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Corrugated veneer joinery and construction material and its sound insulation properties

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Abstract. The article presents a new joinery and construction material made of corrugated veneer. The material under consideration can be used to create lightweight internal enclosing structures of residential premises (interior partitions) and for interior decoration. Within the framework of this study, the tasks related to the determination of sound insulation properties and characteristics of a new joinery and building material and the search for ways to improve its design are considered. The analysis of the regulatory requirements for interior partitions of residential premises and the requirements of standards for the experimental determination of the degree of isolation of air noise by enclosing structures in field conditions is carried out. Methods for determining the sound insulation properties and characteristics of various materials and structures, as well as equipment used for research, have been studied. An experimental installation has been developed to evaluate the effectiveness of insulation from air noise of samples of the proposed joinery and construction material. Samples of the material necessary for the experiment were made, and an experiment plan was drawn up. It has been established that the highest efficiency of isolation from air noise is achieved in the high frequency range from 4800 dB and above. In the area of low and medium frequencies, the sound insulation of the material under study is not effective enough, which requires the use of additional sound insulation layers. The assessment of ways to improve carpentry and construction material to improve its sound insulation properties in the low and medium frequencies has been carried out.

1 Introduction

Currently, environmentally friendly natural building materials and products are in demand in the construction materials market. One of the sources of such materials and products is wood [1, 2]. Worldwide, interest in the use of natural and environmentally friendly materials, including wood [3, 4], is observed not only in terms of their structural and thermal insulation capabilities, but also in terms of their use as noise and sound insulation [5, 6, 7, 8].

Petrozavodsk State University has developed a new carpentry and construction material made of corrugated veneer. The proposed material can be used to create lightweight

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internal enclosing structures of residential premises (interior partitions) and for interior decoration [9, 10]. The material is a panel, the inner layer of which consists of several sheets of corrugated veneer with a cross arrangement of corrugations. The outer layers of the panel may consist of one or more veneer sheets. If the outer layer consists of several layers of veneer, then the direction of the wood fibers in adjacent layers is mutually perpendicular. The panel has "spike-groove" type elements for connecting adjacent panels to each other (Figure 1).

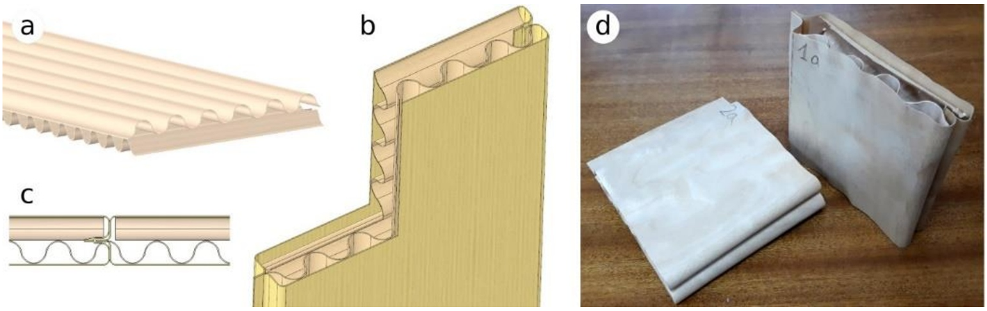

Fig. 1. Corrugated wood veneer panel: a – corrugated veneer; b – 3D model; c – panel connection; d – prototypes (picture and photo by the authors).

Providing a comfortable microclimate in residential premises by construction methods is one of the main tasks of architectural and construction design. It is known that a high pace of life and high psycho-emotional stress negatively affect a modern person. Noise, hum or music distract, irritate and prevent from resting or falling asleep, which contributes to increased stress levels. Thus, the comfort of the living space environment is largely ensured by the acoustic climate. The acoustic climate in a room is largely determined by the ability of enclosing structures to prevent the spread of air and shock noise from a noisier room to a less noisy one, as well as the ability to absorb sounds.

There are many requirements for interior partitions of residential premises, as for internal enclosing structures, among which are good sound insulation, sufficient strength, as well as certain thermal protection characteristics. According to the Russian regulatory document SP 51.13330.2011 "Noise protection", partitions without doors between rooms, between the kitchen and the room in the apartment must provide an air noise isolation index of at least 43 dB. Sound waves with frequencies from 100 to 3000 Hz are recommended for isolation from air noise, as they are the most susceptible to the human body. The task of isolation from shock noise is mainly relevant for interstory overlaps.

Thus, for interior partitions of low-rise buildings, the most important requirement is protection from air noise. To test the sound insulation properties of the proposed corrugated board, it was necessary to conduct experiments to determine the sound insulation characteristics of the prototypes. The purpose of this work is to evaluate the sound insulation properties of the corrugated cardboard panel from air noise.

The frequency of the sound wave has a decisive influence on the effectiveness of sound absorption by the building material of air noise. The material can absorb sounds of one frequency well and another frequency poorly. Therefore, the sound-absorbing properties for the material are determined at different values of sound frequencies. Currently, building materials from the sound absorption point of view are divided into the following groups:

– Medium-high-frequency absorbers (porous materials in the form of plates, fibrous materials with an absorption coefficient in the range of 0.4...1.0);

– Low–frequency absorbers (perforated materials, resonant structures with an absorption coefficient in the range of 0.3...1.0);

- Broadband absorbers (multilayer composite structures).

The study of the proposed material sound insulation properties required the creation of an appropriate experimental installation. Methods and tools analysis for evaluating the building materials sound insulation properties has shown that the methods and experimental and laboratory installations designs differ markedly.

An impedance pipe (Kundt pipe) method is known, which allows measuring material sound insulation properties using compact installations in the pipe form with two volumes. This method does not involve volumetric reverberation chambers use, in comparison with traditional measurement methods. When using an impedance tube the frequency range for determining the sound absorption coefficient is 250-5000 Hz. It is limited in the high-frequency part due to impedance pipe fixed diameter and the uncertainty associated with obtaining small phase differences at low frequencies [11]. For example, at KSU University (Turkey), an experimental installation is used to study the laminated wood composite boards sound insulation properties at low, medium and high frequencies, the design of which is based on the impedance pipe method [12, 13], and the measurement method meets the ASTM E 2611 standard “Standard test method for normal incidence determination of porous material acoustical properties based on the transfer matrix method” (standard of the American Society for Testing and Materials).

The study [14] shows the expediency of using wood as a noise absorbing material. The technology of obtaining a highly porous wood structure by removing lignin and hemicellulose, characterized by a noise reduction coefficient of 0.37 in the frequency range of 250-3000 Hz with a sample thickness of 10 mm, is described. The paper [12] presents the study results of composite wood materials made on the basis of veneer with a thickness of 2.1 mm, using PVA glue and laminated with natural rubber, linoleum, felt, elastomeric sponge of the same thickness of 5 mm. The samples were given a different shape of the outer surface. The study was conducted at low (63-250 Hz), medium (315-1600 Hz), and high (2000-6300 Hz) frequencies. During the study, the test samples were placed in an impedance tube. In this paper, the authors provide sound transmission losses graphs for all tested samples in various frequency ranges. The work [15] is devoted to wood slab materials made of spruce wood analysis. The studies were conducted in the frequency range of 50-5000 Hz. Among the conclusions, the authors note that adhesives in wood building materials, filling the pores of wood, stiffen these materials, but at the same time reduce sound insulation effectiveness. Minimizing the adhesives amount allows to leave more pores of wood open and thereby improve its sound-absorbing properties.

2 Materials and Methods

To establish quantitative indicators of corrugated wood veneer panel sound insulation properties from air noise, an experimental installation was made (Figure 2). The developed installation is a closed chamber in the form of a box with a sound source placed inside and window on one of the walls to accommodate the test sample.

Chamber walls are lined with soundproof material. The installation used a broadband dynamic head p4duc-14 (5 W, 4 ohms) as a sound source, which was connected to an audio frequency amplifier based on the TDA2003 chip. During the experiment, an audio signal of different frequencies from 75 to 9600 Hz was applied to the amplifier. To measure sound volume, a multifunctional device CEM DT-8820 was used, the condenser microphone of which was located opposite the box window in the immediate vicinity of the test sample. When measuring the noise level, a type "A" weighting filter was used, this is recommended for measuring noise levels in workplaces and residential areas. Device measuring range was set to a sub-range of 35-100 dB. During the experiment, the gaps between the chamber opening and the experimental samples with a thickness of 18 mm were filled with a sound-insulating material, which was used as foam rubber.

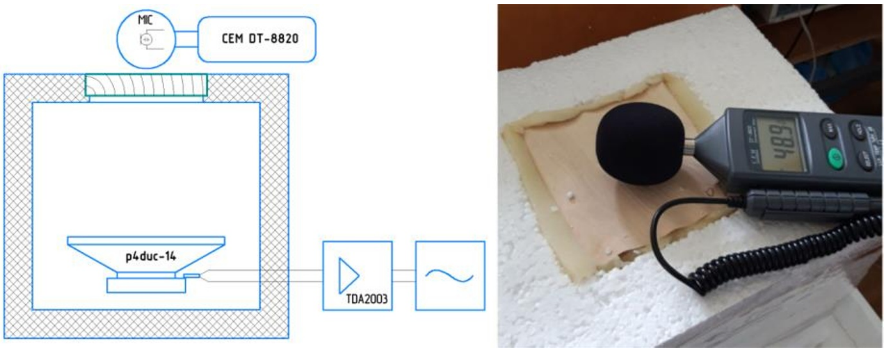

Fig. 2. Experiment box and measurement process (picture and photo by the authors).

During the experiments, measurements were carried out on samples made with both one and two layers of corrugated veneer. With the help of a sound wave generator, noise was created at a certain frequency, which was amplified by an amplifier and reproduced by a broadband dynamic head. The CEM DT-8820 device recorded the noise level, both with an empty window of the experimental installation and when installed in the window of the tested samples. 5 measurements were made for each combination of factors, then they were averaged.

3 Results and Discussion

Experiments results on noise level measurements and difference in sound pressure levels calculations are presented in Table 1 and Figures 3 and 4.

Table 1. Average sound level values at different frequencies, dB

The material in installation opening (window)	**Sound frequency, Hz**							
	75	**150**	**300**	**600**	**1200**	**2400**	**4800**	**9600**
	Sound level, dB							
An empty window opening	60,4	81,1	83,6	83,8	82,9	85,9	91,1	98,5
The corrugated veneer panel	48,2	77,9	73	75	75,5	67,8	69,2	26,5
The corrugated veneer panel (double)	44,4	72,7	70,6	74,7	70,3	62,7	43,5	26
	The reduced difference in sound pressure levels Dn, dB							
The corrugated veneer panel	7,4	-	5,8	4,0	2,6	13,3	17,1	67,2
The corrugated veneer panel (double)	11,2	3,6	8,2	4,3	7,8	18,4	42,8	67,7

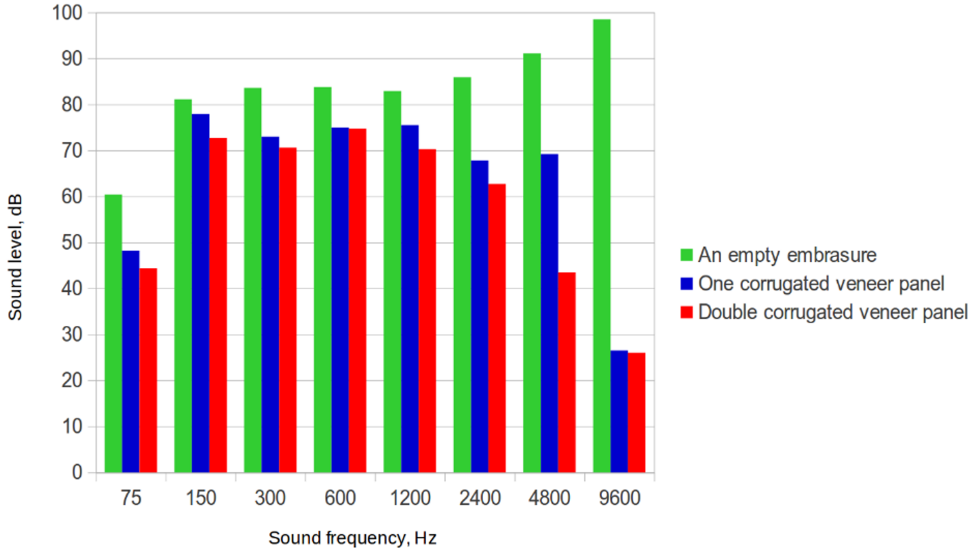

Fig. 3. Sound pressure levels when sound passes through the samples (picture by the authors).

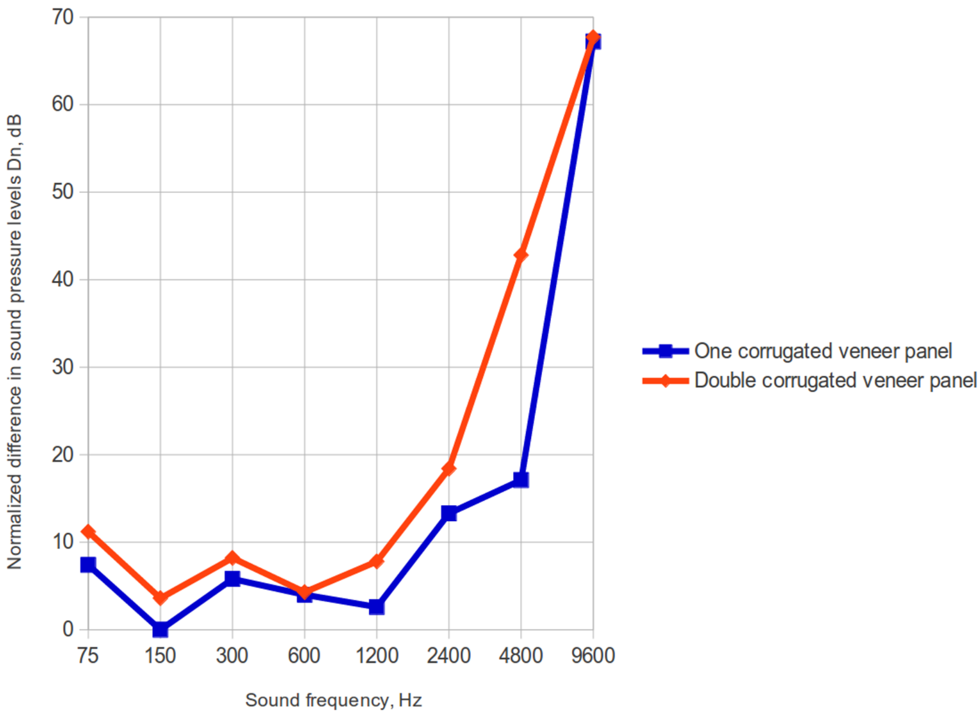

Fig. 4. Present difference of sound pressure levels (picture by the authors).

During the experiment, it was found that for the studied material (single and double corrugated veneer panels), a low ability to isolate air noise is observed in the speech range of the human voice. However, in the area of high frequencies, the ability to isolate air noise with a material is quite satisfactory. The experiment showed slightly better panel performance in the region of 300 Hz, which requires additional study. The experiment showed that the proposed corrugated veneer panel with a thickness of 18 mm has insufficient sound insulation in the low and medium frequencies. The panel can be used in combination with other sound insulation materials to ensure that the sound insulation of interior partitions of residential premises using a corrugated veneer panel meets the Russian regulatory requirements of SP 51.13330.2011 "Noise protection".

Increasing corrugated veneer panel sound insulation properties can be achieved by using filler placed in the voids between the corrugations in the panel. According to research, the filler should be selected from among materials that have good sound insulation properties in the frequency range of 100-3000 Hz and give a synergistic effect in combination with the panel design. Another way to improve the sound insulation properties of the panel is to increase the number of corrugated layers, select the optimal radius of corrugations curvature, and modify the corrugated veneer sheets by perforating them with holes.

4 Conclusions

It was found that corrugated veneer panel obtained samples provide effective sound insulation from noise starting at a frequency of 2400 Hz. For example, at a frequency of 4800 Hz, a single panel reduces the sound level by almost 1.5 times, and a double panel reduces the level by 2 times. The results obtained provide a direction for further research with the proposed material: studying the effect of geometry and perforation of the corrugated middle layer; combinations of corrugations of different sizes in one panel on its noise-insulating characteristics; the use of filler placed in the voids between the corrugations. In addition, it is planned to produce panels with a combination of wood materials, including the use of fiberboard. The task of further research is to improve the sound insulation properties of the panel while maintaining its relatively small thickness.

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