Iranian Society of Acoustics and Vibration
The 14th ISAV2024 International Conference on Acoustics and Vibration
11-12 Dec 2024 Karaj - Iran
Kharazmi University

Investigation of Transmission Loss and Absorption coefficient of the PU Composite Panels for Construction Application

Mina Teymouri[a], Zahra Pourakbar[a*]

[a] *Department of Research and Development, Ayegh Khodro Toos (AKT) Co. of Part Lastic Industry Group, P.O. Box 91851-77209 Mashhad, I.R. IRAN*

* *Corresponding author e-mail: Zpourakbar@aktcom.com*

Abstract

This paper presents the experimental work of a passive polyurethane composite panel for the cancelling of sound. The use of an impedance tube to determine transmission loss and absorption coefficient of panels was undertaken and compared with measured field evaluated from the reverberation room method. These panels with different thicknesses have been investigated. Acoustic results were promising, showing absorption coefficients that, were generally higher than 0.5 from 500 Hz on, and higher than 0.6 from 1 kHz on. Also, the Noise Reduction Coefficient of the samples varies in 0.23–0.42 range, depending on the layer thickness, that makes them a good option for insulating application of buildings.

Keywords: Sound insulation; impedance tube; passive wall systems; Interior noise.

1. Introduction

Sound is the vibrations that travel through the air or other medium and can be heard when they reach a person's or animal's ear. With daily increasing of the number of vehicles and industrial evolution, the sound pollution problem is becoming more important. This kind of pollution may be extremely harmful for the human health and can lead to depression, tinnitus and sleep disorders. So, controlling the specifications of the sound transmitted to the human being is of primary importance[1].

A significant amount of research has been performed to develop control technologies for suppressing the interior noise of the buildings. The advances have come about thanks to the competitive market and increasing customer demand as well as an awareness for improved comfort environments [2-4].

Walls are the outermost part of the envelope that make up the largest component in a building. Walls can be defined as 'prevalent fragments of a building envelope which are expected to provide thermal and acoustic comfort for occupants without compromising the aesthetics of building' [5-8].

The quality of the indoor environment is an issue of fundamental importance for the health and the well-being of the buildings' occupants. It is no coincidence Noise levels having a severe impact on the health of the buildings' occupants, acoustic comfort should be an indispensable part of any study. As a result, the sound insulation capacity of the building elements that enclose spaces with specific indoor noise level requirements is a feature of great significance.

The assessment of acoustic comfort in indoor spaces involves the consideration of several parameters such as reverberation times and indoor noise levels, with the sound insulation capacity of the building elements enclosing them holding a determining role [9].

An acoustically suitable material may be considered to be one which has significant properties of absorbency or reflectivity. Sound is best absorbed by voluminous, soft, and porous materials. Conversely, sound energy is mainly reflected by hard materials with a smooth surface that cannot oscillate [3].

Passive cancellation techniques aim to develop simple and lightweight solutions to attenuate sound transmission [10].

Reverberation time, as one of the most important acoustic parameters inside rooms, has a significant effect on sound quality [11, 12]. In this research, firstly, by using methods based on geometrical acoustics, the collection of required data sets at frequencies of 500 and 2000 Hz is done.

The objective of the current research is to investigate new polymer composites with optimal acoustic properties. To do so, the polyurethane foam is employed as the based polymer and other materials are used as extra ingredients.

The aim of the research is to characterize the sound absorbing and transmission loss behaviour of the innovative tested panel **AKTPAD450001**. This panel is produced in Ayegh Khodro Toos (AKT) company and is approved by Housing & Urban Development Research Centre.

Based on Insulation and sound regulation - Topic 18 of Iran's building regulations, averaged sound reduction index for Separating walls in housing, educational and hotel buildings, averaged sound reduction index (R_w) must be equal or more than 50 dB [15]. The R_w for Panel AKTPAD450001 was 50 dB, that makes it suitable for insulating application of buildings.

This research has specific purposes as follows:

a. Determining the acoustic characteristic of sound absorption of the panels as the effect of thickness.

b. Determining the acoustic characteristic of sound absorption of the panels with different methods.

2. Materials, Experimental facility and methodology

2.1 Materials Physical Properties

Two kinds of panels were investigated, composed by polyurethane foam, glass fibres and other acoustic materials, joined by glue, with a total thickness of 20 mm and 30 mm respectively. Density of the samples were 275 kg/m^3.

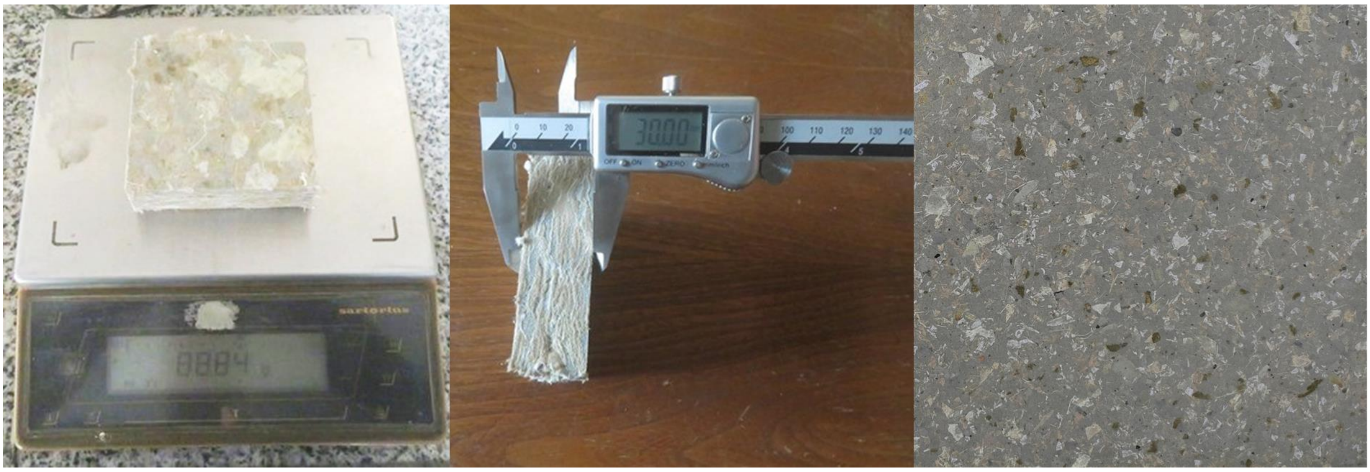

Figure 1 Thickness and weight of panel sample

2.2 Methodology

The most common parameter to characterize acoustic properties of materials is the absorption coefficient. There are two techniques to experimentally determine the absorption coefficient: the reverberant room method usually following ISO 354:2003 and the impedance tube transfer function method which follows ISO 10534-2:1998. In the first case (see Figure 1a) the absorption coefficient is determined in random incident sound field conditions inside a test chamber while in the impedance tube (see Figure 1b) only a direct incident field is considered. The results obtained from these two methods are identical only if the acoustic material is acoustically isotropic which condition is not satisfied in the case of porous acoustic materials[13].

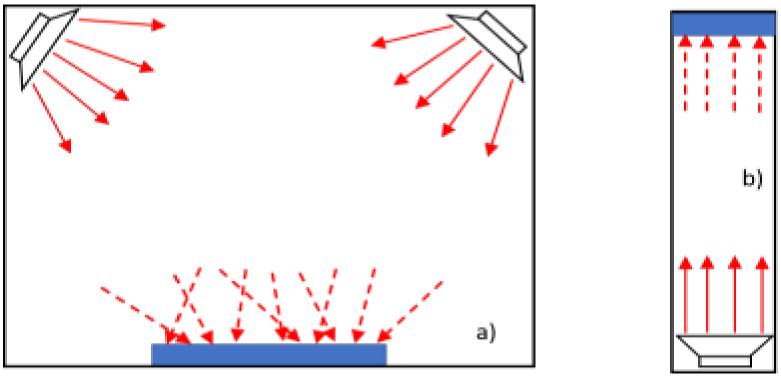

Figure 2 The techniques to experimentally determine the absorption coefficient, a) the reverberant room method, b) the impedance tube method

The main advantage of the impedance tube method is the requirement of only a small test specimen size, equal to the tube cross-section area, usually few square centimetres. The measurable frequency range is determined by the inner diameter of the tube, setting the upper limit by the cut-on frequency of the higher-order modes. Typical measurement frequency range for impedance tube method is 100- 8000 Hz. The standard reverberation room method demanding a minimum specimen size of $10m^2$. The method is suitable for a frequency range from 100 to 5000 Hz. In this paper the absorption coefficient of the acoustic materials is determined in reverberation room and in some cases the results obtained from impedance tube method for comparison are presented.

2.2.1 Reverberation room method

In reverberation room method the averaged sound reduction index is measured inside the room with and without the test specimen fitted into: determining R1 and R2 accordingly. From the difference between the reverberation times an equivalent sound absorption area of the test specimen is calculated and the sound absorption coefficient is obtained by dividing the equivalent sound absorption area by the absorbing area S of the test specimen. The experimental investigation was carried out at Reverberation Room Acoustic Lab, in Road Housing & Urban Development Research Centre, see Figure 3.
The experimental procedure was based on ISO 354, which provides instructions for absorption coefficient evaluations. Reverberation time of the room both with and without the sample (12 panels placed in the centre of the room, covering a total area of 12 m²) were measured.

Figure 3 Reverberation Room Acoustic Lab

2.2.2 Acoustic Measurements: Impedance Tube

According to ISO 10534-2:1998, sound absorption measurements were performed by the transfer function method. Two tubes with different diameters (10 and 3 cm BSWA SW series SW422 and SW477 in Fig.4) and thickness of 20 and 30 mm were used for the test with the aim to consider the largest spectrum range. The tube with an internal diameter of 10 cm had a maximum measurable frequency of 2 kHz and it used two different microphone distances. The emitting end consisted of an 11 cm loudspeaker sealed into a wooden case and suitably isolated from the tube structure by an elastic and protective layer. The second tube, with a diameter of 3 cm, was the same used for the flow resistance measurement. In this case the microphone spacing was 3 cm, and the frequency covered a range between 200 and 6 kHz.

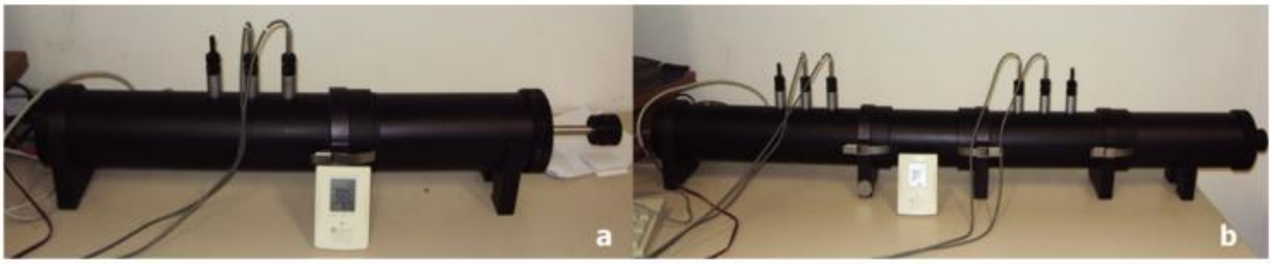

Figure 4 Impedance tube configuration for the absorption coefficient (a) and the transmission loss (b) measurement.

3. Results and discussions

3.1 Acoustic Properties: Reverberation room

The curves in the Fig. 5 graphic shows a comparison between the sound reduction index (R) in function of frequency obtained in trials with the empty reverberation room and then filled with the panels. It is possible to note that the presence of the panels caused a reduction in the measured reverberation index over the entire analysed frequency band. This behaviour shows that the sound absorption of the samples increased successively.

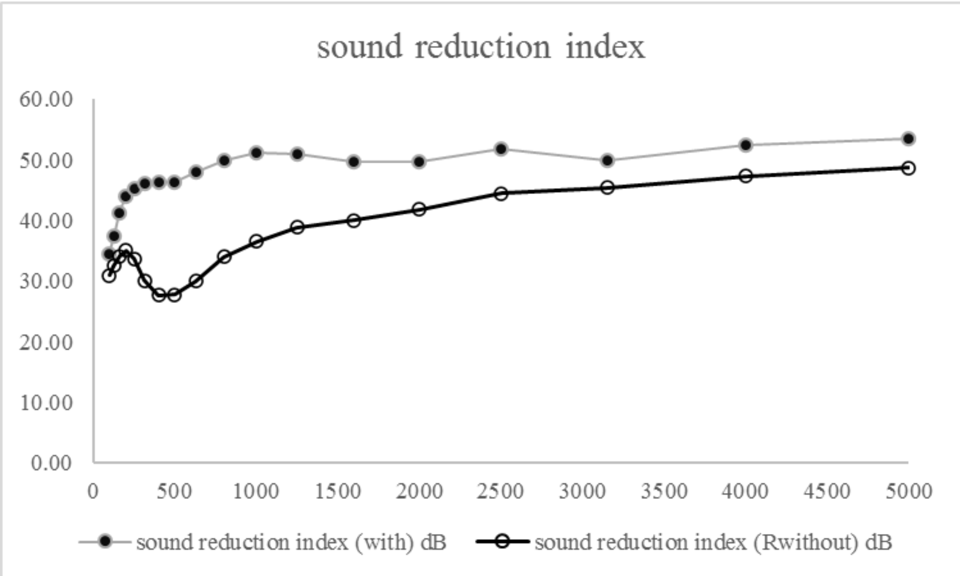

Figure 5 Sound reduction index for room with and without panels

According to this study and analysis, that can conclude that the sound absorption coefficient (α) (Fig. 6) is bigger than 0.3 (except 100 H) for all specimen which means that the sound absorption is categorized as excellent, since good material for sound absorption at least α=0.3 [14].

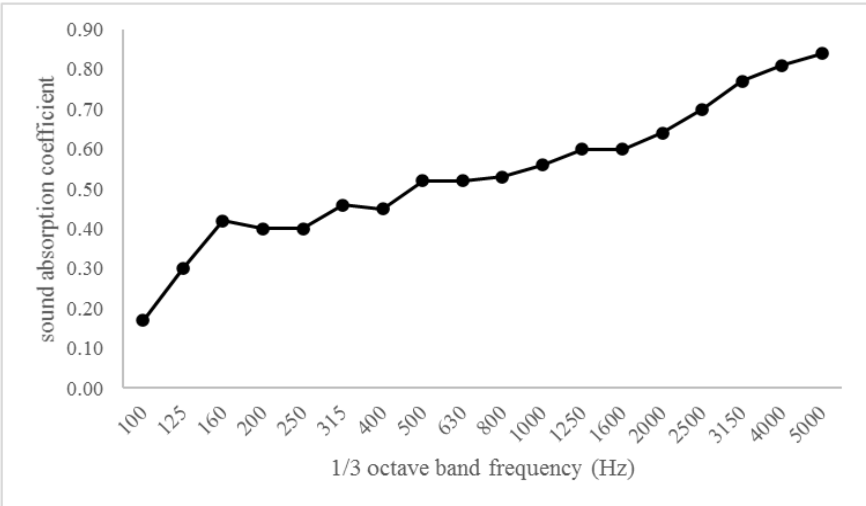

Figure 6 sound absorption coefficient

The R_w for Panel AKTPAD450001 was 50 dB.

3.2 Acoustic Properties: Impedance Tube

The measurement process entails mounting the sample in the tube and calibrating all the microphones used. The position of the sample in the tube is recorded by the VA-lab4 software by inputting the values of distance between the phase matched microphones upstream of the sample (s1), the distance from the sample face to the closest upstream microphone (d1), the distance from the sample face to the first microphone downstream of the sample, (d2), the distance between the phase matched microphones downstream of the sample (s2) and the sample thickness (d). These values inform the software of the exact position of the sample with respect to each microphone. The Transmission Loss of the material (TL) and absorption coefficient for different thicknesses of panel are calculated by the software and presented in a graph form as shown in Figure 7 and 8.

The Transmission Loss trend for 20 and 30 mm is showed in Fig. 7. Both the specimens have the same trend of TL with some drops at the frequencies of 650, 1000, and 2620 Hz. Altogether the Transmission Loss of 20 mm is lower than the 30 mm because of the different thickness of the panels.

The Noise Reduction Coefficient (NRC – the arithmetic value of the absorption coefficient at the frequencies 250, 500, 1000 and 2000 Hz) of the samples varies in 0.23–0.42 range, depending on the layer.

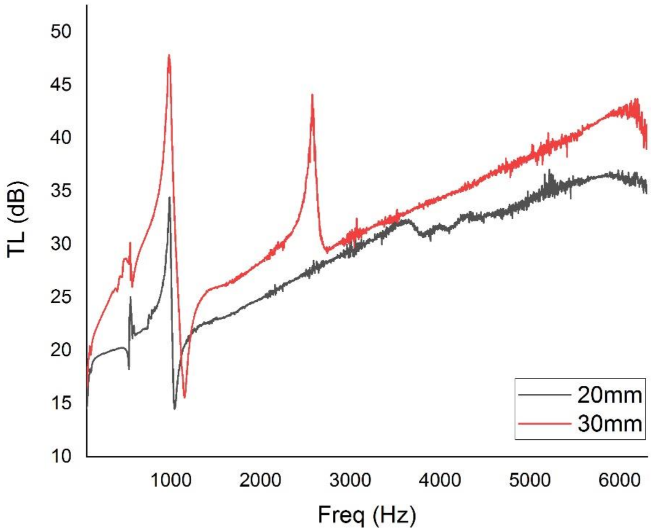

Figure 7 Transmission loss in different thicknesses

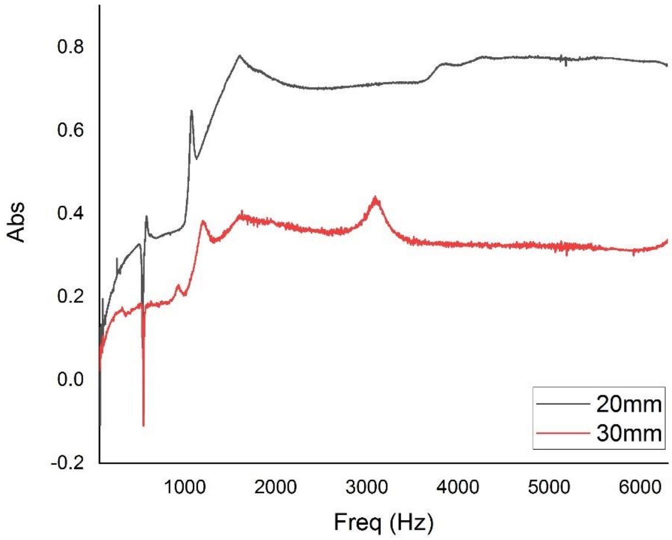

Figure 8 Absorption coefficient in different thicknesses

4. Conclusion

In this paper the acoustic properties for AKTPAD450001 panel with different thicknesses are investigated. The absorption coefficient is determined. The absorption coefficient has been measured by implementing two standard techniques in comparison: the impedance tube method and the reverberation room method. Generally, it has been demonstrated that AKTPAD450001 is effective in both absorption and transmission loss, and can offer a replacement for synthetic foams and fibrous materials.

The general design principles of acoustic materials in order to achieve noise attenuation potential can be listed as follows:

• the best results in TL exhibit 30 mm thickness

• the best results in AB exhibit 20 mm thickness

• the thickness of the material should be large enough to offer reasonable attenuation at lower frequencies

REFERENCES

1. Nourmohammadi, M., et al., *Development of optimal polymeric foams with superior sound absorption and transmission loss.* Journal of Applied Polymer Science, 2022. **139**(28): p. e52507.
2. Pietrzko, S.J. and Q. Mao, *New results in active and passive control of sound transmission through double wall structures.* Aerospace science and technology, 2008. **12**(1): p. 42-53.
3. Badida, M., et al., *Analysis and research on the use of bulk recycled materials for sound insulation applications.* Sustainability, 2022. **14**(18): p. 11539.

4. Moretti, E., E. Belloni, and F. Agosti, *Innovative mineral fiber insulation panels for buildings: Thermal and acoustic characterization.* Applied Energy, 2016. **169**: p. 421-432.
5. Omrany, H., et al., *Application of passive wall systems for improving the energy efficiency in buildings: A comprehensive review.* Renewable and sustainable energy reviews, 2016. **62**: p. 1252-1269.
6. Asdrubali, F., et al., *Experimental and numerical characterization of innovative cardboard based panels: Thermal and acoustic performance analysis and life cycle assessment.* Building and Environment, 2016. **95**: p. 145-159.
7. Peng, L., et al. *Thermodynamic and acoustic behaviors of prefabricated composite wall panel*. in *Structures*. 2020. Elsevier.
8. Van Renterghem, T., *Improving the noise reduction by green roofs due to solar panels and substrate shaping.* Building Acoustics, 2018. **25**(3): p. 219-232.
9. Tsirigoti, D., C. Giarma, and K. Tsikaloudaki, *Indoor acoustic comfort provided by an innovative preconstructed wall module: Sound insulation performance analysis.* Sustainability, 2020. **12**(20): p. 8666.
10. Lu, P. and G. Hawkins. *A Passive Sound Cancelling Material using Lightweight Embedded Machines*. in *48th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference*. 2007.
11. Shafieian, M. and S. Nouri Zehab, *Investigating the performance of machine learning-based methods in classroom reverberation time estimation using neural networks (Research Article).* Journal of Acoustical Society of Iran, 2022. **10**(1): p. 54-66.
12. Hussein, T.M.E.-B., *Calibration and uncertainty estimation for the reference sound source in reverberation room.* Romanian Journal of Acoustics and Vibration, 2020. **17**(2): p. 118-127.
13. Lavrentjev, J. *Green eco-friendly acoustic materials*. in *IOP Conference Series: Materials Science and Engineering*. 2021. IOP Publishing.
14. Suardana, N., I. Sugita, and I. Wardana, *Hybrid acoustic panel: The effect of fiber volume fraction and panel thickness.* Materials Physics and Mechanics, 2020. **44**(1): p. 77-82.
15. مبحث 18 مقررات ملی ساختمان عایق بندی و تنظیم صدا