DOI: 10.61782/fa.2025.0084

FORUM ACUSTICUM EURONOISE 2025

ACOUSTIC PROPERTIES OF A LOUVERED NOISE BARRIER WITH TIRE RUBBER GRANULATE INFILL

Edgaras Strazdas[1*] **Tomas Januševičius**[2]
[1] Department of Environmental Protection and Water Engineering, Vilnius Gediminas Technical University, Lithuania
[2] Research Institute of Environmental Protection, Vilnius Gediminas Technical University, Lithuania

ABSTRACT

To ensure comfortable working and living conditions, various systems such as heating, ventilation, heat pumps, and generators are employed, all of which require high air permeability for optimal performance. Consequently, conventional noise barriers are often unsuitable in these contexts. This study aims to design a louvered noise barrier with high air permeability by incorporating recycled tire rubber granulate as the sound-absorbing material. This approach supports the principles of the circular economy and sustainability by promoting the reuse of secondary materials. The barrier's acoustic performance was evaluated in a semi-anechoic noise reduction chamber. The influence of the number of louvers and their inclination angles on sound attenuation was investigated. Experimental measurements were used to determine the sound reduction index (R'), sound insertion loss (IL), and equivalent sound level loss (L_{Aeq}). The structure achieved a maximum weighted sound reduction index (R'_w) of 4.0 dB. The apparent sound reduction index reached up to 10.2 dB at high frequencies (4000 Hz). The highest recorded sound insertion loss was 12.63 dB at 2500 Hz, while the maximum equivalent sound level loss (L_{Aeq}) was 9.4 dB(A).

Keywords: *acoustic louvers, noise barrier, tire rubber granulate, anechoic chamber, insertion loss.*

[*]***Corresponding author***: edgaras.strazdas@vilniustech.lt.

1. INTRODUCTION

Noise is emitted by air-cooling equipment, water cooling units, fans, and diffusers due to the movement of exhaust and intake airflow, as well as the operation of condensers and compressors. Acoustic comfort issues can be addressed using conventional noise barriers. However, these enclosures are not suitable for ventilation equipment, which must exhaust or intake air to function properly. Increasingly strict noise regulations are prompting many manufacturing and commercial companies to seek effective solutions to avoid exceeding the prescribed noise levels in their environments.

Noise barriers are among the most effective and widely used methods for mitigating noise [1-4]. The selection of a specific type of barrier in each case is usually determined by the position of the noise source, the characteristics of the noise it emits, and the terrain of the site under consideration [5]. The effectiveness of an installed barrier depends on the materials used in its construction, the height of the barrier, surface geometry, shape, acoustic properties of additional elements installed on top of the barrier, as well as the surrounding terrain and meteorological conditions [6-8].

The operation of noise barriers is based on the principle that a sound wave loses its original energy and becomes attenuated when passing directly through an obstacle. A portion of the wave's energy is reflected upon impact, another portion is absorbed and converted into thermal energy, and the remainder is either transmitted through the material or diffracted. This residual energy can reach the receiver, either separately or as a combination of transmitted and diffracted waves [7].

One effective way to reduce noise is through sound absorption. Sound-absorbing materials are often used in combination with perforated plates made from materials such as steel, glass, plastic, and others. Many of these

materials are effective at reducing medium and high-frequency noise but are less effective at controlling low-frequency noise. To increase air permeability or provide adequate shading, scientists have proposed several types of noise barriers, such as sonic crystals or louvered structures. Researchers have found that sonic crystals can achieve noise attenuation levels between 16 and 25 dB(A) [9]. Louvered structures are often used as façade elements or structural components of buildings. They provide necessary light and air permeability while also offering sound attenuation properties [10]. Sound-attenuating louvers can be used to reduce noise from engineering equipment or road traffic [11]. One alternative for reducing noise from ventilation equipment is the use of sound-absorbing louvers made of perforated panels filled with absorbent material. The operating principle of a louvered noise barrier is based on the reflection, absorption, and refraction of incoming sound waves. Reflection occurs when a wave traveling through one medium encounters another medium and is partly scattered such as when a sound wave moves from a liquid to a gaseous medium, or from a solid to a liquid, and so on. Part of the wave passing through different media is reflected back into the original medium, while another part is absorbed and thus enters the new medium. Upon impact, the sound wave also undergoes refraction, changing its propagation trajectory in the new medium. This occurs due to the sudden change in the speed at which the sound wave travels. Sound absorption is directly related to the frequency of the sound waves and also depends on the angle at which the sound waves enter the material. Vilniškis et al. conducted a study examining three different louver configurations. The best noise-reduction performance was observed in louvers covered with glass wool panels, achieving sound insulation values ranging from 10.8 to 12.5 dB. Meanwhile, louvers covered with polystyrene foam panels achieved values between 5.4 and 8.4 dB [12]. Vilniškis also found that increasing the tilt angle of the panel structure increased the pressure near the structure from 45 Pa to 9 kPa, and the air velocity passing through the structure changed from 13 m/s to 70 m/s [13]. Astrauskas et al. found that the noise attenuation of the louvered barrier was greatest in the 2500 Hz and 3150 Hz octave frequency bands. Depending on the tilt angle of the louvers, sound attenuation in these bands reached up to 28 dB(A), and the equivalent sound pressure level was reduced by up to 17 dB(A) [11].
The aim of this paper is to design a louvered noise barrier with high air permeability, incorporating recycled tire rubber granulate as the sound-absorbing material. The paper is organized as follows: Section 2 describes the materials and methods; Section 3 presents the main results; and Section 4 provides the conclusions.

2. MATERIALS AND METHODS

The main research object of this study is a louvered barrier composed of a specific number of identical louvers filled with sound-absorbing recycled tire rubber granulate. The noise barrier consists of horizontal louvers inclined at a specified angle. The horizontal louvers are 30 mm thick and 860 mm long, and are made from bent metal sheets. The upper part of each louver is a solid metal plate, while the lower part is a perforated metal plate. Inside the louvers is the sound-absorbing material. The perforated plate is placed on the underside of the louver to protect the sound-absorbing material from environmental factors such as precipitation, dust, and icing. The structure of the louver is shown in Figure 1.

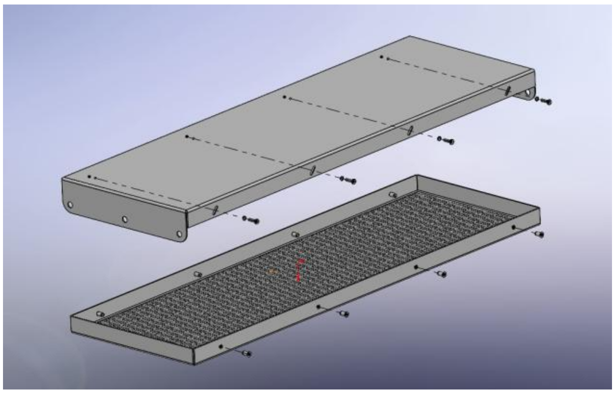

Figure 1. The structure of the louvers in the noise barrier.

The louvers are made from two 2 mm thick bent metal sheets. The upper sheet is a solid metal plate, while the lower one is a perforated metal plate. The parameters of the perforated sheet include 35% open area with round perforations, 5 mm in diameter, and 8 mm centre-to-centre spacing. After the louvers are filled, the metal sheets are joined together using rivets or bolts.
The louver infill consists of two layers of recycled tire rubber: a 10 mm thick rubber granulate plate for sound insulation and a 20 mm thick layer of rubber granules (granule size 2–5 mm) for sound absorption (Figure 2). The rubber granulate plate made from shredded tire rubber granules (1 mm in size), mixed with polyurethane glue in a 30/70% ratio. To prevent the granules from falling out

through the perforated sheet, a metal mesh with 1x1 mm openings is placed on top.

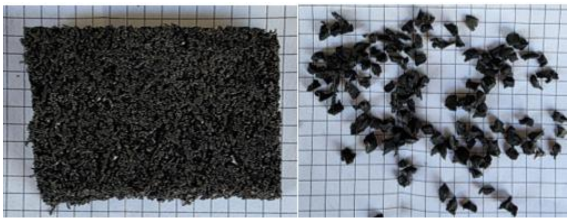

Figure 2. Louvers infill: 10 mm thick rubber granulate plate and 2–5 mm tire rubber granules.

The filled louvers are placed into a wooden frame measuring 900x970 mm and secured with screws from the sides. The frame with louvers is then placed into the window of a semi-anechoic chamber (Figure 4, Figure 5). A general view of the semi-anechoic chamber is shown in Figure 3.

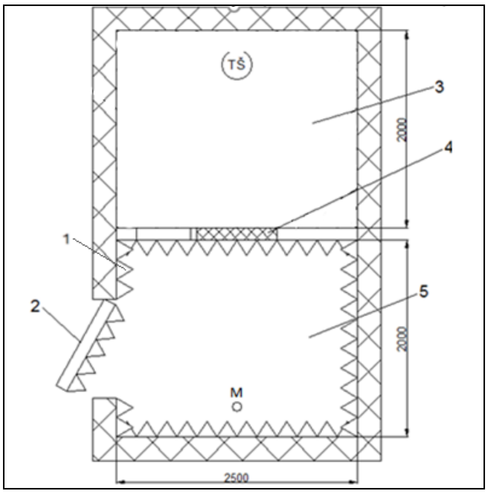

Figure 3. General view of the noise reduction chamber. 1 – walls covered with foam rubber, 2 – door, 3 – room for outgoing sound, 4 – location of structure, 5 – room for receiving sound, M – microphone position, TŠ – noise source.

Three different configurations of the louvered barrier were investigated: structures with 5, 6, and 7 louvers. Each configuration was tested with the louvers tilted at angles of 0, 15, 30, and 45 degrees. In total, 12 different louvered barrier configurations were tested.

The experimental studies were conducted using high-precision equipment from the manufacturer Brüel & Kjær: the sound source "Brüel & Kjær The Omni-Power Sound Source Type 4292-L," the amplifier "Brüel & Kjær Type 2734," and the sound level analyser "Brüel & Kjær 2270." The measuring device complies with standards IEC 61672, IEC 60651, and IEC 60804. During the tests, the sound level was measured using a one-third octave band filter.

Figure 4. Tested louvered noise barrier from room for outgoing sound.

Figure 5. Tested louvered noise barrier from sound receiving room.

The following parameters were determined during the experimental measurements:

- sound reduction index (R').
- sound insertion loss (IL).
- equivalent sound level loss (L_{Aeq}).

According to the [14], the sound insulation level of a louvered noise barrier was determined. This standard provides all the main measurement methods and procedures required to determine sound insulation under laboratory conditions. Sound pressure levels are measured in both the source and receiving rooms. The average sound pressure level is calculated in both rooms (applying background noise correction), and the sound reduction index the barrier is determined. The weighted sound reduction index (R'_w) is determined by fitting a standard reference curve to the measured sound reduction index values across various frequencies, as specified in [15].
Insertion loss was calculated as the difference between the sound pressure level without the louvers and the sound pressure level with the louvers. Insertion loss was calculated according to Eqn. (1) as described in [16].

$$IL = L_{p1} - L_{p2} \quad (1)$$

where L_{p1} is the sound pressure level without the louvers and L_{p2} is the sound pressure level with louvers.
Equivalent sound level loss (L_{Aeq}) is the difference in equivalent noise level between the sound emitted by the noise source, measured in the receiving room without the louvers, and the sound level measured after the louvers have been installed.

3. RESULTS

First, sound reduction measurements of the barrier were performed. Figure 6 presents the results of sound reduction measurements for constructions with 5, 6, and 7 louvers in 1/3 octave frequency bands, ranging from 100 to 5000 Hz. From the obtained results, it can be observed that in the low-frequency range to 500 Hz, the apparent sound reduction index is similar across the all barrier configurations. Additionally, the measured index is relatively high at low frequencies. However, these results may be affected by room or measurement effects. The chamber may have standing waves at low frequencies that "trap" energy, making the insulation performance appear better than it actually is. Moreover, since low frequencies have longer wavelengths, if the microphone is positioned at a node or null point, it may register lower sound levels, thereby artificially increasing the perceived sound insulation. In the mid-frequency range from 500 to 1600 Hz negative sound reduction index values are observed, which is caused by interference resulting from standing waves in the chamber. For these reasons, the most reliable results were obtained when analyzing the sound reduction at high frequencies, ranging from 2000 to 5000 Hz. When examining the barrier composed of 5 louvers, the apparent sound reduction index in these frequencies ranged from 0.1 dB with the louvers positioned at a 0-degree angle, to 5.1 dB when tilted at a 45-degree angle. The weighted sound reduction index (R'_w) ranged from 0.1 dB to 1.5 dB. The barrier with 6 louvers showed sound reduction of up to 8.2 dB at a frequency of 3150 Hz when the louvers were tilted at a 45-degree angle. The weighted sound reduction index (R'_w) ranged from 0.4 dB to 2.1 dB. The construction consisting of 7 louvers achieved the highest results, with the apparent sound reduction index reaching up to 10.2 dB at 4000 Hz when the louvers were tilted at a 45-degree angle. When the louvers were tilted at 30 degrees, the result at high frequencies reached up to 5.3 dB; at 15 degrees, up to 3.1 dB; and up to 2.4 dB at 0 degrees.

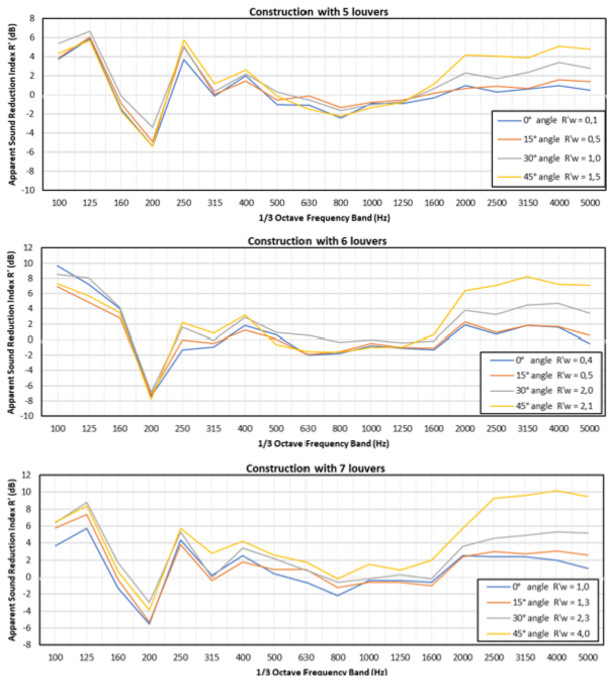

Figure 6. Louvered noise barrier sound reduction.

The weighted sound reduction index (R'$_w$) of construction with 7 louvers ranged from 1.0 dB to 4.0 dB at inclination angle from 0 to 45 degrees.

Another parameter examined was the sound insertion loss (IL). The insertion loss results for the louvered barrier are presented in Figure 7. For the barrier with 5 louvers, the results at low frequencies (100–500 Hz) reached up to 6.01 dB at 100 Hz when the louvers were tilted at a 15-degree angle. At 400 Hz, the highest IL was measured at 5.08 dB with the louvers tilted at 45 degrees. As with the previously analyzed parameter, results at low frequencies can be influenced by room or measurement effects. In the mid-frequency range (500–1600 Hz), the IL reached up to 6.26 dB at 1600 Hz. The highest IL was observed in the high-frequency range, reaching up to 8.35 dB near 5000 Hz with the louvers tilted at a 45-degree angle. At high frequencies, the influence of increasing the tilt angle on achieving higher insertion loss is clearly noticeable.

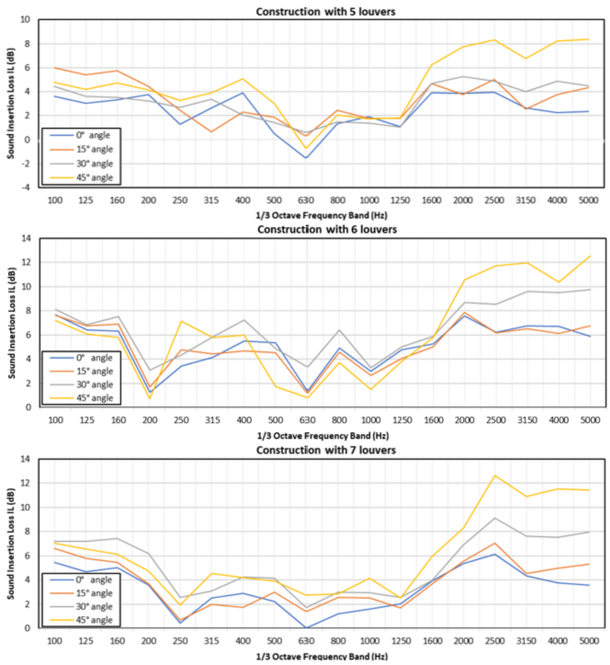

Figure 7. Louvered noise barrier sound insertion loss.

For the barrier with 6 louvers, the results of insertion loss at low frequencies (100–500 Hz) reached up to 7.52 dB at 160 Hz when the louvers were tilted at a 30-degree angle. In the mid-frequency range (500–1600 Hz), the IL reached up to 6.41 dB at 800 Hz with the louvers tilted at a 30-degree angle. The highest insertion loss (IL) was observed in the high-frequency range, reaching up to 12.55 dB at 5000 Hz with the louvers tilted at a 45-degree angle. The construction consisting of 7 louvers achieved the highest IL results overall up to 7.45 dB at low frequencies, 5.96 dB in the mid-frequency range, and up to 12.63 dB at 2500 Hz.

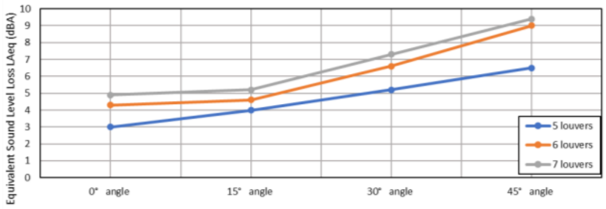

Figure 8. Equivalent sound level loss (L_{Aeq}) results.

Another parameter analyzed to evaluate the effectiveness of the louvered barrier was the Equivalent Sound Level Loss (L_{Aeq}). The results are presented in Figure 8. According to the data, when the number of louvers increased from 5 to 7 with a louver tilt angle of 0 degrees, the results changed from 3.0 dB(A) with 5 louvers to 4.3 dB(A) with 6 louvers, and 4.9 dB(A) with 7 louvers. When the louvers were tilted at a 15-degree angle, the results were 4.0, 4.6, and 5.2 dB(A), respectively. Increasing the tilt angle to 30 degrees, the equivalent sound level loss reached 5.2 dB(A) with 5 louvers, 6.6 dB(A) with 6 louvers, and 7.3 dB(A) with 7 louvers. The highest equivalent sound level loss in all cases was obtained when the louvers were tilted at a 45-degree angle, with results reaching 6.5 dB(A) for 5 louvers, 9.0 dB(A) for 6 louvers, and 9.4 dB(A) for 7 louvers.

In summary, it can be stated that the main parameter determining the effectiveness of the louvered barrier in all cases is the inclination angle of the louvers. The highest efficiency of louvered barrier is achieved when the louvers are tilted at a 45-degree angle and the structure consists of 7 louvers, as this increases the sound-absorbing surface area and reduces the gap between louvers. The louvered barrier is most effective at attenuating noise in the high-frequency range, from 1600 to 5000 Hz. Similar conclusions were reached by researchers who studied a similar type of louvered noise barrier with sound-absorbing materials applied to the louvers [11-12, 17].

4. CONCLUSIONS

This study evaluated the acoustic performance of a louvered noise barrier incorporating recycled tire rubber granulate as a sound-absorbing material. The experimental results demonstrated that both the number of louvers and their inclination angle significantly affect the barrier's effectiveness in reducing noise. The most influential parameter across all configurations was the louver tilt angle, with the highest performance observed at 45 degrees. Increasing the number of louvers from 5 to 7 consistently improved sound attenuation results, due to the greater surface area of sound-absorbing material and reduced spacing between louvers. Among the tested configurations, the barrier with 7 louvers tilted at 45 degrees exhibited the best acoustic performance, achieving a maximum apparent sound reduction index of 10.2 dB at 4000 Hz, a sound insertion loss of 12.63 dB at 2500 Hz and an equivalent sound level loss (L_{Aeq}) of 9.4 dB(A). The barrier is most effective in the high-frequency range (1600–5000 Hz), aligning with the typical operational noise range of HVAC and similar equipment. These findings confirm the potential of louvered barriers using sustainable infill materials for application in ventilation-related noise control.

5. REFERENCES

[1] H. M. Ariff, T. T. Dele-Afolabi, T. H. Rafin, D. W. Jung, Z. Leman, K. A. M. Rezali, and R. Calin, "Temporary sound barrier system from natural fiber polymeric composite," *Materials Today: Proceedings*, 2022. DOI: 10.1016/J.MATPR.2022.11.142.

[2] A. I. Komkin and G. M. Nazarov, "Features of sound diffraction by a noise absorbing screen," *Acoustical Physics*, vol. 67, no. 3, pp. 298–301, 2021. DOI: 10.1134/S1063771021030076.

[3] A. Nowoświat, J. Bochen, L. Dulak, and R. Zuchowski, "Study on sound absorption of road acoustic screens under simulated weathering," *Archives of Acoustics*, vol. 43, no. 2, pp. 323–337, 2018. DOI: 10.24425/122380.

[4] V. Zaets and S. Kotenko, "Investigation of the efficiency of a noise protection screen with an opening at its base," *Eastern-European Journal of Enterprise Technologies*, vol. 5, no. 5(89), pp. 4–11, 2017. DOI: 10.15587/1729-4061.2017.112350

[5] I. Ekici and H. Bougdah, "A review of research on environmental noise barriers," *Building Acoustics*, vol. 10, no. 4, pp. 289–323, 2003. DOI: 10.1260/135101003772776712.

[6] S. Grubeša, K. Jambrošić, and H. Domitrović, "Noise barriers with varying cross-section optimized by genetic algorithms," *Applied Acoustics*, vol. 73, no. 11, pp. 1129–1137, 2012. DOI: 10.1016/J.APACOUST.2012.05.005.

[7] V. Laxmi, C. Thakre, and R. Vijay, "Evaluation of noise barriers based on geometries and materials: a review," *Environmental Science and Pollution Research*, vol. 29, no. 2, pp. 1729–1745, 2022. DOI: 10.1007/S11356-021-16944-2.

[8] G. Watts, "Factors affecting the performance of traffic noise barriers," in *Proc. of Internoise 2000 – DC/ConfOrg*, pp. 3–4, 2000.

[9] S. M. Dimitrijević, V. M. García-Chocano, F. Cervera, E. Roth, and J. Sánchez-Dehesa, "Sound insulation and reflection properties of sonic crystal barrier based on micro-perforated cylinders," *Materials*, 2019.

[10] J. Lee, J. D. Chang, and R. Coffeen, "Acoustical evaluations of a double skin façade as a noise barrier of a naturally-ventilated facade," *Journal of Acoustics*, vol. 2, no. 1, 2020.

[11] T. Astrauskas, P. Baltrėnas, T. Januševičius, and R. Grubliauskas, "Louvred noise barrier for traffic noise reduction," *The Baltic Journal of Road and Bridge Engineering*, 2021. DOI: 10.7250/bjrbe.2021-16.519.

[12] T. Vilniškis, P. Baltrėnas, and T. Januševičius, "Case study: Evaluation of noise reduction in frequencies and sound reduction index of construction with variable noise isolation," *Noise Control Engineering Journal*, 2020. DOI: 10.3397/1/376817.

[13] T. Vilniškis and T. Januševičius, "Modelling of acoustic louvers aerodynamic drag," in *Conf. for Junior Researchers: Science – Future of Lithuania*, 2018. DOI: 10.3846/aainz.2018.021.

[14] ISO 10140-2:2021, *Acoustics – Laboratory measurement of sound insulation of building elements – Part 2: Measurement of airborne sound insulation*, 2021.

[15] ISO 717-1, *Acoustics – Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation*, latest edition.

[16] ISO 11691:2020, *Acoustics – Measurement of insertion loss of noise barriers in situ*, 2020.

[17] J. Lee, J. D. Chang, and R. Coffeen, "Acoustical evaluations of a double skin façade as a noise barrier of a naturally-ventilated façade," *Journal of Acoustics*, vol. 2, no. 1, 2020. DOI: 10.20900/joa20200001.