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CERCETĂRI PRIVIND ATENUAREA UNDELOR SONORE PRIN UTILIZAREA PANOURILOR REALIZATE DIN MATERIALE COMPOZITE

RESEARCH ON ATTENUATION OF SOUND WAVES BY USING PANELS MADE OF COMPOSITE MATERIALS

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Noise is a well known source of environmental pollution in urban areas or at work. Sound pressure level has a harmful effect on human health.

In this paper we present our research on making a new type of composite material and testing its properties of noise attenuation level. Tests were carried out in the anechoic chamber using barrier attenuators of sound waves made of composite material consisting of 50% formaldehyde resin reinforced polypropylene granules formed from waste 50%.

It was also determined the efficiency of the panel by calculating the diffraction pression according to the sound waves dispersion on the acoustic panel's surface and mapping the attenuation of noise levels due to the composite material..

Zgomotul este o sursă bine cunoscută de poluare a mediului din zonele urbane sau la locul de muncă. Nivelul de presiune sonoră produce efecte nocive asupra sănătăţii oamenilor.

În această lucrare sunt prezentate cercetări efectuate privind elaborarea unui nou tip de material compozit precum şi testarea proprietăţilor lui de atenuare a nivelului de zgomot. S-au efectuat teste în camera anecoică utilizându-se un panou acustic din material compozit alcătuit din răşină formaldehidică 50% armată cu deşeu format din granule de polipropilenă 50%.

De asemenea, s-a determinat eficienţa panoului prin calcularea presiunii difractate în funcţie de dispersia undelor acustice pe conturul panoului acustic şi evidenţierea atenuării acustice a panoului din material compozit.

Keywords: *composite materials, waste, acoustic panel, anechoic chamber, sound waves,*

1. Introduction

The industrial activity produces important environment modifications. It is important to stress out that the impact of industrial activities on the environment and human communities depends on the realized product and technologic process type or on the technologic efficiency of pollution control technologies [1]. The noise is a well-known environmental pollution source existing in urban areas or at the work place.

The noise exposure is one of the most wide spread environmental stress source in our day to day life. There are many proofs that sustain the relation between the ambient exposure and human mental health [2, 3]. Thus, a series of measures have been taken to reduce the noise level, both in environmental surroundings and at the work places. The European Union membership force our country to align to the legal requirements in the field where a series of measures have been promoted to limit the noise level [4].

The rapid evolution in the last ten years of the materials science and engineering implies the development of new state of the art materials, with functional and esthetic characteristics capable to reduce the level of phonic pollution. Obtaining durable, economic and in the same time ecologic materials represents a top preoccupation in the field [5-7].

If the level of acoustic pressure of the noise exceeds the maximum allowable value, it is necessary to realize a supplementary attenuation by using the noise attenuation system [7].

The work proposes the obtaining of a sound-absorbing panel made of polymeric composite material reinforced with polypropylene wastes, testing the sound waves attenuation in anechoic

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chamber and simulation regarding the produced sound-absorbing panel efficiency.

2. Experimental part

A composite sound-absorbing material panel was made of formaldehyde resin in a 50% proportion reinforced with polypropylene waste granules in a of 50 % proportion. In Figure 1 it is presented the technologic process scheme for obtaining a composite material.

The obtaining of the composite material has been realized with reference to the following parameters:

- The reinforcement material and resin dosage has been according to weight.
- The homogenization has been realised in a container for 10 min.
- The casting has been realized in a moulding device with the following dimensions: length = 1.5 m; width = 1.5 m and height = 0.08 m.
- Strengthening has been realised in 24 hours at the room temperature.

The used resin has been obtained through a discontinuous process, with low formaldehyde emissions and not exceeding the current legal limits [8,9]. From the speciality literature is known that the formaldehyde resins are obtained through continuous and discontinuous processes, in two or more steps by a condensation reaction between urea and formaldehyde. The formaldehyde emissions during the technologic process for obtaining the composite material have been influenced by the free formaldehyde content from the produced adhesive, namely, as the free formaldehyde content is lower the emissions are lower [8÷10].

The attenuation test for the noise level has been done in the anechoic chamber (figure 2), and the determination of the noise level at the receptor has been done with a sonometer (Solo 01 dB MTRAVIB) of class 1 having a 1/1 octave filter (Receiver). The attenuation barrier represents the obtained composite material. For the sound wave emissions has been used an omnidirectional source (Source) made of loudspeakers, and the sound waves for each frequency have been produced by a sound wave generator.

In Figure 2 is presented a testing sketch from anechoic chamber for measure a sound-absorbing panel made of composite materials.

The mean-square pressure p_2^2, from the receiver when a barrier is posed between the source and the receiver is given by the following expression [7,11,12]:

$$p_2^2 = p_{r2}^2 + p_{b2}^2 \qquad (\mathrm{Pa}^2) \qquad (1)$$

where: p_{r2}^2 = mean-square pressure from the receiver due to the reverberation domain expressed in Pa^2; p_{b2}^2 = mean-square pressure from the receiver due to the diffracted domains around the barrier margins, in Pa^2.

Then the level of sound pressure, L_{p2}, is given by the expression [7,11,12]:

$$L_{p2} = 10 \log \left(\frac{p_2^2}{p_{re}^2} \right) \qquad (\mathrm{dB}) \qquad (2)$$

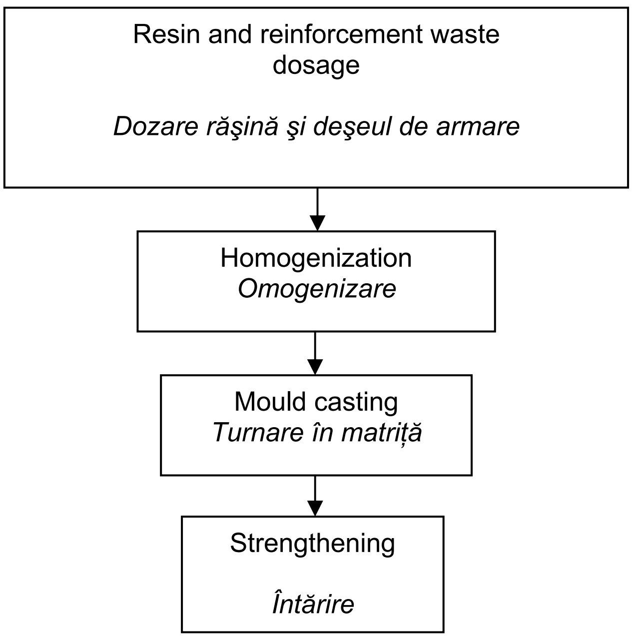

Fig. 1 - The technologic process scheme for obtaining the sound-absorbing composite material panel / *Schema procesului tehnologic de obținere a panoului fonoabsorbant din material compozit.*

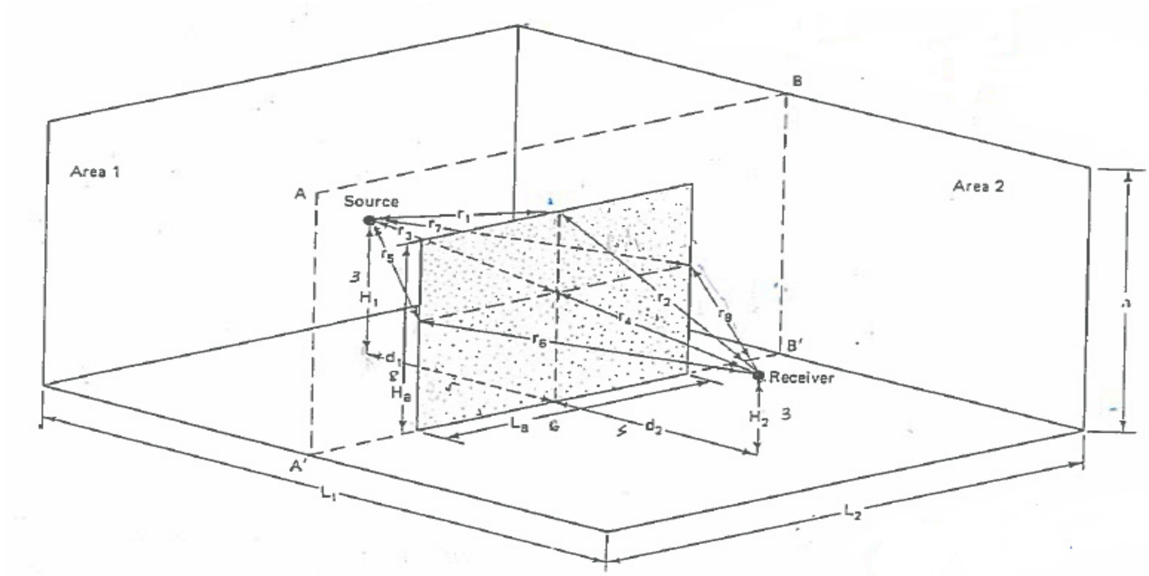

Fig. 2 - Testing sketch from anechoic chamber / *Schița testului din camera anecoică.*

where p_{re}^2 is the mean-square pressure in the reverberant field, on the back of the barrier, in Pa^2.

Through combination of expression (1) with expression (2) results:

$$L_{p2} = 10 \log\left(\frac{p_{r2}^2 + p_{b2}^2}{p_{re}^2}\right) \quad \text{(dB)} \qquad (3)$$

The relation (3) expresses the level of sound pressure, L_{p2}, from the receiver, in that is regarding the reverberant and diffracted domains.

To demonstrate effectiveness of the analyzed sample from the point of view of the sound waves absorption, the attenuation of the acoustic panel should be determined. The diffraction is referring to the diverse phenomena associated with the obstacles waves detour arising in their way and it has been produced in the case of any wave type, including the acoustic waves [13], as it is observed in the Figure 3.

The way of noise transmission is not always only the direct one. The wave that is directed through the barrier margins is transmitted due to the diffraction phenomenon towards the receiver. This phenomenon is occurring also as a loss of noise energy [13].

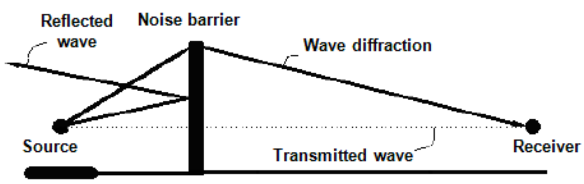

Fig. 3 - Sketch of diffraction wave / *Schița undei de difracție* [13]

The diffraction theory due to barriers can be well developed in the case of surfaces having the length greater than height. In this respect researches made by Born and Wolf should to be mentioned [14].

An expression of the diffracted pressure is also suggested, resulting this way a new equation with reference to the mean-square pressure as follows [11,12]:

$$p_{b2}^2 = p_{d2}^2 \sum_{i=1}^{n} \frac{1}{3 + 10N_i} \quad \text{(Pa}^2\text{)} \qquad (4)$$

where: p_{d2}^2 = the mean-square pressure is due to the direct fields before putting the barrier expressed, in Pa^2, N_i = represents the Fresnel number that is given by the following expression:

$$N_i = 2\delta_i / \lambda \qquad (5)$$

where: δ_i is the difference between the direct and the diffracted ways between source and receiver, in m; λ = the wave length, in m.

The difference among direct and diffracted ways between the source and receiver is computed in the following way:

$$\begin{aligned} \delta_1 &= [(r_1 + r_2) - (r_3 + r_4)] \quad \text{(m)} \\ \delta_2 &= [(r_5 + r_6) - (r_3 + r_4)] \quad \text{(m)} \qquad (6) \\ \delta_3 &= [(r_7 + r_8) - (r_3 + r_4)] \quad \text{(m)} \end{aligned}$$

where r$_1$ ÷ r$_8$ are distances that represent the length between source – and the edges of receiver barrier (see fig. 4).

The equation (4) can be extended in the following way:

$$p_{b2}^2 = p_{d2}^2\left(\frac{1}{3+10N_1}+\frac{1}{3+10N_2}+\frac{1}{3+10N_4}\right) \text{ (Pa}^2\text{)} \tag{7}$$

Depending on the directivity coefficient of the acoustic source the produced attenuation by the acoustic panel can be computed as follows:

$$Q_{b2} = Q_{d2}\sum_{i=1}^{3}\frac{1}{3+10N_i}$$
$$\Rightarrow \frac{Q_{b2}}{Q_{d2}} = \sum_{i=1}^{3}\frac{1}{3+10N_i} \tag{8}$$

where Q_{b2} is the coefficient of directivity of acoustic source behind the screen (near the receptor); Q_{d2} is the directivity coefficient of the acoustic source in the front of the screen (on the side of the acoustic source).

The attenuation coefficient of the acoustic panel, A_p, in dB, can be calculated as a function of the Fresnel number that is characteristic of each octave bands, in the following way:

$$A_p = 10\log\left(\frac{Q_{d2}}{Q_{b2}}\right) = 10\log\left[\left(\sum_{i=1}^{3}\frac{1}{3+10N_i}\right)^{-1}\right] \text{(dB)} \tag{9}$$

3. Results and discussions

After obtaining of the sample of composite material, made according to the technological process presented in the scheme in figure 1, that sample is tested in the anechoic chamber from the point of view of the attenuation properties of the sound waves and then, for determining by computation the phonic attenuation efficiency of the sonic waves. The diffraction is referring to the different associated phenomena with the by-pass of the sound waves of the occurred obstacles and that phenomena is happened in the case of any wave, including the acoustic waves.

In Figure 4 is presented the experimental installation that has been used to test the attenuation level of the sound wave of the sample made of composite material, with the following dimensions: L_1 = the sample length (the wall attenuator) = 1.5 m; L_2 = the length of the source – wall = 1.5 m; L_3 = the length of the wall – receptor = 1 m; H_1 = the height of the wall = 1.2 m; H_2 = the height at which there is the source = 0.50 m; H_3 = the height at which there is the receptor = 0.75 m.

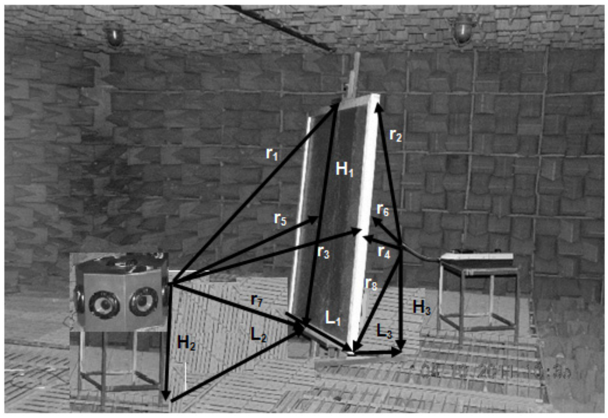

Fig. 4 - The experimental installation to determine the attenuation level of the sound waves from the anechoic chamber / *Instalația experimentală de determinare a nivelului de atenuare a undelor sonore din camera surdă.*

The measurements of the noise level have been realized using a frequency range of 250 ÷ 8000 Hz at the initial moment without sample (attenuator wall) – series a –, then has been introduced the sound-absorbing panel between the source and the receptor, respectively the sample made of composite material, – series b –. The results are shown in Figure 5.

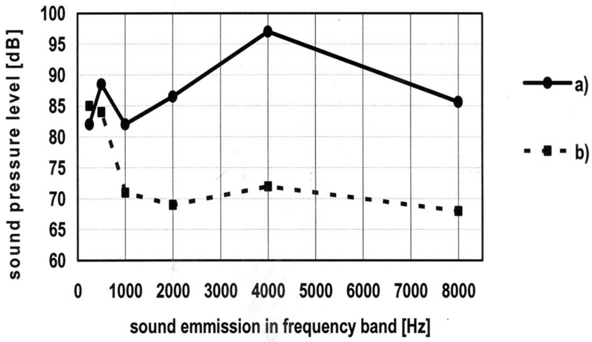

Fig. 5 - Variation of sound pressure level depending on frequency, without the attenuation barrier (a) and with attenuation barrier (b) / *Variația nivelului presiunii sonore funcție de frecvență, fără barieră atenuatoare (a) şi cu barieră atenuatoare (b).*

Thus, there is a slight increase of the acoustic pressure level, remarked at a low frequency of 250 Hz, an increase from 82 dB has been recorded at the initial moment, to 85 dB after the sample of composite material has been introduced. That is explained because at low frequency the panel rigidity influences the attenuation of sound waves.

Afterwards, at the increase of the frequency, a decrease of the acoustic pressure level is remarked on the entire frequency range. To demonstrate the effectiveness of the analysed sample from the point of view of sound wave attenuation the attenuation coefficient should be determined.

This way, taking into account the attenuator wall dimensions L1÷L3 and H1÷H3 (presented in Figure 4), the distances $r_1 \div r_8$ have been computed, representing the length between source – and the barrier's edges, resulting in the following values: r_1 = 1.66 m; r_2 = 1.10 m; r_3 = 1.68 m; r_4 = 1.25 m; r_5 = 1.50 m; r_6 = 1.00 m; r_7 = 1.58 m; r_8 = 1.25 m.

Taking into account those values the quantities $\delta_1 \div \delta_3$ representing the difference between the direct part and the diffracted part between the source and the receiver, have been computed [15,16]. Obtained values are: δ_1 = 0.25 m; δ_2 = 0.43 m; δ_3 = 0.33 m.

The wave length, λ, for each frequency f, (frequency band) is computed with the expression:

$$\lambda = \frac{c}{f} \quad \text{(m)} \tag{10}$$

where c = 343 m/s is the propagation speed of sound wave in the air.

Based on expression (5) has been computed the Fresnel number N_i for each frequency and for the computed values $\delta_1 \div \delta_3$. The obtained results are presented in the Table 1, columns 3, 4 and 5.

Using the relations (7), (8) and (9) for each frequency, the attenuation coefficient A_p, in dB, of the acoustic panel made of studied composite material, and the results are presented in the table 1, column 6.

With the obtained values, a graphical representation is plotted for the variation of attenuation coefficient of the sound waves, A_p, in the Figure 6, as a function of frequency, for the analyzed sample from formaldehyde resin 50% reinforced with polypropylene waste granules 50%.

An increase of the sound waves attenuation coefficient was remarked in the same time with the increase of the work frequency. Although the low frequencies, respectively 250 Hz, as has been previously remarked, the wall rigidity is influenced by the attenuation of the sound waves, otherwise saying in the same time with the increase work frequency, the sound-absorbing properties of the composite material panel increase.

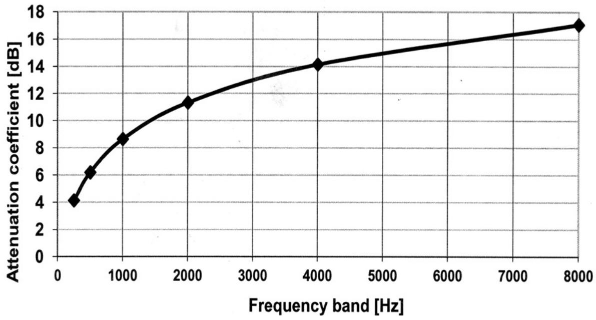

Fig. 6 - The variation of attenuation coefficient of the sound-absorbing panel as a frequency function / *Variația coeficientului de atenuare al panoului fonoabsorbant în funcție de frecvență*

4. Conclusions

- the structure of the studied sample and the geometry and dimensions determine a good attenuation of the sound waves;
- the direct transmission wave on the direction of receptor can has a certain influence – the increase of attenuation due to the absorption of the corresponding material the loss of acoustic energy;
- the attenuation level due to the acoustic panel, augments in the same time with the increase of the frequency, having greater values, exceeding 17 dB in the band of 8000 Hz;
- due to the production technologies of those panels' types (with a content of 50 % waste), the final production costs have been reduced, resulting the acoustic panels with sound-absorbing qualities similar to those on the market.

Table 1

The calculated wavelength λ, the number of Fresnel N_i and attenuation of acoustic panel A_p according to the frequency f / *Valorile calculate pentru lungimea de undă λ, numărul lui Fresnel N_i şi atenuarea panoului acustic A_p funcție de frecvența f*

Frequency, f, [Hz]	λ [m]	N_1	N_2	N_3	A_p [dB]
1	2	3	4	5	6
250	1.372	0.37	0.62	0.48	4.13
500	0.686	0.73	1.25	0.97	6.19
1000	0.343	1.47	2.49	1.93	8.63
2000	0.1715	2.94	4.98	3.86	11.32
4000	0.0857	5.87	9.96	7.72	14.15
8000	0.0428	11.75	19.92	15.45	17.08

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