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Soundproofing performance evaluation of panels made of fibers of acrylonitrile butadiene styrene copolymer (ABS)

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Abstract

Industrial development and intensive mechanization of all production processes, multiplication and diversification of transport, development of traffic flows in urban and extra-urban areas, all lead to the increased noise in terms of intensity, frequency, duration of exposure to noise. In these circumstances, a global interest goes to the monitoring and analysis of the road traffic noise maps and to the noise and vibration sources. Thus, several European and national directives on the road traffic noise and beyond have been introduced, including guides and noise assessment methods. The paper aims to present the acoustic behavior of composite panels made from chips resulted in the milling process of acrylonitrile butadiene styrene (ABS), in terms of sound proofing performance in connection with the factors which affect the sound insulation of noise level. The panels with the sizes of 300x300x15 up to 20 mm were produced by hot pressing the ABS chips, at a temperature of 100 - 110 °C for 10 minutes. The link between chips was achieved by melting point of acrylonitrile. The experimental tests investigated: the influence of the distance between source and the noise barrier formed by the composite material made from ABS; the influence of the noise level emitted by the source; the influence of the distance between the sound barrier and the receptors placed collinear with the source; the influence of the position of receptors against the lateral ends of the barrier; the influence of the barrier angle relative to vertical plane of symmetry. The research highlighted the acoustic performance of composites made from ABS waste, innovative products, which can be considered an ecological, technological and economic solution in obtaining the core of acoustic barrier structures. Increased thickness of ABS fiberboard or combined with other absorbent material can lead to the increase of sound absorption coefficient and to obtain superior acoustic performances.

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Keywords: soundproofing; plates from acrylonitrile butadiene styrene chips; environment; noise level

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1. Introduction

The use of acoustic barriers between source and receptor is one of the most effective methods of reducing airborne noise from road and rail traffic. The noise barriers act as noise filters media with different acoustic properties depending on the level of noise produced by the sound source. The porous materials absorb high and medium frequencies. In the case of material resonator, the absorption occurs through the mechanism of resonance, and only certain frequencies are extracted from the sound field. Helmholtz-type structures consist of cavity full of pegboard panels filled with mineral fiber core, which are generally used as ceilings or double walls in concert halls. In order to increase the quality of the sandwich core, the expanded fillers with high strength and stiffness are used. Sandwich structures are based on two-phase systems consisting of rigid or elastic-plastic phase and gas. The properties of these materials depend on the properties of the polymer from which they are made. The literature emphasizes the advantages of sandwich composites for applications that require some criteria such as low density, high bending stiffness, high fault tolerance, vibration damping capacity and high sound absorption [1, 2]. Some studies focus on the acoustic performance of noise reduction devices with different configurations and design of the superstructure end (profile Y, T, U, flat, cylindrical, double shielded), including research on the combination of lightweight, absorbent and rigid-reflective of such structures [3, 4]. The various types of asphalt (porous or dense) in combination with noise barriers with a height of 2 m conducted to maximum acoustic performance in case of porous asphalt barrier, leading to a decrease in sound pressure level LA_{max} (dB) 12.4 dB (A). [5] studied the absorption properties of materials made from different sized rubber powder obtained by recycling used tires. In order to determine the acoustic characteristics, they used the impedance tube. They noted that the sound absorption coefficient was found to be up to 0.75, in the frequency band 100-5000 Hz, recommending that material to be used in the construction field for the sound barrier [5]. [6,7] studied the acoustic performance of composites made from vegetable particles or biomass. In previous research, the sound absorption coefficient of composite panels obtained from ABS chips was determined with acoustic tube and parameters of sound level were measured in open filed [9].

The aim of paper is to analyze the factors which have influence on the noise reduction capability of panels made from chips resulted in the milling process of ABS edge of furniture components. Processing of profiles or parts made from acrylonitrile butadiene styrene, known under commercially name – ABS, in the automotive industry (dashboards, buttons, columns, wing components, shock bar, door handles, seat backs, seat belts parts, spoilers, wheel guards, block lights (signaling), etc.), in the manufacture of electronics and electrics or in furniture manufacturing industry, lead to waste which can be recovered in new products, reducing the risk of increasing environmental pollution. Based on the mechanical properties of ABS (high toughness, good stiffness, a high surface hardness and a very good dimensional stability, good heat resistance, good acoustic properties), as well as considerable quantities of waste in the form of chips resulting from the milling edge/ABS profiles of the components of the furniture, the research conducted to identify a new direction to use ABS chips namely obtaining sound-absorbing panels with acoustic role in barrier structure and sound insulation panels of buildings.

Nomenclature

ABS	Acrylonitrile Butadiene Styrene
OSB	Oriented strand board
R	receptor
S	source
d_S	distance between noise source and acoustic panel [mm]
d_R	distance between acoustic panel and receptor [mm]
β	angle of acoustic panel related to vertical plane [°]
$L_{A\ max}$	sound pressure level [dB]
L	length [mm]
H	height [mm]
N	noise level emitted by source [dB(A)]

2. Materials and method

The chips of ABS were placed in a rectangular mold and pressed at a temperature of 100 - 110°C for 10 minutes, in order to obtain panels with dimensions of 300 mm x 300 mm and thickness h of 30±5 mm. Link between chips was achieved by melting point of acrylonitrile butadiene styrene, by creating physical links between the molecules. The density of the panels depends on the distance between the press plates. In order to test the new composite structure, an experimental stand shown in Fig. 1 was made consisting of a metal frame (1) with the option of turning the panel to the vertical plane in both directions, an oriented strand board (OSB) (2) as support and plates of soundproofing materials (3). Dimensions of tested sound barrier were as follows: length L= 6000 mm and height H=2000 mm. The experimental devices shown in Fig. 2 were used for the measurements. Noise generated by the Signal Generator B&K 2260 Investigator was amplified by the power amplifier and transmitted to omnidirectional power source S. The source emitted noise at a predetermined noise level (N1 = 100 dB(A) and then N2=103 dB(A)). Between source and receiver represented by Sound meter B&K2250 Light, which measures all parameters simultaneously, an acoustic barrier was placed. The acquired data were processed and visualized with the program Noise Explorer B&K 7815. The experiment was conducted in open field with fixed source. Apparent sound reduction index was calculated as the difference between the sound pressure level measured at the source and the sound pressure level measured at the point of reception [8,9].

Fig. 1. Acoustic barrier: (a) experimental stand; (b) composite plate made from ABS chips.

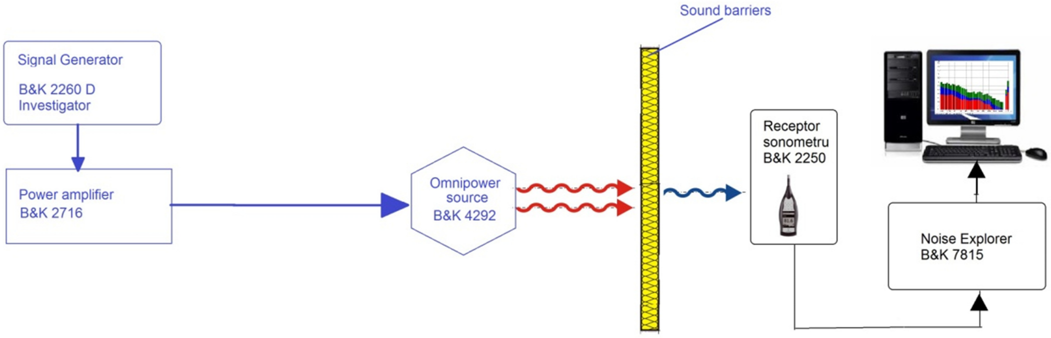


Fig. 2. Experimental set-up

The objective of the tests was to determine the level of soundproofing acoustic barrier obtained by the difference between the weighted sound pressure level emitted by the source (S) and receiver (R). The following investigations were performed: the influence of the distance between the source and the acoustic barrier made from ABS chips (d_{S1}=2000 mm; d_{S2} = 4000 mm); the influence of noise level emitted by the source (N_1=100 dB(A), N_2=103 dB(A)); the influence of the distance between the barrier and the receivers placed in a collinear position with the source (d_{R1}=2000 mm; d_{R2}=4000 mm; d_{R3}=6000 mm); the influence of the receptor position along the barrier and the influence of acoustic barrier angle relative to the vertical plane of symmetry (β = 0°; β=30°; β = -30°).

The first step after installing the experimental equipment was to measure the noise level from omnidirectional source N_i in three different points (P1, P2, P3) at a distance of 1000 mm from the source for 20 s (Fig. 3).

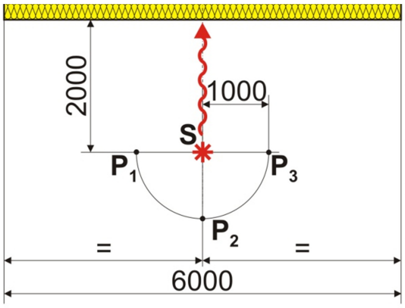


Fig. 3. Schematic disposal of measurement equipment

The measured background noise level was measured for 1 min 24 s, having a value of 48.92 dB(A). The next step was to record the noise in different cases of receiver position related to source and acoustic barrier. In order to extract and visualize the results, the Noise Explorer Type 7815 has been used. Fig. 4 presents the sound spectrum recorded for the farthest position of the sound-level meter (6000 mm).

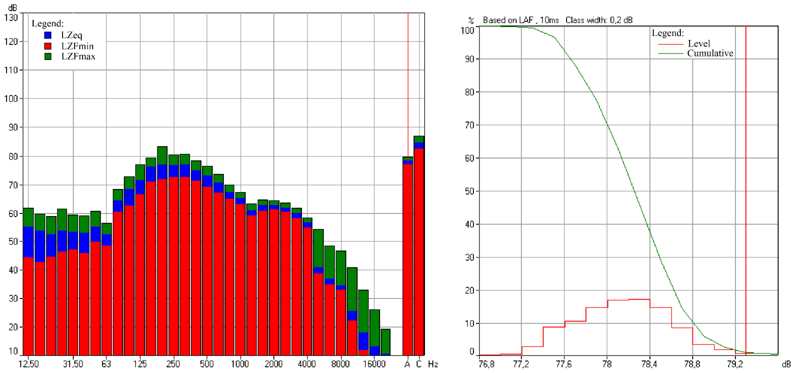


Fig. 4. Sound spectrum recorded at 6000mm distance (d_{R3}) between acoustic screen and receivers;

3. Results and discussion

3.1. Influence of the distance between the source - panel - receptor

The sound meter used to receive the noise level was successively placed at a distance of 2000, 4000 and 6000 mm perpendicular on the studied panel and the source was placed first at 2000 mm, than at 4000 mm (Fig. 5). It was found that the sound pressure level in the three measuring points is about 20...22 dB less than the amount emitted by the source (Fig. 6, a). With the increase of distance between the source and the acoustic barrier on one hand, and increasing of the distance between barrier and receptors, on the other hand, the noise reduction index increased, too.

In Fig. 6 (b) the variation of the noise reduction index with the increasing of noise level emitted by the source from 100.56 dB(A) to 103.67 dB(A) is presented, by maintaining the same position of the source and receiver. It was found that screening did not significantly reduce the noise. The large reduction in terms of noise reduction indices depended on the receptors position of acoustic barrier, and it was recorded in the vicinity of the screen (at a distance of 2000 mm) (Fig 6, b). The reduced noise in point R1 is explained by the acoustic shadow effect.

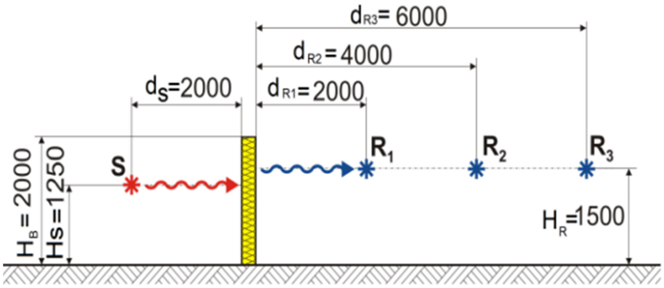
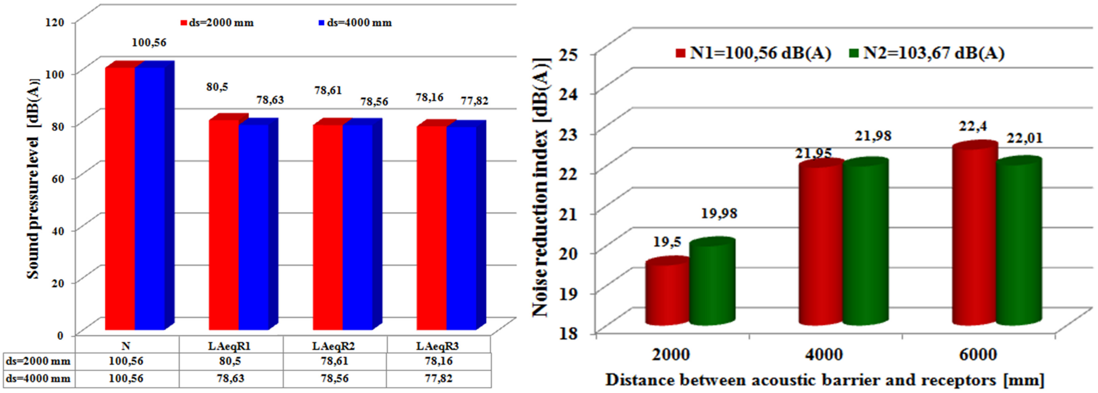


Fig. 5. Positioning of receivers - B&K 2250 sound-level meter;



a) b)

Fig. 6. (a) variation of sound pressure level according to the distance between the source and the sound barrier.first picture; (b) variation of noise reduction indices with increasing of noise emitted by the source.

3.2. *Influence of acoustic barrier angle from the vertical plane of symmetry (β=0°, β=+30°, β=-30°)*

In all the above experimental results, the sound acoustic panel in the vertically position was studied (Fig 7, b). As the test device allowed rotation of acoustic panel, sound pressure levels were measured in two cases of the inclination of the panel: the angles β=30° (Fig.7, a) and β=-30° against to the vertical plane (Fig.7, c). The noise emitted by the source was 103 dB(A), the distance between the source and the panel was of 2000 mm, and the position of the receivers from acoustical panel was the same as in the previous measurements.

Analyzing the sound pressure level measured at different distances in the three cases of the acoustic panel orientation, it was noticed that the vertical position of the panel and the sloped position to the receptors (-30°) are the most advantageous positions in terms of noise reduction. Looking at the variation chart of the noise reduction index it was noticed that the phenomenon of diffraction, which occurs at the upper edge of the acoustic panel when it was tilted, conducted to the increased sound attenuation with the increasing of the distance to the measuring point (Fig. 8). As a result to the sound barrier design, various shapes of the upper edge of the panel, elements or materials to potentiate the ability of diffraction of the sound waves might be provided, so to be inclined at a certain angle.

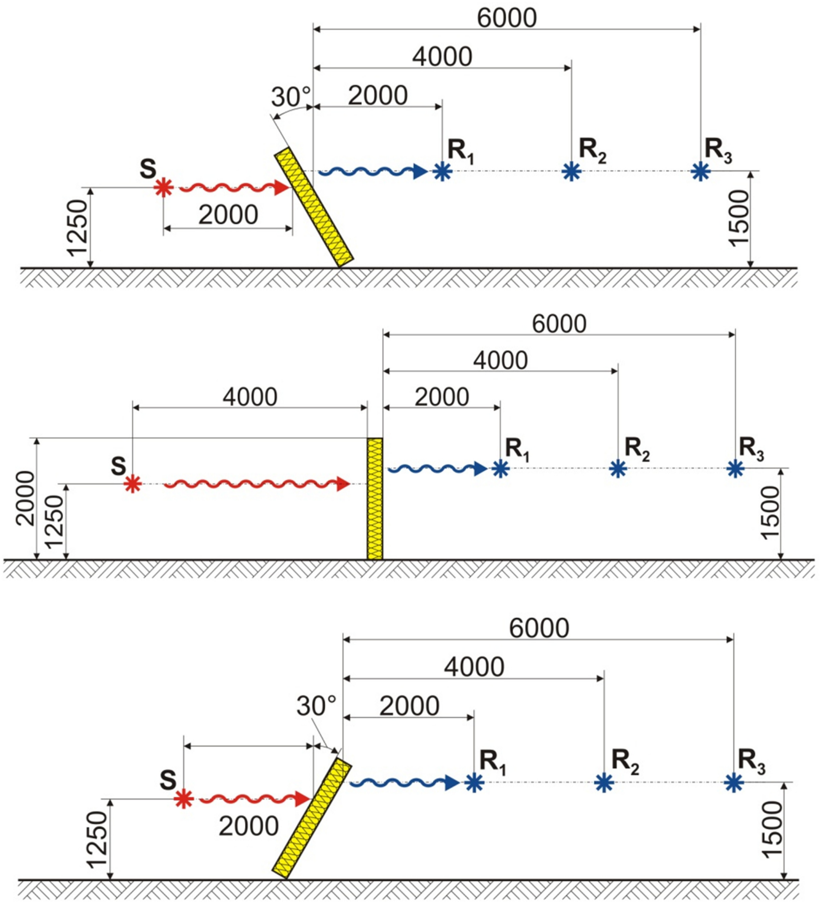


Fig. 7. Acoustic screen position when studying the influence of the rotation angle of the panel: (a) with angle β=+ 30°related to vertical position, (b) with angle β=0° - in vertical position; (c) with angle β=- 30°related to vertical position.

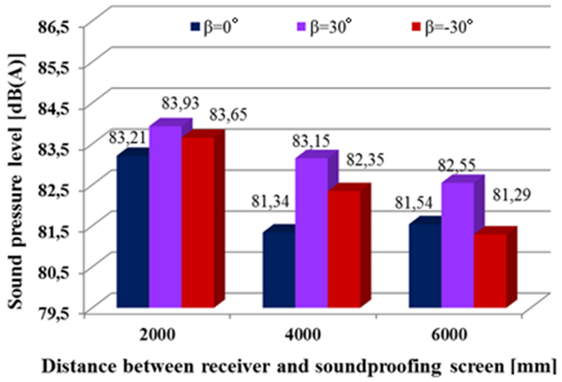


Fig. 8. Sound pressure level measurement at different distance from acoustic panel in three cases of panel position.

3.3. Influence of receptor disposal along the acoustic barrier

Another group of tests were performed in accordance with the distribution of receptor parallel to the acoustic panel. The distance between the receivers and acoustic panel was 1000 mm, and between the measurement points the distances shown in Fig. 9 (a) were established. The noise levels were measured on the third octave band, both in case of acoustic screen panel composed only of OSB and in case of ABS boards with addition of mineral wool layer. Absorption coefficients of more used natural and synthetic materials are presented in [10], mineral wool with 40 mm thickness having absorption coefficient of 0.7, for frequency of 500 Hz. The distribution map of the noise level measured along the acoustic panel is shown in Fig. 9 (b), in both cases of soundproofing materials.

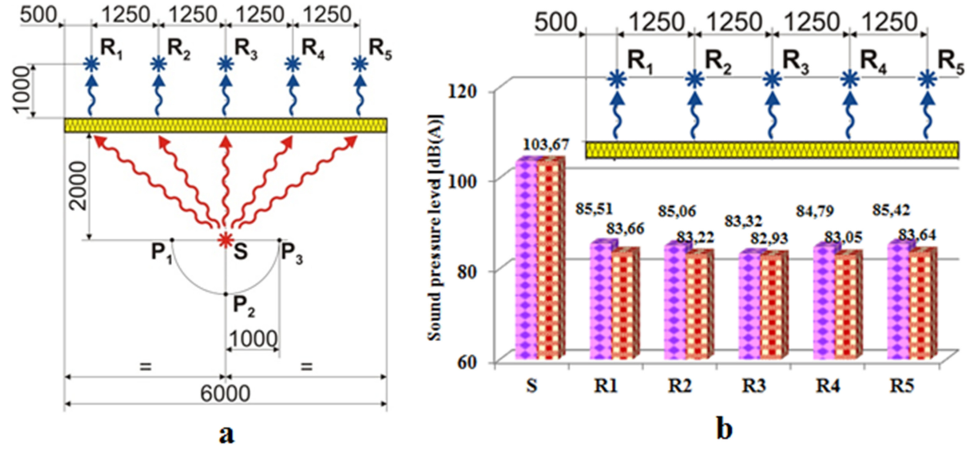


Fig. 9. (a) measurement points in the longitudinal direction to the plane of the panel; (b) variation of sound pressure level measured over the panel acoustic noise compared to the amount emitted by the source.

It is noticed that the addition of mineral wool lower the noise by approximately 1.5 dB. In conclusion, for efficient acoustic barriers and in order to obtain high absorption indices, it is recommended to combine materials with absorbing properties. In Fig. 10, there are compared the noise reduction indices in a longitudinal direction of the acoustic barrier. Reported to the longitudinal axis of the panel, the maximum values of sound reduction indices were recorded in the middle of the panel, the sound barrier being lower on the edges.

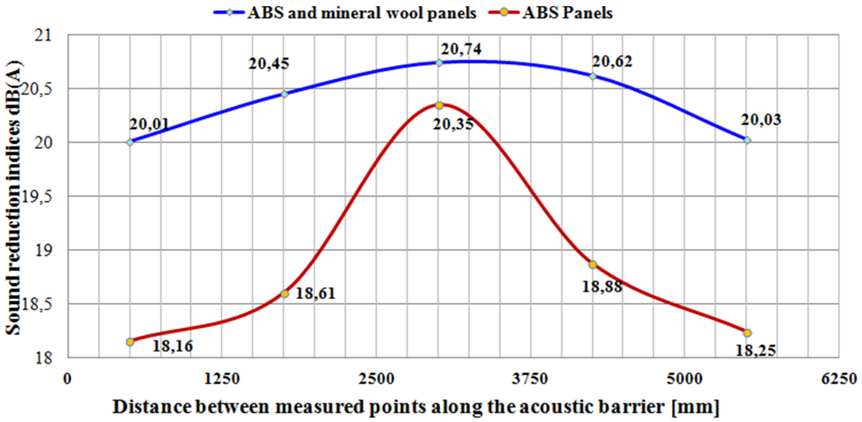


Fig. 10. Sound reduction index variation along the sound barriers

4. Conclusion

The experiments conducted on the experimental stand presented in the paper have shown that the panels made from acrylonitrile butadiene styrene residues have a good absorption, but the sound insulation capacity barriers as a whole is influenced by other factors: distance between source and receptor, receptor from the source position/barrier, angle of sound barrier against the vertical position. The combination with other materials correlated with a continuous geometric structure can lead to more effective sound insulation barrier. The present study revealed that the achievement of the noise barrier with ABS core depends on the height, thickness, shape, tilted position, place and the surroundings in which it will be located.

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