

BULETINUL INSTITUTULUI POLITEHNIC DIN IAȘI

Publicat de

Universitatea Tehnică „Gheorghe Asachi” din Iași

Volumul 69 (73), Numărul 2, 2023

Secția

CONSTRUCȚII DE MAȘINI

DOI:10.2478/bipcm-2023-0015



STUDY OF SOUND ABSORBING PANELS USED IN ROAD TRAFFIC

BY

ELENA-ADELINA CHIRIAC* and CARMEN BUJOREANU

“Gheorghe Asachi” Technical University of Iași,
Faculty of Mechanical Engineering, Iași, Romania

Received: June 20, 2023

Accepted for publication: July 21, 2023

Abstract. The noise pollution has a negative effect on the human body and in some situations, exposure to high levels of pollution can lead to serious health problems. Referring to current studies, we can see a high interest in finding solutions to reduce the effects of noise pollution, such as sound absorbing panels. The purpose of this paper is to present the current stage of development of sound absorbing panels and the absorption coefficient of the materials used. The article will provide information on different types of panels and materials used in their construction, as well as their mechanical properties. New discoveries in the field related to recyclable materials used in the construction of sound absorbing panels represent an additional point of interest, as the construction of such prototypes protects the environment. The use of waste in the construction process of sound absorbing panels can be considered sustainable a future method.

Keywords: absorption coefficient, sound absorbing panels, road traffic, recycling materials, noise pollution.

*Corresponding author; *e-mail*: elena-adelina.chiriac@student.tuiasi.ro

© 2023 Elena-Adelina Chiriac and Carmen Bujoreanu

This is an open access article licensed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

1. Introduction

Although we are excited about modern technologies and the easy way to get from one point to another, we cannot ignore the fact that noise pollution has reached a high level of discomfort in urban areas. From states of nervousness, lack of concentration, stress, sleep disorders, and even professional performance decline, all are effects of exposure to noise. There are also cases where, due to health problems, such as partial hearing loss, blood pressure, cardiovascular accidents, mental problems, or even diabetes. According to studies, about 18 million people suffer from long-term exposure to high levels of noise produced by intense traffic in urban areas (Petrovici *et al.*, 2020).

To reduce noise pollution, both governments and major vehicle manufacturers are advocating for the introduction of electric cars. One of the European Commission's plans is the "Zero pollution vision for 2050," and among its objectives is a 30% reduction in the number of people affected by exposure to traffic noise by 2050 (https://environment.ec.europa.eu/strategy/zero-pollution-action-plan_en).

In addition to the attempt to introduce electric cars, researchers have focused their attention on studying the most efficient technical solutions that could reduce the high level of noise. Some of the solutions studied or proposed by researchers refer to the use of materials with a high absorption coefficient. The absorption coefficient measures the amount of sound that is absorbed by materials. This coefficient can be studied for materials used in various solutions, such as building materials used in building structures, materials used for vehicle bodies, sound-absorbing panels, etc. (Bujoreanu *et al.*, 2017).

The conducted research investigations primarily focused on the sound absorption and acoustic performance of protective screens, which play a crucial role in effectively safeguarding built-up areas. To ascertain the factors influencing sound absorption, several aspects were examined, including shielding efficiency, screen design and structure, and the choice of materials used. Additional studies delved into analyzing various cross-section types of anti-noise barriers, as well as investigating the diffraction process in sound-absorbing partitions. The sound absorption capabilities of acoustic screens emerged as a pivotal factor in determining their overall effectiveness (Nowoświat *et al.*, 2016).

In this article, we will focus on current studies based on the absorption coefficients of sound-absorbing panels.

2. Sound absorbing panels

To reduce the noise caused by traffic and lower the level of noise pollution, authorities are trying to use technical solutions such as noise barriers. These barriers are devices mounted between the noise sources, in this case represented by road traffic, and the receptors, which are the population in the

respective area. By installing these barriers, the propagation of sound waves is altered, and the level of noise is reduced through refraction, reflection, or absorption.

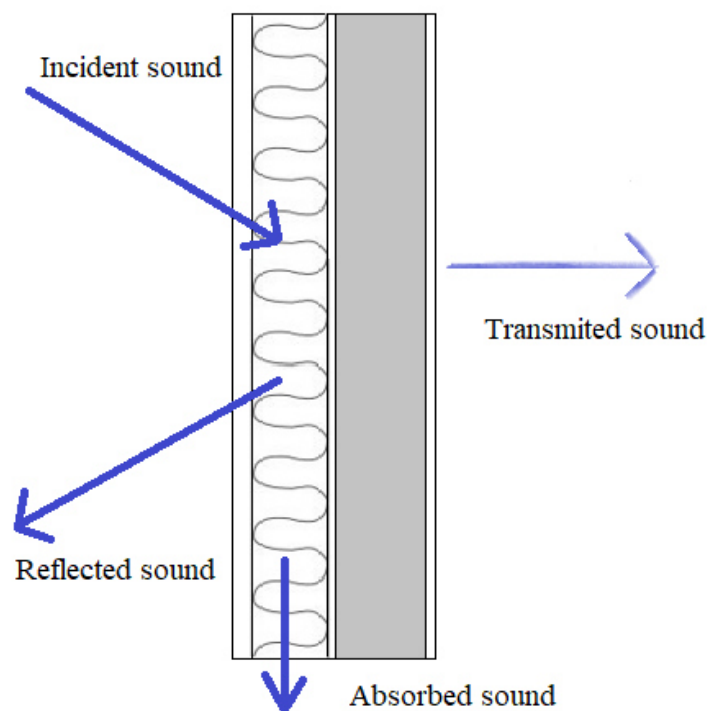


Fig. 1 – Sound waves propagation.

If we want a noise barrier to be considered sound-absorbing, it must contain elements that have the property of absorbing sound. Below is a classification of sound-absorbing panels.

2.1. Acrylic glass panels

They provide superior sound control, environmental sustainability, fire resistance, durability, and visual appeal, making them an ideal choice for a wide range of applications.

Another advantage of glass phono absorbent panels is their environmental sustainability. The panels are made from recycled glass, which reduces the amount of waste sent to landfills. In addition, the panels themselves are 100% recyclable, further reducing their environmental impact. This makes them an ideal choice for environmentally conscious designers and building owners.



Fig. 2 – Acrylic glass phonoabsorbent panels (Ștefan, 2018).

The sound absorption coefficient of glass depends on various factors, such as the thickness of the glass, the type of glass, and the presence of any coatings or laminates. Generally speaking, glass has poor sound absorption properties compared to traditional sound-absorbing materials like fiberglass and mineral wool (Ștefan, 2018).

The sound absorption coefficient is measured on a scale of 0 to 1, with 0 indicating complete sound reflection and 1 indicating complete sound absorption. The sound absorption coefficient of glass phonoabsorbent panels varies depending on the specific product, but it typically ranges from 0.3 to 0.9. This means that the panels can absorb anywhere from 30% to 90% of the sound that strikes them, depending on the frequency of the sound and the thickness and configuration of the panels (Wang *et al.*, 2021).

2.2. Reinforced concrete panels

Considering that concrete is one of the most commonly used construction materials and is found everywhere around us, both in building structures and sidewalks, the use of this material for the construction of sound-absorbing panels is justified by its properties.

Concrete phonoabsorbent panels are a type of composite material that consists of a concrete base layer and a sound-absorbing foam layer. The foam layer is typically made of materials like polyurethane or mineral wool, which are

known for their sound-absorbing properties. The concrete layer provides structural support and can be finished with a range of surface treatments to enhance its appearance and acoustic properties. The sound absorption coefficient of concrete phonoabsorbent panels can vary depending on the specific product, but it generally ranges from 0.5 to 0.9.



Fig. 3 – Reinforced concrete phonoabsorbent panels (Ștefan, 2018).

The foam layer of concrete phonoabsorbent panels is the primary contributor to their sound-absorbing properties. By trapping and dissipating sound waves, the foam layer reduces the amount of sound that is reflected back into the environment. The concrete layer, on the other hand, provides mass and stiffness, which can help to improve the low-frequency sound absorption of the panels (Proença *et al.*, 2020).

2.3. Panels made of plastic materials

The foam core layer of plastic phonoabsorbent panels is typically made of materials like polyurethane, polyethylene, or polystyrene, which are known for their sound-absorbing properties. The rigid plastic sheets can be made of a variety of materials, such as polyvinyl chloride (PVC), polycarbonate, or acrylic (Tiuc *et al.*, 2015).



Fig. 4 – Phonoabsorbent panels made of plastic materials (Ștefan, 2018).

The sound absorption coefficient of plastic phonoabsorbent panels can vary depending on the specific product and design, but typically ranges from 0.2 to 0.8 across a range of frequencies.

2.4. Panels made of metallic materials

These panels can be made, for example, from steel, stainless steel, or aluminum. One reason to choose aluminum as a sound-absorbing material for panels is its low weight. On the other hand, steel is preferred for its strength, hardness, and elasticity. Additionally, this material does not rust, which can be an important factor in choosing the sound-absorbing component. When installing such panels, weather conditions in that area are also taken into account (Ștefan, 2018).

The sound absorption coefficient of metallic panels depends on several factors, including the size and shape of the perforations, the thickness and density of the backing material, and the type of metal used for the panel. Research has shown that different perforation patterns and backing materials can significantly affect the sound absorption performance of metallic panels.



Fig. 5 – Phonoabsorbent panels made of metallic materials (Ștefan, 2018).

2.5. Panels made of recyclable materials

Many sound-absorbing panels are made from recycled materials such as recycled rubber, plastic, and glass. These materials are often used as the primary sound-absorbing material or as a backing material for perforated panels.

Recycled rubber is a popular material for sound-absorbing panels because it is highly effective at absorbing sound and is durable and long-lasting. Recycled rubber can be used in a variety of panel configurations, including tiles, sheets, and rolls (Xinwu Xu *et al.*, 2018).

Recycled plastic is also commonly used in sound-absorbing panels, particularly in the form of PET (polyethylene terephthalate) felt. PET felt is made from recycled plastic bottles and has excellent sound-absorbing properties. It is often used as a backing material for perforated metal panels.

In a study published in *Building and Environment*, researchers investigated the sound absorption properties of recycled rubber panels and compared them to panels made from virgin rubber. The study found that the recycled rubber panels had similar or slightly better sound absorption coefficients than the virgin rubber panels (Xinwu Xu *et al.*, 2018).

From this category, in the study “Circular reutilization of coffee waste for sound absorbing panels: A perspective on material recycling” it was studied the methods to recycle coffee waste and use it in the production of sound absorbing panels. To determine the acoustic absorption coefficient for this study, researchers developed CWSA (coffee waste sound absorption) samples by combining coffee waste with urea resin. In order to obtain the targeted results, researchers conducted experiments on a total of 12 cases. These cases comprised four different particle size scenarios, including a reference case and three categories based on particle size: particles larger than 300 μm , particles ranging between 300 μm and 600 μm , and particles larger than 600 μm . Additionally, they examined the influence of three particle density variations, specifically 0.4 g/cm^3 , 0.5 g/cm^3 , and 0.6 g/cm^3 (Beom Yeol *et al.*, 2020).

Among the three different density types of samples, the highest sound absorption coefficient was observed in the sample with a density of 0.4 g/cm^3 . It is noteworthy that this density represents the lowest value among the tested densities.

Another study on the field, “Towards fossil-carbon free buildings: Production and environmental performance of innovative sound absorbing panels made from sunflower straw”, highlights the idea of producing sound absorbing panels made of sunflowers straw. Scientists manufactured sound absorption panels utilizing sunflower pith as the primary material, incorporating starch and chitosan as binding agents. In addition to evaluating the two distinct formulations that employed starch and chitosan for producing the sunflower pith panels, they also created two panels using commercial cork samples and one panel using commercial melamine foam as points of comparison.

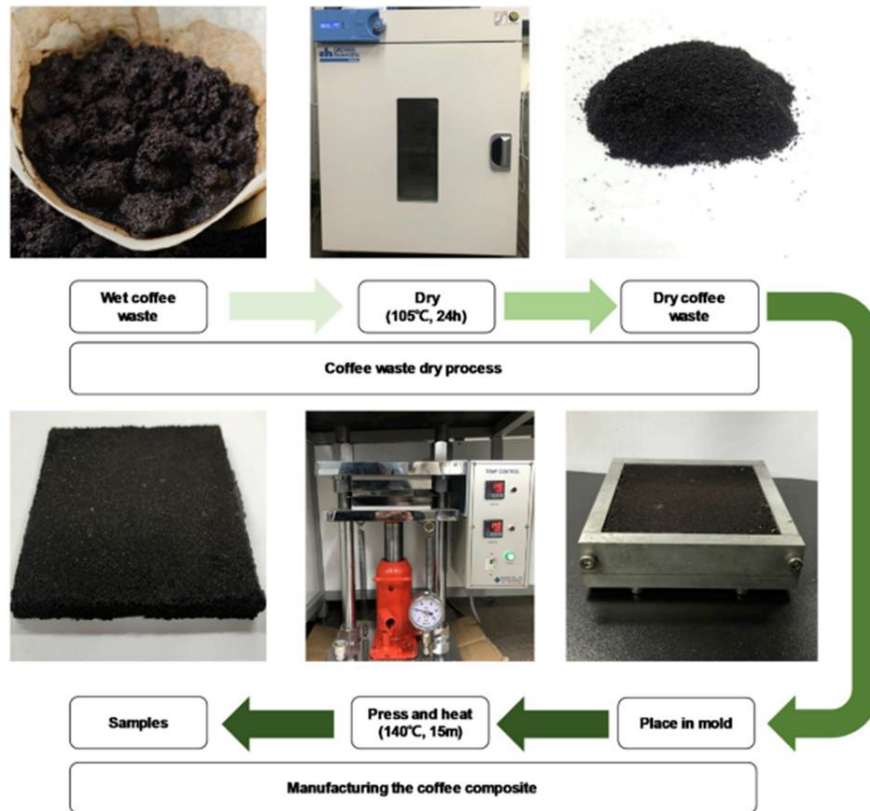


Fig. 6 – Manufacturing process of coffee waste sound absorption sample (Beom Yeol *et al.*, 2020).

As a conclusion, the article emphasizes that the sunflower pith panels demonstrated exceptional performance at lower frequencies (250-400 Hz), exhibiting absorption coefficient values that surpassed those of existing industrial panels by a remarkable 6 to 9 times (Gomez-Campos *et al.*, 2023).

3. Parameters that influence the sound absorbing coefficient

Regarding the selection of materials for sound-absorbing panels, research shows that certain characteristics are considered, such as, acoustic absorption and isolation, transmissibility, as well as parameters such as porosity, air flow resistance, tortuosity and material thickness (Ştefan, 2018).

Porosity (ϕ) is the ratio between the volume of open pores and the total volume of the material. This characteristic depends on the mass, volume, density of the material's fibers, and is determined using the following relationship:

$$h = 1 - \frac{M_m}{V_m \rho_f} \quad (1)$$

where: M_m is the mass of the sample, V_m is the volume of the sample and ρ_f is the density of the fibers.

According to studies in the field, researchers have found that a higher number of fibers leads to an increase in density, and less dense structures absorb low-frequency sounds, while denser structures are suitable for frequencies above 2000 Hz (Ștefan, 2018).

This means that the density and fiber content of a sound-absorbing material are important factors in determining its effectiveness in absorbing sound at different frequencies. Materials with higher fiber content and lower density may be more effective at absorbing low-frequency sounds, while materials with lower fiber content and higher density may be more effective at absorbing high-frequency sounds (Leitao Cao *et al.*, 2018).

The resistance to the passage of air currents (σ) is a crucial characteristic of a sound-absorbing material, directly influencing its sound absorption capacity. The acoustic properties of materials are significantly affected by their resistance to air currents. The resistance to the passage of air currents is defined as the pressure difference required to force a given amount of air through a material, indicating the energy losses due to the viscous effect during the propagation of sound waves.

$$\sigma = \frac{\eta}{k_0} \quad (2)$$

where: η represents the viscosity and k_0 the permeability.

The resistance to the passage of air currents, also known as airflow resistance or airflow resistivity, is an essential property of sound-absorbing materials. It is measured in Rayls per meter (Rayl/m) and indicates the level of impedance that the material provides to the flow of air. The higher the resistance to airflow, the more difficult it is for sound waves to pass through the material. This results in a greater amount of energy loss and a higher sound absorption coefficient. The resistance to airflow is affected by several factors, such as the thickness and density of the material, the pore size and structure, and the orientation of the fibers or particles in the material. Therefore, it is crucial to consider the resistance to airflow when selecting and designing sound-absorbing materials for specific applications, such as in architectural acoustics, automotive industry, or aerospace engineering (Howard *et al.*, 2017).

Tortuosity (α_∞) is a physical property that characterizes the degree of twisting or turning in a material's structure, which affects the ease with which fluids can flow through it. In the context of sound-absorbing materials, tortuosity

is an important parameter that influences the material's acoustic properties, particularly its sound absorption coefficient.

The relation to determine this parameter is:

$$\alpha_{\infty} = 1 + \frac{1 - h}{2h} \quad (3)$$

Studies have shown that materials with a more tortuous pore structure tend to have higher sound absorption coefficients across a range of frequencies. This is because the longer and more convoluted pore structure provides a greater surface area for sound waves to interact with and be absorbed by the material (Leitao Cao *et al.*, 2018).

The thickness of a sound-absorbing material is an important parameter that affects its acoustic performance. In general, the thicker the material, the greater its sound absorption capacity. This is because the sound wave has to travel a longer distance through the material, allowing more opportunities for it to be absorbed and dissipated as heat. However, there is typically a point of diminishing returns where increasing the thickness of the material no longer leads to a significant improvement in sound absorption (Amares *et al.*, 2017).

4. Conclusions

The paper highlights the actual studies of the sound absorbing panels, the materials used, with focus on the sound absorbing coefficients. Based on the experimental data, researchers demonstrate that we should not limit ourselves to the materials initially used for the manufacture of sound-absorbing panels, but we can use either recycled materials or bio-based materials. The scholar studies presented in the paper demonstrate that there are new potential materials that can be studied, with better absorption properties, a fact that leads to obtain new solutions in the field, which can be either cheaper or more sustainable. The study of sound absorbing coefficient of different recycling materials will be a subject of the upcoming studies.

REFERENCES

- Amares S., Sujatmika E., Hong T.W., Durairaj R., Hamid H.S.H.B., *A Review: Characteristics of Noise Absorption Material*, ICADME 2017, IOP Conf. Series: Journal of Physics: Conf. Series 908 (2017).
- Beom Yeol Yun, Hyun Mi Cho, Young Uk Kim, Sung Chan Lee, Umberto Berardi, Sumin Kim, *Circular reutilization of coffee waste for sound absorbing panels: A perspective on material recycling*, Korea, 2020.

- Bujoreanu C., Nedeff F., Benchea M., Agop M., *Experimental and theoretical considerations on sound absorption performance of waste materials including the effect of backing plates*, Iași, 2017.
- Gomez-Campos A., Sablayrolles C., Hamelin L., Rouilly A., Evon P., Vialle C., *Towards fossil-carbon free buildings: Production and environmental performance of innovative sound absorbing panels made from sunflower straw*, France, 2023.
- Howard D.M., Angus J.A.S., *Acoustics and Psychoacoustics* (Fifth Edition), New York, 2017.
- Leitao Cao, Qiuxia Fu, Yang Si, Bin Ding, Jianyong Yu, *Porous materials for sound absorption*, Shanghai, 2018.
- Nowoświat A., Bochen J., Dulak L., Żuchowski R., *Investigation studies involving sound absorbing parameters of roadside screen panels subjected to aging in simulated condition*, Poland, 2016.
- Petrovici A., Cueto J.L., Nedeff V., Nava E., Nedeff F., Hernandez R., Bujoreanu C., Irimiciuc S.A., Agop M., *Dynamic Evaluation of Traffic Noise through Standard and Multifractal Models*, Symmetry, 2020.
- Proença M., Neves e Sousa A., Garrido M., Correia J.R., *Acoustic performance of composite sandwich panels for building floors: Experimental tests and numerical-analytical simulation*, Portugal, 2020.
- Ștefan I., *Contribuții privind îmbunătățirea confortului acustic urban*, Iași, 2018.
- Tiuc A.-E., Vermeșan H., Gabor T., Vasile O., *Improved sound absorption properties of polyurethane foam mixed with textile waste*, Romania, 2015.
- Wang S., Li F., *A broadband sound absorber of hybrid-arranged perforated panels with perforated partitions*, China, 2021.
- Xinwu Xu, Huixiang Wang, Yan Sun, Jingquan Han, Runzhou Huang, *Sound absorbing properties of perforated composite panels of recycled rubber, fiberboard sawdust, and high density polyethylene*, China, 2018.
- https://environment.ec.europa.eu/strategy/zero-pollution-action-plan_en, accessed on 12.04.2023.

STUDIUL PANOURILOR FONOABSORBANTE UTILIZATE ÎN TRAFICUL RUTIER

(Rezumat)

Poluarea fonică are un efect negativ asupra corpului uman, iar în anumite situații, expunerea la niveluri ridicate de poluare poate duce la probleme grave de sănătate. Referindu-ne la studiile actuale, putem observa un interes crescut în găsirea soluțiilor pentru reducerea efectelor poluării fonice, cum ar fi panourile fonoabsorbante. Scopul acestui articol este acela de a prezenta stadiul actual de dezvoltare al panourilor fonoabsorbante și coeficientul de absorbție al materialelor utilizate. Articolul oferă informații despre diferite tipuri de panouri și materiale utilizate în construcția lor, precum și despre proprietățile mecanice ale acestora. Noile descoperiri în domeniul materialelor reciclabile utilizate în construcția panourilor fonoabsorbante reprezintă un punct de

interes suplimentar, deoarece construcția unor astfel de prototipuri protejează mediul înconjurător. Utilizarea deșeurilor în procesul de construcție a panourilor fonoabsorbante poate fi considerată o metodă sustenabilă pentru viitor.