ACOUSTIC PERFORMANCES ANALYSIS OF A COMPOSITE SYSTEM FOR NOISE BARRIERS SPECIFIC TO ROAD TRAFFIC

Ana GHEORGHE

“Dunărea de Jos” University of Galați, Engineering Faculty of Brăila,
Domnească Street, 47, RO-800008, Galati, Romania

ana_gheorghe80@yahoo.com

ABSTRACT

This paper presents the interaction model of acoustic waves from road traffic and noise barrier made of light materials, without inertial effects, by establishing sound absorption coefficient depending on the frequency, for a number of samples, thus setting sound absorption capacity for each material made from absorbent materials. In this context, it is sets the acoustic attenuation capability of a simple panel made of light elements (elements with low density) function on the geometry elements, structural elements, position elements and propagation of road traffic noise.

KEYWORDS: soundproofing materials, sound absorption coefficient, sawdust, recycled material particles

1. INTRODUCTION

Various human activities generate noise. Combating noise is a problem of work system, system in this case, represents an assembly consisting in noise sources, the propagation medium (ways) of acoustic energy and receivers. With the development of modern industry and traffic, noise has become one of the factors that are responsible for the adverse effects on human health and the environment worldwide.

Noise pollution is one of the biggest problems facing humanity in the last decade alongside air pollution and waste management. Devices for protection against noise (noise barriers) are designed to reduce existing noise levels or predictable in sensitive areas to this parameter, located in close proximity to buildings or built spaces (factories, warehouses, etc.), what constitutes the harmful sources of noise pollution, as well as those located in close proximity to major communication routes (highways, roads with intense traffic), having a high level of road traffic.

Under these conditions in conceptual terms, noise reduction devices can be defined as an obstacle placed between the noise source (road traffic) and receiver (assemblies built highways, the population in the immediate vicinity of communication routes) that modify the propagation of the sound wave and which by reflection, refraction and absorption reduce noise levels.

2. UNDULATORY PROCESSES OF THE ACOUSTIC PROPAGATION

Sound wave propagation characteristics have a decisive role in the processes of distribution, attenuation or amplification of sound energy. Under acoustic aspect, a simple wall is a building element made from various parties related supportive of each other so that at action of the sound waves it can be characterized as a unitary structure, [2].

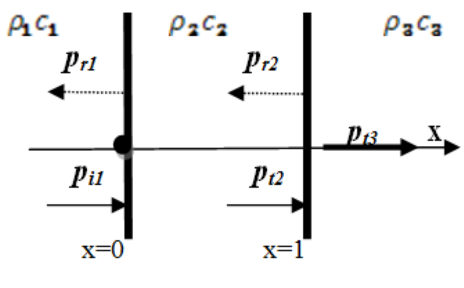

Fig. 1. Acoustic structure for partition wall

Propagation of sound waves through a simple wall, consists of three successive mediums with characteristics $\rho_1 c_1$, $\rho_2 c_2$, $\rho_3 c_3$, so that the medium $\rho_2 c_2$ can form acoustic structure for partition wall as it is shown in figure 1.

The first separation plan occurs incidence of direct wave with pressure p_{i1} and reflection with pressure p_{1r} as well as wave transmission with pressure p_{t2}, and in medium $\rho_2 c_2$ occurs incident on the surface of separation for x-1 with reflection p_{r2} and pressure transmission p_{t3} in medium $\rho_3 c_3$.

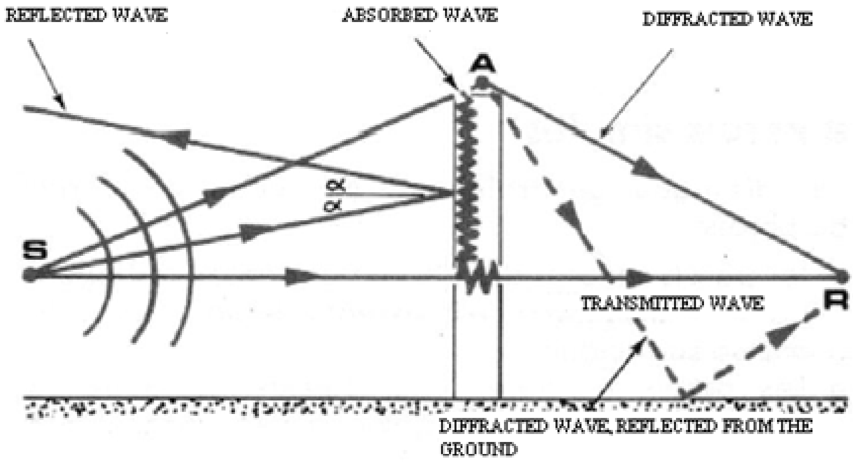

Fig. 2. Transmission of sound waves in presence of noise barrier

Sound wave pressures in the three mediums are the undulatory functions, represented as complex numbers, such:

$$p_{i1} = P_{i1} e^{i(\omega t - k_1 x)} \quad (1)$$

$$p_{t2} = P_{t2} e^{i(\omega t - k_2 x)} \quad (2)$$

$$p_{r2} = P_{r2} e^{i[\omega t + k_2(x-l)]} \quad (3)$$

$$p_{t3} = P_{t3} e^{i[\omega t - k_2(x-l)]} \quad (4)$$

Air particle velocity depending on the pressure is of the form:

$$v_j = \frac{P_k}{\rho_j c_j} e^{i(\omega t - k_j x)}, \text{ where } j = 1, 2, 3, \ldots \quad (6)$$

Noting the relative impedances of the three mediums with $z_{12} = \frac{\rho_2 c_2}{\rho_1 c_1}$, $z_{23} = \frac{\rho_3 c_3}{\rho_2 c_2}$, $z_{13} = \frac{\rho_3 c_3}{\rho_1 c_1}$, and using Euler's formula for trigonometric form of complex numbers for relationships [1, 2, 3, 4, 5, 6] we determine the pressure of the direct wave P_{i1}. Prompting the coefficient of energy transmission between mediums $\rho_1 c_1$ and $\rho_3 c_3$, τ and basis to relationship for pressures [1,2] and for speeds, is established wall attenuation such:

$$R = D = 10 \log \frac{1 + \frac{1}{4}\left(z_{12} + \frac{1}{z_{12}}\right)^2 tg^2 k_2 l}{1 + tg^2 k_2 l}, \quad (7)$$

where $k_2 = \frac{\omega}{c_2}$ is wave's number for elastic medium $\rho_2 c_2$.

To the propagation of sound waves through the medium, in addition to the phenomenon of attenuation occurs and absorption phenomenon. Sound absorption defines defines way in which surface composition from enclosed spaces behaves in relation to incident sound waves. Sound waves lose their energy gradually this transformed into heat. Sound absorption is highly dependent on his frequency, higher sounds (higher ν) are more strongly absorbed than those low. This phenomenon is because the energy emitted by the source is divided on spherical surfaces with increasing ray (like is shown in the following figure sum) thus energy intensity per unit area decreases with the square of the radius of the sphere, respectively the distance between source and receiver.

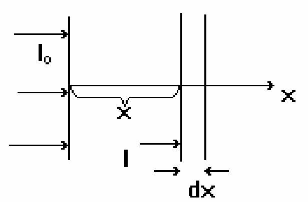

Fig. 3. Attenuation of sound intensity

Sound absorption is characterized by "sound absorption coefficient, α” defined as the ratio of the total amount of transmitted energy and total energy absorbed and total energy incidence of sound waves. Absorption coefficients are used to evaluate the effectiveness of a material to absorb the sound.

$$\alpha = \frac{E_i - E_r}{E_i} = \frac{E_a + E_r}{E_i} \quad (8)$$

Sound absorption capacity of a material as being the ability of a material to convert acoustical energy into thermal energy (vibrations), reflecting its lower part. Based on experiments carried out by researchers in the field, it was noted that in areas built with traditionally materials like marble, brick or glass, which not possess a high soundproofing capacity, echo phenomenon appears, due the reflection of sound waves, change in it led to a general increase in noise level.

Sound absorption phenomenon may occur, in generally, for any of the following cases: porosity (seen in materials with a fibrous structure such as wood based products), cavity resonance (seen at noise barriers perforated or slotted) or membranes (membranes can be made of rubber, plastic sheets, fabrics, etc. and depending on the material used for filling structure can give the same absorption properties as in the case of the cavity resonance)

Sound insulation, also called transmission loss, is the ability to prevent the transmission of sound energy because a part of the acoustic energy is "hindered" to cross certain materials, similar with other conductive materials that are poor heat and electricity. This ability is determined, in general, by material mass *m* *[kg/m²]* and sound frequency *f [Hz*], being limited by certain mechanical characteristics which, for certain frequencies, resulting in a "transparent" for sound, causing resonance effects.

Sound energy transmission factor is defined as the ratio between acoustic energy flow of waves transmitted Wt and acoustic energy flow of incident waves on the separation surface of two medium Wi, his value is less than the material retention ability of sound waves is higher.

Soundproofing is given by

$$R = 10 \log \frac{1}{\tau} \text{ dB} \quad (9)$$

where

$$\tau = \frac{W_t}{W_i}, \quad (10)$$

[2].

3. COMPOSITE SYSTEMS

Composite materials are a new category of products, with importance of technical point of view and economic. These are systems of deformable solid bodies, mixed on a macroscopic scale of several materials, in order to obtain superior characteristics as: mechanical properties, corrosion resistance, wear and tear, lightweight, good reaction at temperatures, soundproofing, aesthetic aspect, ecological properties, etc.. [1]. Other experts define composite materials like structures with anisotropic properties made up of several components, whose organization and development allow use of the best features of components, in such that they have the final properties, generally above from elements that are formed [Cristescu].

Knowledge of absorbing material, and their structure, is essential for noise control. The main feature that defines absorbing materials is their porous structure, pores communicating with each other through channels or openings of the material. Because of the viscosity of air, both between the particles of air, and between them and the pore walls occur friction forces which irreversibly transformed into heat energy a part from acoustic energy of waves, [3]. Thermal conductivity of air helps dissipate at acoustic energy waves which crossing sound-absorbing material. Along with the air are put in motion fibers of material, they suffer bending movements. Internal friction of the fibers of material, that occur due their deformations, lead to increasing sound absorption material, [3].

Acoustical absorption of sound absorbing materials is in close contact with a number of physical characteristics, of which the most important are the porosity and resistance to air flow through them.

Porosity sound absorbing material is given by the ratio of pore volume and total volume of the material properties that shall be studied in terms of sound absorption are absorption coefficient and specific impedance. Porosity, for fibrous materials, is recommended calculate with relation, [3]:

$$y = 1 - \frac{M_m}{V_m \rho_f} \quad (11)$$

where:

M_m – is the mass of sample material;
V_m – sample volume of material;
ρ_f – fiber density.

4. EXPERIMENTAL DATA CONCERNING ABSORPTION COEFFICIENTS OF MATERIALS MADE

Below are presented the values obtained, for a number of composite structures made of soundproofing materials, for sound absorption coefficient (practical value), as a result of the tests performed in the laboratory of acoustics from ICECON Bucureşti, using method of interferometer acoustic (Kundt tube)). I mention that the materials samples have been prepared by Eng. Ancuța TIUC, Ph.D. – Technical University of Cluj-Napoca and tested in the laboratory, in various combinations, through my participation in the development, processing and testing samples.

Samples 1 were made of a layer of recycled rubber particles and polyurethane binder with a thickness of 15 mm and a layer of material made from sawdust and polyurethane material with a thickness of 15 mm.

Sample 2 were made of a layer of recycled rubber particles and polyurethane binder with a thickness of 15 mm and a layer of material made from sawdust and polyurethane material with a thickness of 15 mm and layer of material made from fabric wastes with a thickness of 3 mm.

Sample 3 were made of a layer of recycled rubber particles and polyurethane binder with a thickness of 15 mm and a layer of material made from sawdust and polyurethane material with a thickness of 15 mm has a layer of cork with a thickness of 3 mm.

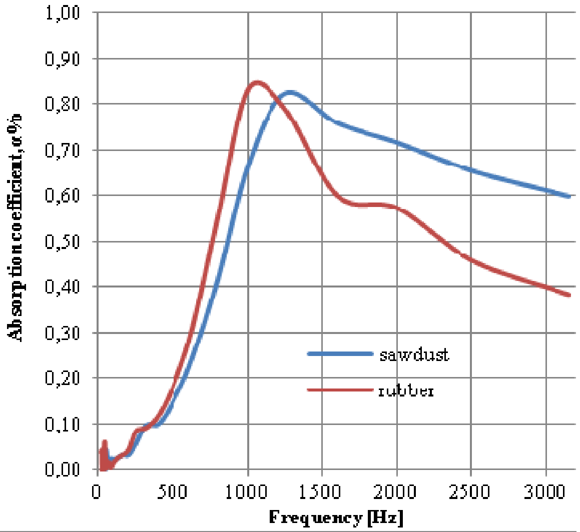

Fig. 4. Sound absorption coefficient variation depending on frequency for sample 1

Sample 4 has a thickness of 40 mm and it was made of sawdust as reinforcing material and polyurethane binder.

Sample 5 has a thickness of 40 mm and it was made of particles of recycled rubber and polyurethane binder.

Sample 6 has a thickness of 40 mm, reinforcement was made with sawdust and particles of recycled rubber, with a rate of 50% each from the reinforcing material mass, and 20% polyurethane binder

The sound absorption coefficient for sample 2 depending on frequency (like we can seen in figure 5). We can observe that the sound absorption properties of the sample are better when the measurement was made on the rubber side at frequencies higher than 500 Hz.

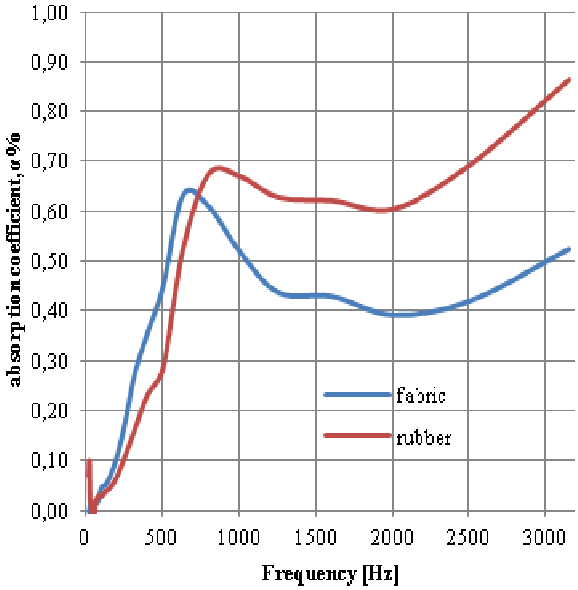

Fig. 5. Sound absorption coefficient variation depending on frequency for sample 2

Sample 3 has the most different values for the sound absorption coefficient depending on the side on which the measurement was made, figure 6. We can see a significant increase of the absorption coefficient in the frequency range 500 ÷ 1000 Hz, in the case the measurement was made on the cork side.

At frequencies higher than 1000 Hz, the sound absorption properties are significantly better if the measurement was made on the rubber side rather than the cork side.

In figures 7 and 8 is presented a comparison between the sound absorption coefficient of samples 1 ÷ 3 both on the rubber side (figure 7) and also on the sawdust/fabric material/cork sides. Is observed that the samples 1 and 3 have good absorption sound properties if measurements surface have been made for rubber layer, while for sample 2 absorption sound coefficient is good for fabric material layer, in frequencies range 500÷100 Hz, while layer made from rubber the coefficient is good for frequencies range 1000÷2000 Hz. Also observed that for sample 3 sound absorption coefficient shows a slight stagnation for frequencies range 1500÷2500 Hz, and then begins to increase.

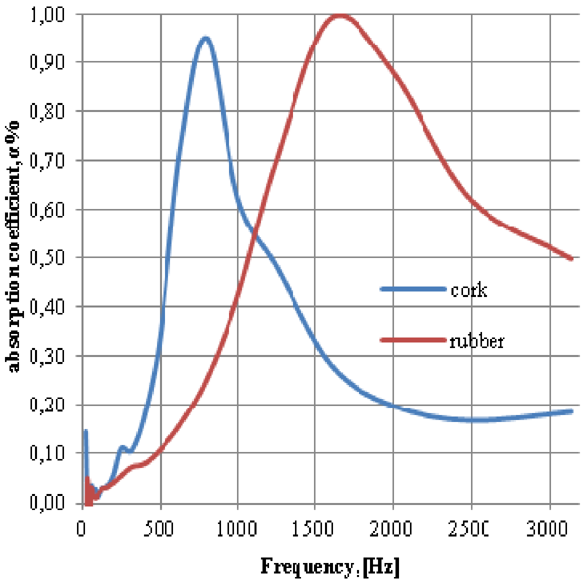

Fig. 6. Sound absorption coefficient variation depending on frequency for sample 3

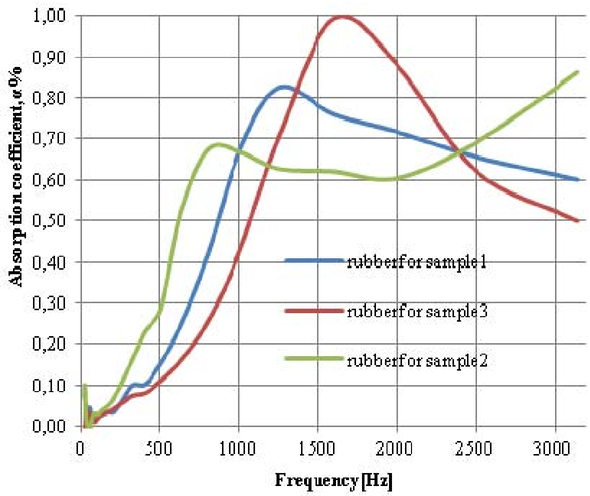

Fig. 7. Sound absorption coefficient variation depending on frequency for samples 1÷3, measured on the rubber side

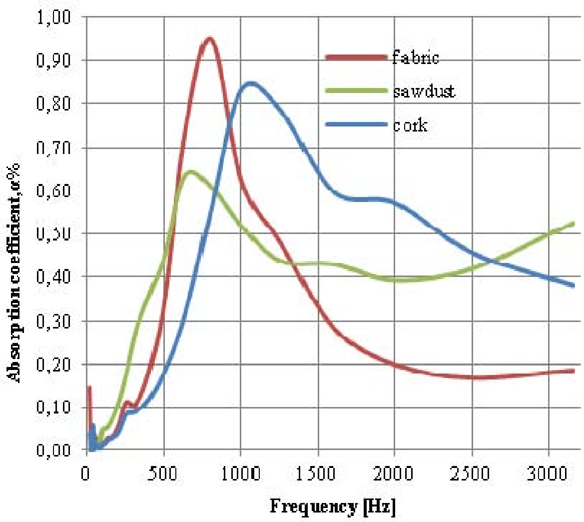

Fig. 8. Sound absorption coefficient variation depending on frequency for samples 1÷3, measured on the sawdust/fabric material/cork side

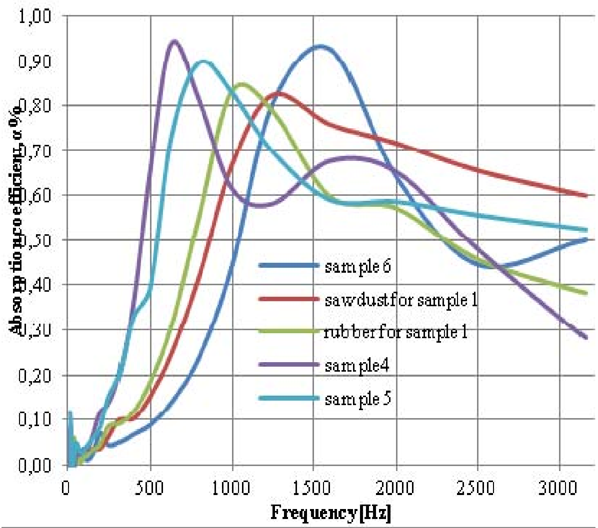

Fig. 9. Sound absorption coefficient variation depending on frequency for samples 1, 4, 5 and 6

In figure 9 is represented a comparison of the sound absorption coefficient depending on frequency for samples 1, 4, 5 and 6. From the chart representation we can see that sample 4, made only from sawdust, has the best sound absorption properties, especially in the frequency range 500 ÷ 1000 Hz, while samples 5 excel in the frequency range 500 ÷1500 Hz and sample 6 excel in the frequency range 500÷2000 Hz. Sample 1 has maximum values in the range 1000 ÷ 1500 Hz.

5. CONCLUSIONS

Comparing the results with acoustic absorption classes, according to EN ISO 11654 [4], is found that the materials produced have good sound absorption properties on a large frequency range, which would provide advantages when it comes to reducing the noise. When using cork as a testing surface improves sound absorption in the frequency range 100÷1500 Hz and decreases it a frequencies larger than 1500 Hz, while the fabric material improves sound absorption in the frequency range 100 ÷ 1000 Hz and decreases it a frequencies larger than 1000 Hz up to a frequency range of 2500 Hz, then begins to rise slightly.

For samples made from sawdust, rubber particles and polyurethane binder we obtain properties better if the samples are made in mixture (sample 6) rather than those made in layers (sample 1).

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