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ACOUSTIC ABSORPTION CHARACTERISTICS THAT ARE USED IN THE ACOUSTIC DESIGN OF INTERIORS - COMPARISONS BETWEEN SOME CLASSICAL MATERIALS AND NATURAL, ECOLOGICAL MATERIALS

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Abstract

In the case of the acoustic design of some rooms, such as audition rooms, classrooms for education, etc., the knowledge of the acoustic absorption characteristics of the materials/products that will be used for the interior surface finishes (walls, floors, ceilings) is of particular importance. Depending on the activity that takes place in the room, it is necessary to obtain a certain value of the reverberation time in order to achieve acoustic comfort. In many research projects, carried out in INCD URBAN-INCERC, INCERC Bucharest Branch, laboratory experiments were carried out on some types of classic materials (polyethylene, felt in plates of basaltic mineral wool) or natural, ecological materials (wool for use in construction, or wooden boards, etc.). The research ware carried out in the reverberation chamber in the Building Acoustics Laboratory. The results of the studies are presented in the article as acoustic absorption coefficient in the diffuse field, `$\alpha_s$`, in graphical forms of frequency range 100 to 5000 Hz and as the evaluation acoustic absorption coefficient `$\alpha_w$` and are compared considering the influence of the physical characteristics of the tested materials.

***Key words**: absorption coefficients, acoustics, civil buildings, reverberation.*

INTRODUCTION

Noise is defined as excessive or annoying sound that can harm human health and the environment. It involves irregular waves that are unpleasant, unwanted, and usually unavoidable, with no meaningful relationship between their amplitude, frequency, and length (Tajic & Ghadami, 2008; Jafari Malekabad et al., 2022). A growing problem in many urban areas, noise affects the physical and mental health of millions worldwide (Mihalache et al., 2023). Because its effects on the population are really worrying, environmental noise is one of the issues that is regulated by an increasingly legal framework, attracting more and more attention worldwide (Titu et al., 2022).

The control of noise in the work environment is crucial to the comfort and efficiency of the individual. Poor acoustic indoor environments have been shown (Kang et al., 2017; Glean et al., 2022) to negatively impact the cognitive performance and well-being of occupants, thus negatively affecting their productivity. The acoustic design of buildings is a field that ensures the acoustic comfort of people in buildings (Zaharia, 1999; Nowicka, 2020). The acoustic design of the rooms, such as audition rooms, classrooms for education, etc., must be done according to the activities carried out in those spaces, because each type of activity requires ensuring a certain reverberation time, so that that activity takes place in conditions of acoustic comfort for the users (C125, 2013; Zaharia & Delia, 2014; Zaharia, 2020). Reverberation noise is a component of noise in a room, resulting from the reflection of an acoustic wave from the surfaces bounding the room and from objects in it. Thus, it is the noise that is transmitted inside the room and directly affects the room.

Adjusting the reverberation time in a room is done by providing materials/products with sound-absorbing characteristics on the internal delimiting surfaces (walls, floors, ceilings) (C125, 2013; Zaharia, 1999; Scamoni et al., 2022; Hyung et al., 2015). Various techniques are utilized to control noise in industrial settings, one of this technique is noise absorption materials (Yang & Yu, 2011). To determine the sound absorption characteristics of materials/products that can be used for finishes the inside surfaces of a room, tests are necessary. In the present research, the laboratory tests were conducted on several types of classical materials (polyethylene, felt in plates of basalt mineral wool) or on natural, ecological materials (wool for building, wood panels). The laboratory experiments were carried out in the reverberation chamber of the Building Acoustics Laboratory at INCD -URBAN-INCERC institute (Zaharia et al., 2019; Vasile et al., 2019).

MATERIALS AND METHODS

In Romania, the C125, 2013 - "Normative regarding Acoustics in buildings and urban areas", provides information about the sound absorption coefficient, α_s, in the frequency range 125-4000 Hz, the evaluation sound absorption coefficient, α_w, the sound absorption classes according to α_w, and the form indicators L, M, H. In the same standard there are some stipulations for protection against reverberation in rooms with a high level of reverberation. There are also guidelines on the maximum acceptable reverberation time (Tm, s) of a room. This depends on the volume of the room, V(m^3), and the type of activity that takes place in the room. These are illustrated in Figure 1.

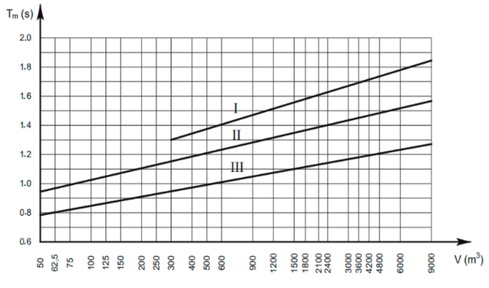

Figure 1. Admissible values of the average reverberation time, Tm, in rooms of different types of buildings:
I - rooms in industrial buildings;
II - dining rooms (in restaurants, etc.);
III - classrooms, amphitheatres, offices

Given that the reverberation time required in a room can be achieved by providing materials/products with specific sound-absorbing characteristics on the interior boundary surfaces, such materials have been investigated. Some materials/products are of the classical type: polyethylene, polyurethane foam, felt in basaltic mineral wool plates, melamine foam. Other materials considered are natural, environmentally friendly, sheep's wool for use in construction, or wooden boards, wood chip boards. A recycled product, uniquely designed within project PN 19 33 03 01, made exclusively from recyclable materials was also analyzed, namely - Plastic bottles (PET) - (wrapped rolls). In this article, nine materials produced by different manufacturers were analyzed. The description and photo of the selected materials/products is presented in Table 1.

The investigations consist of measurements to determine the absorption coefficient of different types of materials according to SR EN ISO 354 "Acoustics - Measurement of sound absorption in reverberation chamber" and SR EN ISO 11654 "Acoustics - Sound absorbers for use in buildings - Evaluation of sound absorption".

According to SR EN ISO 354, 2004, the measurement methodology consists of determining the reverberation times for the empty reverberation chamber, and the reverberation times for the reverberation chamber with the investigated sample. The calculation of sound absorption coefficients is performed according to the specific standards mentioned. The measurement of the reverberation time was carried out by the interrupted noise method, using a broadband signal, of the "pink noise" type.

The measurements were performed in 6 positions of the microphone, with the two acoustic sources located in 2 points. According to the measurement standard, the test specimen shall be made on an area of 10.00 sqm - 12.00 sqm and mounted, depending on the type of material/product, according to the specific mountings in the measurement standard.

The sample may be tested by placing it on one of the side walls of the reverberation chamber or on the floor of the reverberation chamber. The ratio between the sides of the sample shall be l / L = 0.75-1.0.

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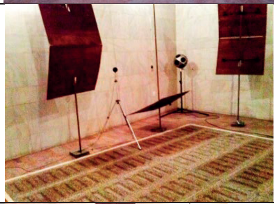
Table 1. Materials analysed description

No.	Type of material	Description of material and photo of the sample mounted in reverberation room	
1	felt in plates of basaltic mineral wool	Felt in plates of basaltic mineral wool with a thickness of 100 mm and apparent density of 40 kg/m^3 [7 - Test Report No.: 7/2006]	
2	polyethylene	Polyethylene plates with a thickness of 60 mm and apparent density 25 kg/m^3 (PREGIS) [1 - Test Report No.: 9/2009]	
3	polyurethane foam	Profiled polyurethane foam sheet N2244, pyramidal profile, white (960 mm x 960 mm x 65 mm) [5 - Test Report No.: 84/2016]	
4	polyurethane foam	Profiled polyurethane foam sheet RF2828, pyramidal profile, anthracite grey (960 mm x 960 mm x 60 mm) [8 - Test Report No.: 81/2016]	
5	polyurethane foam	ACOUSTICART decorative acoustic panels, lightweight, open-cell polyurethane foam, applied in two layers, with a thickness of 30 mm [2 - Test Report No.: 34/2015]	
6	melamine foam	Melamine Foam Plate Basotect G +, gray (615 mm x 615 mm x 60 mm) [4 - Test Report No.: 74/2016]	

No.	Type of material	Description of material and photo of the sample mounted in reverberation room	
7	sheep wool	Thermal insulating and sound-absorbing wool-based sheep wool, 50 mm thick and apparent density of 30 kg/m^3 [6 - Test Report No.: 58/2018]	
8	Panel of wood chips and mineral wool	DUNAPREF phonoabsorbent panel, 90 mm total thickness, made of: HERAKLITH panels laid on 40mm thick basalt mineral wool, with apparent density aprox.60 kg/m^3 [3 - Test Report No.: 26/2014]	
9	recycled materials made from PET plastic bottles (wrapped rolled)	Plastic bottles (PET), (rapped rolled), recyclable materials, with an aprox. thickness of 10 to 60 mm [9 - Test within the project no. PN 19 33 03 01]	

RESULTS AND DISCUSSIONS

Between 2006 and 2023, numerous acoustic measurements were carried out in the reverberation chamber for different types of materials and products. The nine selected materials/products are representative, and the measurement results are shown in Figures 2 to 10. These results are given as values of the evaluation sound absorption coefficient `$\alpha_W$`, and in graphical form in the frequency range from 100 to 5000 Hz for the diffuse field sound absorption coefficient, `$\alpha_S$`.

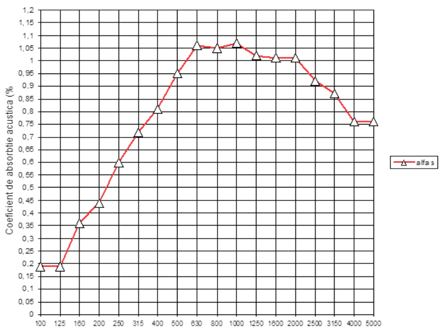


Figure 2. Acoustic results for felt in plates of basaltic mineral wool, α_w = 1.00 [7 - Test Report No.: 7/2006]

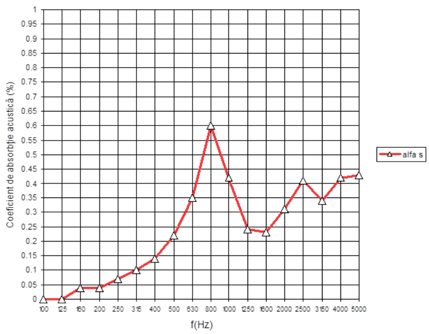


Figure 3. Acoustic results for Polyethylene, α_w = 0.30 [1 - Test Report No.: 9/2009]

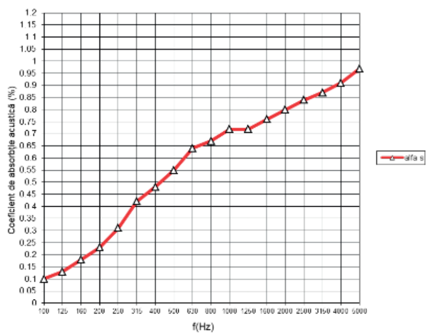


Figure 4. Acoustic results for polyurethane foam α_w = 0.55 (H) [5 - Test Report No.: 84/2016]

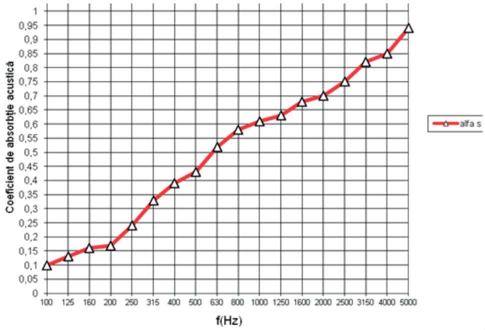


Figure 5. Acoustic results for polyurethane foam
α_w = 0.50 (H) [8 - Test Report No.: 81/2016]

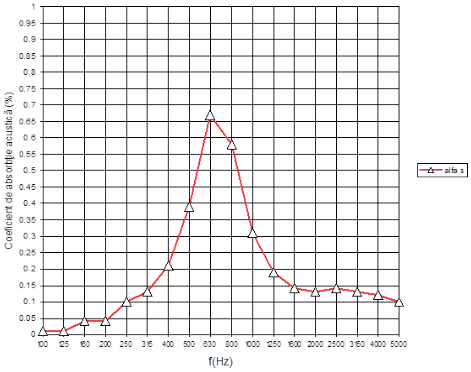


Figure 6. Acoustic results for polyurethane foam
α_w = 0.20 [2 - Test Report No.: 34/2015]

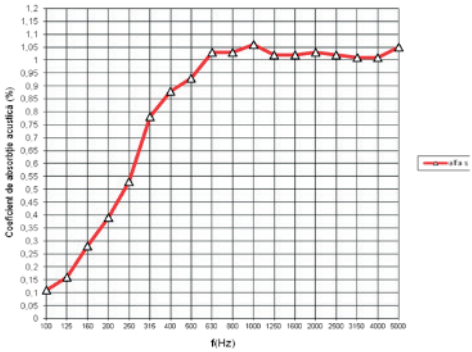


Figure 7. Acoustic results for melamine foam
α_w = 0.85 (H) [4 - Test Report No.: 74/2016]

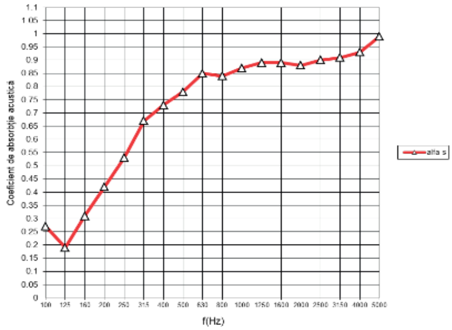


Figure 8. Acoustic results for sheep wool
α_w = 0.80 (H) [6 - Test Report No.: 58/2018]

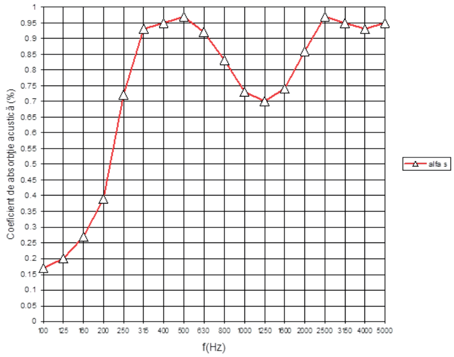


Figure 9. Acoustic results for panel of wood chips and mineral wool
α_w = 0.85 [3 - Test Report No.: 26/2014]

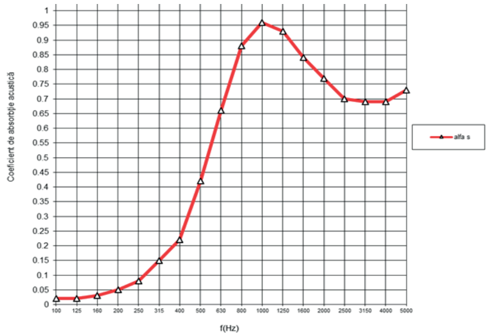


Figure 10. Acoustic results for recycled materials made from PET plastic bottles, α_w = 0.40 (M, H) [9 - Test within the project no. PN 19 33 03 01]

When we studied the results of the experiments, we compared the values obtained for the acoustic absorption coefficient considering the influence of the type of material from which they are made (Figure 11), the density of materials (Figure 12) and the geometrical materials characteristics (Figure 13). We compared the values of diffuse sound absorption coefficient, α_s, as graphs in the frequency range 100 to 5000 Hz, and the evaluation sound absorption coefficient, α_w.

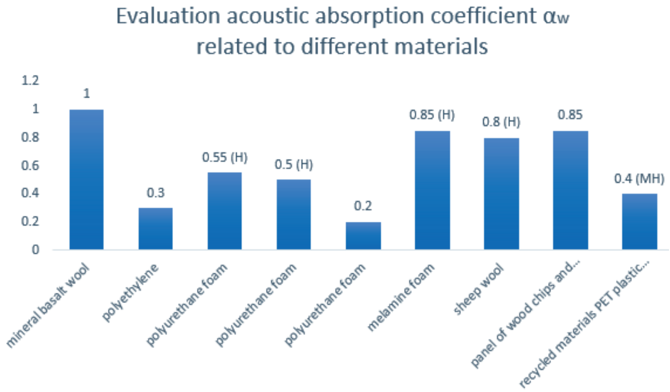


Figure 11. Types of material - acoustic absorption coefficient, relationship

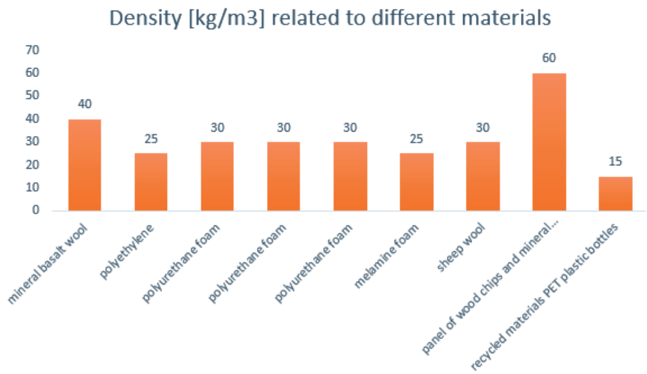


Figure 12. Types of material - density, relationship

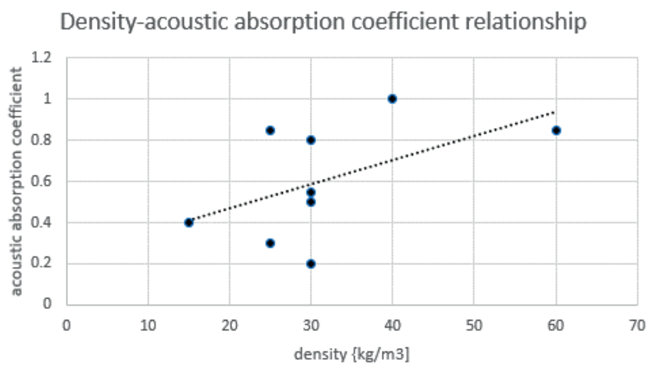


Figure 13. Density - acoustic absorption coefficient, relationship

CONCLUSIONS

The conclusions following from the analyzation of the phono-acoustical results presented above, are:

A) We analyzed materials that have an apparent density between 15 kg/m^3 and 40 kg/m^3, exception only for the Panel of wood chips which has a higher density, approx. 60 kg/m^3;

B) We analyzed materials that have the thickness between 30 mm to 100 mm;

C) In case of materials which have low density, around 30 kg/m^3, like rigid polyurethane foam and polyethylene, the acoustic absorption coefficient, α_s, in graph forms, have: a) very low values, around zero, in low frequency domain; b) a higher values, with a pick of 0,6..0,65, in the zone of frequency 630 Hz - 800 Hz, and c) low-medium values around 0.35 to 0.15, in the zone of frequency 1250 to 5000 Hz; and the coefficient α_w is between 0.2 to 0.30, depending on the type of thickness and the chemical configuration of the material structure;

D) In case of other materials which have low density, around 30 kg/m^3, like pyramidal profiled polyurethane foam, the acoustic absorption coefficient, α_s, in graph forms, have: a) very low values, around 0.15 to 0.25, in low frequency domain; b) a linear increase in values, in the medium and higher zone of frequency; and the coefficient α_w is 0.55(H), depending on the type of thickness and the profiled configuration of the material structure;

E) In case of materials with density around 30 to 60 kg/m^3, like felt in plates of basaltic mineral wool, wood chips and mineral wool, and sheep wool, which are almost natural materials, the acoustic absorption coefficient, α_s, in graph forms, have: a) low values, around 0.15 to 0.25, in low frequency domain, in the zone of frequency 100 Hz - 200 Hz; b) a higher values, around 0.7 to 1.00, in the zone of frequency 400 Hz - 4000 Hz - 5000 Hz; and the coefficient α_w is between 0.80-1.00 depending on the type of configuration of the natural material structure;

F) Melamine foam has the same very good acoustic absorption characteristics, with the coefficient α_w = 0.85 (H), because of the chemical configuration of the material structure, which is soft and smooth.

G) From the analysis of the results obtained for the acoustic measurements performed on the unique sample, made of Plastic Bottles (PET) (rapped rolled), with an approx. thickness of 10 to 60 mm, - respectively from recyclable materials that could be used in different types of rooms with large construction volumes -, tested in the reverberation chamber by the team of researchers, it can be concluded that, from the point of view of the sound-absorbing characteristics of this type of product made of recyclable materials, even if it has a very low density (around 15 kg/m^3), because of the configuration of the spatial pyramidal surface and the geometric interior air cavities of the bottles, it proves to be a very good sound-absorbing material for sounds at medium and high frequencies, with very good performances, comparable to those of some modern materials/products (melamine, etc.) that can be used to adjust the reverberation duration in rooms with specific acoustic requirements, especially for medium and high frequencies.

H) From the statistical analysis that correlates the density of the materials with the acoustic absorption coefficient, combined with the two previous analyses, regarding the type of material, the acoustic absorption coefficient, and the density, it can also be concluded that a particular importance, for obtaining a good absorption of a product, it also has the geometric and texture configuration of the finished part of the product surfaces.

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- PN 19 33 03 01, "Research to achieve the acoustic and thermal comfort inside the buildings, using an innovative tool for choosing

the optimum structures of construction elements, from classical versus modern materials".
- PN 09-14.04.07, "Methods to combat urban noise. Analysis and multi-criteria solution of the acoustics of buildings and living areas in urban and rural areas exposed to noise".

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Test reports of Building Acoustic laboratory of INCD URBAN-INCERC, INCERC Bucharest Branch:

1 Test Report No.: 9/2009;
2 Test Report No.: 34/2015;
3 Test Report No.: 26/2014;
4 Test Report No.: 74/2016;
5 Test Report No.: 84/2016;
6 Test Report No.: 58/2018;
7 Test Report No.: 7/2006;
8 Test Report No.: 81/2016;
9 Test within the project PN 19 33 03 01.