EVALUATING THERMAL INSULATION PROPERTY OF THE CORRUGATED VENEER BIRCH WOOD PANEL OFFERED TO USE AS A MODERN CLADDING MATERIAL FOR INTERIOR DECORATION

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Abstract: The trend of using natural materials for consumer goods has been increasingly pronounced recently. Construction industry is no exception here, with wooden house construction developing within it rapidly, and board structures utilized on a large scale. Given this, the task of searching for new technical solutions in manufacturing natural material board structures seems a crucial one. The paper describes the patented structure of corrugated veneer panel developed by the authors. Its heat insulating properties are evaluated by finding the thermal conductivity coefficient. Another advantage of the corrugated veneer panel under consideration is its capacity to help expand the scope of use of birch wood, which is currently highly limited.

Keywords: birch, veneer, board material, corrugated veneer panel, natural materials.

1 Introduction

At present, there is a great variety of construction materials designed as boards which are utilized in wooden house construction. For example, among these, there is oriented strand board (OSB), wood fiberboard, wood chipboard, medium density fiberboard (MDF), laminated wood board (plywood), etc. These materials differ in their operational characteristics determined by the production technology. Board materials have found application in house construction, in particular, in construction of partition walls, as framing, surfacing, heat insulating, and other types of materials.

Currently, growth of consumer interest in the use of natural, environmentally friendly materials is observed. Most board materials are essentially composites where elements of wood in the form of chips and sawdust are used as filler, and various resins are used as binder.

The use of sawdust and chips, i.e., smaller wood particles, makes it necessary to apply considerably large amounts of binder, which results in the materials giving off resin vapors in the process of operation, in its turn. So, due to resins in their composition, these materials cannot be called completely sustainable.

This is why there is currently a need of searching for new board materials being both environmentally friendly and manufactured of wood with the minimum amount of adhesives.

A problem of forestry sector consists in the 2022 complete shutdown of exports of birch wood from the Republic of Karelia to Finland bordering on it. This resulted in vast quantities of unclaimed birch wood accumulated within the area of the republic; consequently, timber producers had difficulties selling it.

All the above necessitated looking for new solutions which would help involve birch wood into production, on the one hand, and on the other – create a new product sought after in the wooden house construction market.

During the brainstorm conducted by the staff of the Department of technology and management of forest industry complex at the Institute of Forestry, Mining, and Construction Sciences of Petrozavodsk State University and involving students and postgraduate students, a new board material was proposed named "Corrugated veneer panel" (see Figure 1).

The novelty in design of this board material is confirmed by utility model patent RU 220698 "Corrugated veneer panel" with priority dated 22/05/2023.

This panel is manufactured of birch veneer sheet by placing corrugated sheets between the external and internal flat ones. The panel design uses the minimum amount of adhesive which is applied on flute crests of the corrugated veneer sheets only.

Construction use of this material needed a comprehensive study of its physical and mechanic properties. One of the important characteristics of the material is its thermal conductivity, which is the subject of study of this paper.

2 Literature Review

This research into thermal conductivity needed conducting some experimental studies. In planning of the experiment, the first stage included studying previous experience gained in this domain.

V.P. Lugovaya (2013) cites thermal conductivity data of heat insulating material called "Ecovata Plus". This material is a wool-like mass consisting of fluff cellulose. fibers and designed for heat insulation of houses. According to the data of AS Resourse testing laboratory, this material features the following thermal conductivity value at the temperature of 25°C – 0,028 W/(m·K).

I.V. Susoeva, T.N. Vakhnina, A.A. Titunin, and V.E. Rumyantseva (2022) discuss the technology of manufacturing composition heat insulating board material from plant fibers based on using the linen and cotton filament waste and soft waste of wood with thermosetting binder. The data are cited that with carbamide and formaldehyde binder at the 20% volume, thermal conductivity coefficient of the resulting material amounts to 0,05 … 0,06 W/(m·K).

However, natural heat insulating materials have to compete with artificial materials based on polyurethane or, if strength is a priority, cement.

Jelle B.P. (2011) notes that typical thermal conductivity values of foam polyurethane (PUR) (heat insulator produced in the form of boards) range within 0,02 … 0,03 W/(m·K). Alongside this, the author highlights that under standard operation, foam polyurethane performs its heat insulating duties and is safe for human health, but it is a major hazard in case of fire, because it emits highly toxic gases when burning (Jelle, 2011).

The work of V.A. Kudryashov, S.S. Botyan, and S.M. Zhamoidik (2019) is describes the technique of a series of experimental studies for evaluating effective thermal conductivity coefficient of cement fiberglass-reinforced boards in conditions of fire.

As laboratory equipment to find out thermal physical properties of the construction material, these researchers used the EKPS-10/1300 electric muffle furnace which supports heat modes within the 20 to 1300°C temperature range.

T. Seyitniyazova, A. Orazgulyiev, and A. Kashanov (2008) consider the idea of generalization of problems of finding thermal conductivity in plane, cylinder, and spherical walls, i.e., the problems conventionally worded for each geometrical wall shape individually.

The work by A.A. Bakatovich, N.V. Bakatovich, and A.N. Penkrat (2022) describes a number of studies, including one to find thermal conductivity coefficient of crushed pine bark for optimizing the particle size of structure-forming material in heat insulating boards made with the said bark.

N.V. Kilyusheva, V.E. Danilov, and A.M. Aizenshtadt (2016) point out that for finding thermal conductivity of a pine extract and bark heat insulating material, the probe technique using MIT-1 thermal conductivity meter as per GOST 30256–94 "Building materials and products. Method of thermal conductivity determination by cylindrical probe".

V.A. Kudryashov and S.S. Botyan (2017) discuss various methods of finding thermal conductivity of construction materials. In particular, they look into techniques corresponding to GOST 30290-94, GOST 30256-94, STB 1618-2006, STB EN 12667-2007, and STB EN 12939-2007.

3 Research Methodological Framework

The objective is to evaluate thermal conductivity of corrugated veneer panel of birch wood.

Tasks of the research include:

- to study methods of exploring thermal conductivity of board construction materials used in house construction;
- to find the thermal conductivity of corrugated veneer panel by means of experiments;
- to provide comparative evaluation of thermal conductivity of corrugated veneer panel versus other board construction materials utilized in wooden house construction.

The object of this study is corrugated veneer panel;

Its subject is thermal conductivity properties of corrugated veneer panel.

The following methods were used to achieve the set objective and perform the tasks outlined:

- patent and information search and analysis of scientific technical literature. Using the method, the authors could collect and systemize all the necessary information for the research;
- the comparison method. This method helped conduct comparative analysis of the object of the study and similar materials and reveal their differences. Comparative analysis was conducted proceeding not only from the results of studying scientific technical literature, but also from the data returned by the laboratory-based experiment conducted to find the thermal conductivity coefficient value of corrugated veneer panel.

For the experiment to find the thermal conductivity coefficient value characterizing energy performance of corrugated veneer panel, a set-up was designed, basically representing a box with a source of heat inside and a window in one of the walls.

The window had fasteners to secure the material under study in its opening. Walls of the box were lined with a heat insulating material to ensure extra protection against loss of heat.

In the research, samples of the panel manufactured of corrugated birch veneer (Figure 1) were used: their dimensions were 135 x 140 mm, thickness of the samples was 28 mm, which included two corrugated veneer layers with 14 mm flute size.

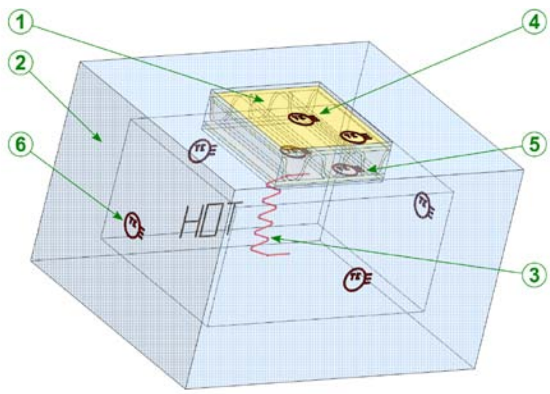
The heat source was located inside the box and powered from the 220V AC network.

The power of the heat source was 60 W. The ambient air temperature in the laboratory was 21°C during the experiment.

Figure 1 Test Sample of Corrugated Veneer Panel

To measure the temperature of the internal and external wall surfaces of the material under study (facing towards the interior of the box and outside, respectively), as well as to monitor the operation of the set-up and the ambient air temperature in the room, the DS18B20 temperature sensors fitted with a metal sleeve were used (DS18B20 Programmable Resolution 1-Wire Digital Thermometer, 2023). DS18B20 sensors were chosen owing to their reliability, simple operation, and ensured precision of ±0.5°C which is sufficient for the experimental conditions within the range of temperatures measured from -10°C to +85°C. So, the set-up included: two temperature sensors to measure the temperature of the material wall facing towards the interior of the box; two sensors to take the temperature of the external wall of the material; four sensors for monitoring the temperature on the surface of walls of the box itself; and three more sensors to monitor the ambient air temperature of the room (Figure 2).

Figure 2 Diagram of the Experimental Set-Up



1 – sample under study; 2 – box; 3 – heat source; 4 – temperature sensor located on the external side of the material; 5 – temperature sensor located on the internal side of the material; 6 – temperature sensor located on the box wall

As DS18B20 sensors support the 1-Wire protocol, they were connected to the Arduino microcontroller platform, using which the temperature data were taken from the sensors every second and sent to the laptop outputting them on the screen. In addition, the course of experiments with the materials was monitored using the Testo 875-1i thermal imager which features a high thermal sensitivity (Testo 875-1i - Thermal imager, 2023).

The experiment was conducted in line with the following technique. The tested material was placed in the box window opening, secured, and sealed in the opening. Power was supplied to the heating element, as a result of which the interior of the box was heated, and the internal wall of the material sample under study was heated, too. Readings of temperature sensors were output on the laptop screen and registered.

Heating was continued until readings of the temperature sensors installed on the wall surface of the tested material stopped increasing and were at a stable value.

With the data obtained, the thermal conductivity coefficient was calculated according to the known formula (Heat engineering experiment, 1982):

$$\lambda = \frac{(Q - Q_W) \cdot \delta}{(T_{W1} - T_{W2})F} \quad W/(mK)$$

here Q is the supplied heat flow, W;

Q_W – the heat flow escaping through walls, W;

δ – thickness of the sample, m;

T_{W1}, T_{W2} – temperatures of the internal and external surfaces of the sample, respectively, K;

F – area of the sample, m_2.

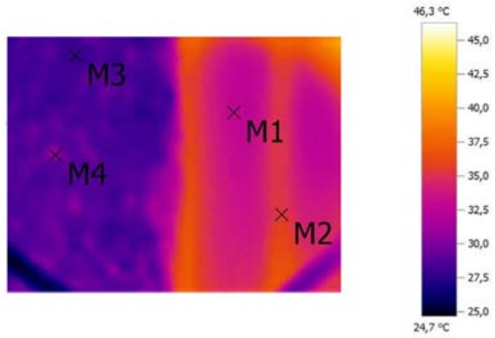
4 Results and Discussion

In the course of the research, the average heating temperature of the internal surface of the panel under study, i.e., the one facing towards the interior of the experimental set-up housing, was 72°C, while the average temperature on the external surface of the panel under study was 34°C during the experiment.

The measurements were stopped as soon as the temperature difference on the external surface of the samples was less than 0,5°C between measurements taken in 120 seconds.

After this, readings of sensors installed on the external and internal walls of the material under study were registered, and readings of the thermal meter were taken (Figure 3).

Figure 3 Readings Registered with a Thermal Imager



M1 – 32,9°C; M2 – 35,5°C; M3 – 27,7°C; M4 – 30,3°C.

The average time for the external sample surface temperature to achieve the steady-state condition amounted to 38,85 minutes.

In the course of the experiment, 812 measurements were conducted in series of four takes. The large sampling size is associated with registering three five-second reports on the ongoing basis at the interval of 120 seconds.

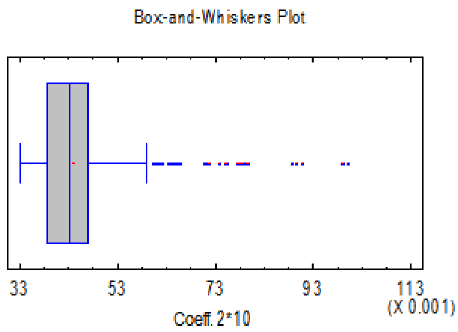
Statistical characteristics of the findings are given in Table 1.

Table 1 Statistical Characteristics of Sampling Obtained by Measuring the Thermal Conductivity Coefficient

Characteristics	Values
Sampling size	812
Average	0.0441951
Dispersion	0.0431595
Standard deviation	0.0000676495
Variation coefficient	0.00822493
Standard error	18.6105%
Minimum value	0.000288638
Maximum value	0.0332101
Skewness coefficient	0.00820557
Standardized skewness coefficient	2.41654
Coefficient of excess	28.1123
Standardized coefficient of excess	10.0559

The high values of skewness and excess coefficients suggest a distribution which is different from the normal one. This is explained by including the thermal conductivity values obtained at the early stages of measurement into the general bulk of results. Thus, when constructing the box-and-whiskers plot (see Figure 4), the thermal conductivity values of 0,06 and more should be considered outliers, and there are 31 of them. With this quantity amounting to 3,8% of the sampling, they can be excluded from the research.

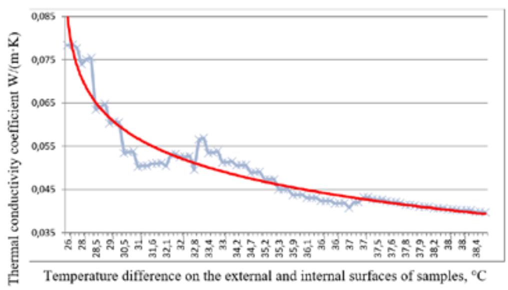
Figure 4 Box-and-Whiskers Plot



In the course of work, graphs have been obtained characterizing the change of thermal conductivity and given in Figure 5 and Figure 6. In the said figures, the grey curve characterizes the averaged values of thermal conductivity for all measurements conducted, and the red solid curve represents the regressional relationship (R2 = 93.378) of change of the calculated thermal conductivity throughout the measurements:

$$\lambda_{exp} = -0{,}001 ln(T_{W1} - T_{W2}) + 0.0085$$

Figure 5 Dependence of Thermal Conductivity Coefficient of the Samples on the Difference of Temperatures on the External and Internal Sample Surfaces



So, the calculated thermal conductivity coefficient value based on regression equation was 0,04043 W/(m·K), while the said coefficient value obtained by tests amounted to 0,03991 W/(m·K).

5 Conclusion

For the research, the experimental set-up was designed, with a system for monitoring temperature inside and outside the set-up. In the course of the research, thermal conductivity of corrugated veneer panel was evaluated. So, its thermal conductivity coefficient value was registered at 0,03991 W/m·K. Findings of the research have demonstrated the possibility of using corrugated veneer panel as an interior-grade facing material. Further on, the authors plan to evaluate sound-insulating properties of the said material, as well as its strength performance.

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