements, Figure 1. The calculation results were presented in the form of sound level values for individual receivers and on horizontal and vertical noise maps, Figs. 4 and 5.
3. Results and discussions
The laboratory results comprised the results from the measuring points without the screen, with the acoustic screen and with the edge sound reducer on the acoustic screen. The measuring points of 1.0 m, 2.0 m, 3.0 m and 4.0 m behind the screen were considered, and at each of these points the heights of 1.0 m, 1.5 m, 2.0 m, 2.5 m, 3.0 m and 3.5 m were taken into account.

The screen of the height of 2.0 m was considered and the screen of 1.5 m + 0.5 m of the height of the edge sound reducer mounted on the edge of the screen. Such an approach allowed us to capture the impact of the reducer without the impact of the additional screen heights. The discussed road noise protection device in the form of a simple screen fitted with an edge sound reducer was manufactured in the Czech Republic as shown in Figure 6.
The measurement results are collected in Figure 7.

Analysing the results presented in Figure 7, it can be observed that with the progressing height of the measurement point, the screen's effectiveness is deteriorating. And at the distance of 1.0 m behind the screen, the impact of sound wave refraction on the edge of the screen is so large that the sound level at the height of 3.5 m is not much lower than the sound level at that height without the acoustic screen. In addition, when we move further away from the screen, the described effect is getting worse. Another interesting observation is the fact that at larger heights the influence of the orthogonal-type edge reducer lowers the effectiveness of the screen.

This observation inspired the authors of this publication to investigate the effectiveness of the screens with edge reducers having other shapes (Figure 8) than the orthogonal shape tested in the laboratory.
Figure 8. Acoustic screens with edge sound reducers of different geometry.

The comparative results involving the sound levels at the points located behind the screen in terms of the type of the top edge of the screen are presented in Figure 9.

Figure 9. Sound levels at the measuring points at different heights for different upper screen edges obtained in the SoundPlan program.

Using the simulation, we obtained the effect similar to that obtained in the laboratory tests. The obtained effect primarily demonstrates that at the highest points the levels of sounds are distinctly higher than at the lowest points. It means that the effectiveness of acoustic screens will deteriorate with the increasing height, even if these heights are in the so-called acoustic shade.
4. Conclusions
Basing on the carried out tests and simulations, the following conclusions can be formulated:

- The test conditions in the anechoic chamber can be considered as reflecting the free field conditions (external environment), in the same way as computer simulations,
- The results obtained both in the laboratory and in the simulation indicate that compared with a simple screen, the edge sound reducer of the orthogonal shape (Figure 8d) reduces the effectiveness of the screen at the heights above the screen.
- Along with the increase of height, the effectiveness of the acoustic screens decreases, even if the measuring points are in the so-called acoustic shade,
- The best performance was found for the screens with a curved edge (Figure 8 b, e)

The last conclusion suggests that the curvature of the screen edge gives better results than designing edges which disperse sound waves.

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