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Modelling of Thermal Conductivity of a Wooden Wall with a Reed Thermal-Insulating Mat

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Abstract. The problem of using natural building materials in low-rise construction lies in ensuring their durability during operation in conditions of atmospheric fluctuations, as well as in ensuring their thermal insulation properties. The purpose of this study is to find the thermal insulation properties of materials, namely thermally modified common hornbeam wood (the outer surface of the building), common pine wood (the inner surface of the building) and a thermal insulation layer of reeds, which allow justifying the effectiveness of their use in construction. The study uses a comprehensive research method, which included figuring out the thermal insulation properties of materials and justifying their feasibility in construction. The thermal insulation properties of wood and reed materials were calculated based on thermophysical dependences. The coefficient of thermal conductivity for wood reaches 0.0082 W/(m·K), and for reed – 0.0022 W/(m·K). Therewith, the thermal conductivity is no more than $0.19 \cdot 10^{-6}$ m^2/s, the heat capacity of wood is within 70÷90 kJ/(kg·K), and the heat capacity of a reed product is 337.2 kJ/(kg·K) respectively, which refers them to thermal-insulating materials. The practical value of this study lies in the substantiation of the method of establishing thermal insulation characteristics of building materials by finding their physical and thermophysical properties. The obtained results also expand the scope of application of products and building structures made of wood and reed

Keywords: natural building materials, wood and reeds, thermal insulation products, thermal conductivity, thermophysical properties

Introduction

Products made of organic materials, namely wood and its modifications, such as thermally modified wood, reeds, etc., are used in construction. Since they have several unique characteristics – low volume weight, low coefficient of thermal conductivity, rather high weather resistance. Furthermore, they are described by high strength and elasticity.

Wood and reed products are widely used in low-rise construction. Thermally modified wood is used for exterior decoration of structures, as it can withstand atmospheric fluctuations [1]. Reed boards are mainly used in the construction of walls, partitions, floors, and roofs, which are protected by thermal-insulating and sound-proofing material. Having a tubular stem structure, reeds have a low weight and low thermal conductivity, and due to the presence of flint deposits in reed cells, they are less susceptible to rot than wood. The production of construction products from reeds is not difficult and without excessive costs can be organised in places with reed stands. Reed nodes are thickened rings-joints and are placed along the stem every 15-20 centimetres. Inside the rings, there are partitions that do not allow air and water to pass through. Such structure of reeds causes low thermal conductivity of products made from it and sufficient strength.

Thus, the use of products made of wood, including thermally modified, and reed, for the construction of walls, requires the establishment of certain characteristics of the materials. For effective design and subsequent manufacture of construction products, it is necessary to establish thermophysical properties. Therefore, conducting these studies is relevant and of great practical importance.

The use of plant-based materials in construction has gained great importance recently. Therefore, the search and

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justification of technological aspects of the production of building structures based on wood panel boards with the necessary thermal insulation characteristics is the basis of many studies [2; 3]. However, the task does not make provision for an analysis of the physical condition of the product during long-term operation in an environment with changes in temperature and humidity. Technologies for moulding materials with the addition of mineral impurities to plant fibres are increasingly being developed. Various combinations of hydrophobic components with natural materials such as asbestos, mica, basalt, etc. are used [4; 5]. As a result of this combination, structures of increased rigidity are obtained, but their resistance to atmospheric fluctuations has not been studied.

In [6], the authors investigated the dependence of the density and plasticity of a material made from a mixture of linen fibres and cotton on quantitative changes in plant components. In addition, the authors studied the indicators of flexibility of such thermal insulation products, which change depending on the applied binding element. The issue of thermal conductivity stays unresolved, which reduces the effectiveness of the results obtained.

The study [7] estimates the influence of the environmental conditions of operation of products made of fibreboards on their thermal conductivity. It was proven that the reliability of data on the thermal properties of insulation materials is crucial in numerical modelling, which increases efficiency with the correct design of structures. However, the method for determining thermal conductivity has not been covered.

The study [8] presents the data on the production technology of a construction material based on hemp fibre glued with alabaster binding material, as well as the thermophysical properties of the material. The authors substantiated the possibility of its use as a thermal-insulating construction element. But finding the influence of structural components on its thermal insulation stays an unresolved issue. The products presented in [9] are made based on of basalt fibre and are described by prominent thermal insulation properties. However, the production technology and methodology for determining thermal insulation and strength properties are not given.

The cited studies [10] substantiate the modelling that describes the regularities of heat distribution and its retention in the insulating material, considering the features of the thermal insulator. Combinations of both natural and synthetically produced fibres were considered as structural elements. However, the dependence of heat transfer on changes in the pore shape of composite particles in this model is not considered.

The study [11] presents a method of a hot disk transition plane source, which allows characterising the thermal properties of various materials in a few minutes. This method is increasingly used to estimate the thermal conductivity of insulating building materials. Three types of materials are tested: conventional isotropic materials (e.g., extruded polystyrene foam), anisotropic compressible materials (e.g., wood fibre insulation), and heterogeneous anisotropic materials (e.g., lightweight bio-concrete). The influence of tuning parameters (volume heat capacity, time limit for estimation) is analysed in the light of repeatability and reproducibility errors. The suitability of the hot disk method based on an isotropic or anisotropic model for characterising non-contiguous isotropic heterogeneous materials is discussed and compared with steady-state measurements. The results obtained for particular cases cannot be generalised, especially for heterogeneous materials, such as biological-based building insulation materials.

The study [12] presents an assessment of environmental impact by analysing the life cycle of a new type of wood-based sandwich panel. To identify the processes that most affect the environment of the proposed cross-laminated timber (CLT) panel solution during the life cycle. The analysis is performed considering various life cycle completion scenarios during production. The study includes a comparative assessment of changes in the thickness of wood layers relative to the optimised cross-insulated timber (CIT) panels; the use of an alternative to the base material, namely insulation cork board (ICB); the use of structurally equivalent CLT panels. The results show that the CIT panel manufacturing process, namely polyurethane foam production and the moulding and curing processes during panel assembly, are the ones that have the highest impact. This means that an optimised solution in terms of economic costs is also the solution that has the least impact on the environment. Compared to equivalent CIT panels with ICB core and CLT solutions, the environmental characteristics of the proposed panel were better for some impact categories, while they were worse for others. However, there is still the need to switch to natural materials in the future.

The study [13] focused on the possibility of reducing the amount of diphenylmethane diisocyanate (pMDI) in the composition of insulating wood fibreboards by 50% by adding 1% BioPiva 395 or Indulin as two types of soft wood kraft lignin and lignin-rich canola husk together with propylene carbonate as a solvent. As a result, panels with a density of 160 kg/m^3 and 40 mm thick were obtained. The curing of this material was investigated using two types of methods: hot steam (HS) and the innovative hot air/hot steam (HA/HS) process. The insulating wood fibreboards were then tested for their physical and mechanical properties. The equilibrium moisture content was found under two different climatic conditions. An approximate study of thermal conductivity was also performed. The plates under study also underwent further chemical analysis for the content of extractives and elemental (C, N) composition. The results show that it is possible to produce insulating wood fibreboards with less pMDI resin and the addition of lignin with improved physical and mechanical properties of the board, which do not lose thermal conductivity or moisture absorption, especially when curing using the HA/HS process.

The paper [14] investigated the use of plaster filled with two untreated plant-based fibres – wood fibre and grain straw fibre, for their use in the thermal insulation of buildings. Composite materials were made with different densities (0%; 5%; 10%; 15%; 20% by volume). Their thermophysical features were described in terms of chemical structure, crystallinity, thermal conductivity, thermal conductivity coefficient, and water absorption. Two linear correlations were established regarding the thermal conductivity and thermal conductivity of the samples. The results show that the introduction of wood fibres and grain straw fibres reduces the thermal conductivity, as well as the heat capacity and weight of composite materials. A comparison of other composite materials shows that the proposed composite is a good competitor compared to the materials used in insulation.

Thermal insulation is considered one of the key technologies to combat the ever-increasing energy consumption. In [15], the authors propose an efficient method for developing innovative and cost-effective basic materials for vacuum insulation panels (VIP). They contain natural and resistant wood pulp fibres with the addition of various amounts of glass fibre as a reinforcing component. To create such a hybrid multi-level network composite, the usual wet paper manufacturing is used. The authors investigated the main features of both wood pulp and glass fibre, including the effect of glass fibre on the texture properties and thermal insulation characteristics of composite panel core materials. The results showed that all components achieved a uniform distribution over the thickness of the material, and the fibre axes were randomly placed in a three-dimensional structure. As the glass fibre content increased, the thermal conductivity of the panels gradually decreased due to structural changes in the filling materials. Both the pore diameter and porosity increased along with the glass fibre content. As a result, thermal conductivity of 6.48 and 4.69 mW/(m·K) was obtained, respectively, for panels made of 100% wood pulp fibre and wood pulp/glass fibre composites (mass ratio of 50%). Furthermore, after 365 days of storage, the composite material with 50% fibreglass maintained a thermal conductivity of 7.42 mW/(m·K) without a gas absorber or dehumidifier. Even under conditions of accelerated ageing, after 28 days the increase in thermal conductivity was less than 5.00 mW/(m·K).

Given the current environmental awareness and growing interest in advanced and sustainable materials, the use of waste wood fibre and phosphogypsum has led to the development of environmentally friendly composites. The article [16] presents a study of a new composite material made from a phosphogypsum matrix reinforced with waste wood fibre made from used fibreboard or natural wood fibre obtained from natural wood. Fibre in the samples was included in the amount from 0 to 5%. Furthermore, a certain amount of synthetic zeolite waste has been added to reduce the content of harmful soluble acid impurities. It was found that wood fibres from boards improve the mechanical strength of the material more effectively than natural fibres. The highest values of compressive strength – 25.1 and 21.9 MPa – were achieved with the addition of 0.5% of fibres from boards and 1% of natural fibres, respectively. A further increase in their number reduced the compressive strength of the samples by reducing the density of the material. Thermal conductivity decreased due to the addition of fibre, while the level of sound absorption did not change. Considering the comprehensively investigated properties, the optimal recipe for phosphogypsum composite samples includes 3% wood fibre obtained from boards, demonstrating a compressive strength of 13.5 MPa, a thermal conductivity of 0.39 W/mK and a sound absorption level of 64.5 dBA.

Thermal insulation materials made by mixing carpet waste with a solution of raw colemanite ore and with the addition of colemanite waste were also studied [17]. It is shown that adjusting the content of components becomes possible to ensure the process of thermal insulation.

Thus, the use of a wall from wood and reeds, primarily in construction, requires the establishment of thermophysical properties. Finding these indicators is a relevant area of research and is aimed at the effectiveness of design and subsequent manufacture of products with thermal insulation features.

The purpose of this study was to establish the thermophysical characteristics of construction products made of wood and reeds for determining the conditions of thermal insulation of a building structure.

To achieve this result, the following tasks were set:

– to establish the features of reducing the heat exchange process for walls made of thermally modified wood (external), pine wood (internal) and reed as a thermal insulator;

– to substantiate the features of the heat transfer process between the elements of a building structure made of wood and reed.

The scientific originality of this study lies in finding the thermophysical properties in a combination of a building structure made of thermally modified common hornbeam wood, common pine wood and a thermal insulation layer made of reeds, as well as in substantiating their use in the manufacture of building walls.

Materials and Methods

For the study of thermal conductivity, the authors used samples of thermally modified common hornbeam wood (outer surface), common pine wood (inner surface) with dimensions of about 150x150x20 mm, and reeds with a diameter of up to 10 mm (thermal-insulating layer) bound in a mat with dimensions of about 150x150x25 mm (Fig. 1). Therewith, reed stems of different layers were placed perpendicular to the previous one.

a) b) c)

Figure 1. Samples of materials for research: a – thermally modified common hornbeam wood, b – thermal-insulating reed mat, c – common pine wood

Special equipment was used to investigate the thermal insulation properties of materials [3].

The essence of studies to determine thermal conductivity is that a thermocouple of a heater was placed in a sample of the material, and a thermocouple was placed on the reverse side of the wall to control heat transfer (Fig. 2). The end of the thermocouple was fixed so that the sample was pressed against it. The heater voltage was turned on and the temperature on the sample surface was measured.

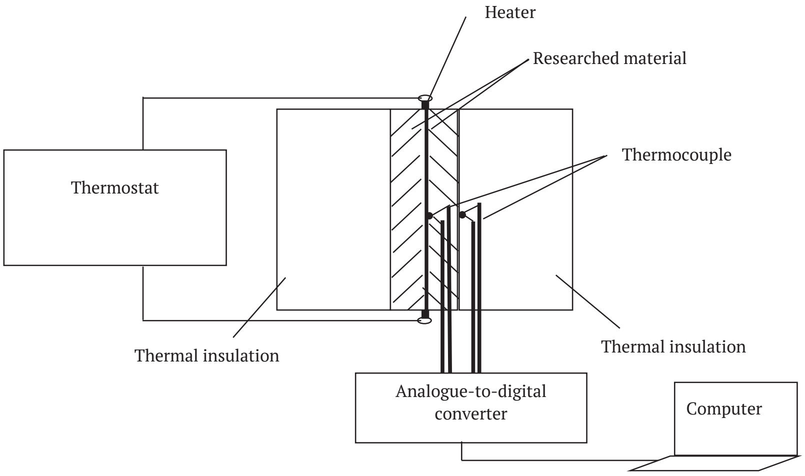

Figure 2. Device for studying the thermal conductivity of materials

When the temperature reached 70°C, the heater was switched off, continuing to measure the temperature until the value was set $0.5T_{max}$ on the reverse side of the assembly wall. The thermal-insulating properties of the sample were figured out from the measured values.

The criterion for determining the thermal conductivity of the material from the heat source is the time it takes to reach the temperature at $0.5T_{max}$ from the back surface of the wall.

Modelling of parameters of heat exchange processes in various materials of building structures. It is precisely the method of figuring out the thermal conductivity for a plate that is proposed to establish the thermophysical characteristics of the materials under study [3]. One of the sample surfaces is heated by a heat flow passing through the wall, and the temperature changes along the same vector (Fig. 2). To establish the thermal insulation properties, it is necessary to find the temperature distribution along this vector at any time.

To describe the heat transfer process, a differential equation is applied, which has the following form [18]:

$$\frac{\partial^2 T(x,\tau)}{\partial x^2} - \frac{1}{a}\frac{\partial T(x,\tau)}{\partial \tau} = 0, (\tau > 0; 0 < x < \infty). \quad (1)$$

For this equation, the initial and boundary conditions are as follows:

$$T(x,0) = T_0, \quad (2)$$

$$\lambda \frac{\partial T(x,\tau)}{\partial x} = q = const, \quad (3)$$

$$T(\infty,\tau) = 0, \quad (4)$$

$$\frac{\partial T(\infty,\tau)}{\partial x} = 0, \quad (5)$$

where T_0 is the temperature of the material in the initial period, °C; $T(x, \tau)$ is the temperature field of the wall at points with coordinates x at a time τ, °C; a is the coefficient of thermal conductivity of the wall, m²/s; τ is the duration of stay of the sample in a high-temperature field, s; q is the temperature flow, W/m²; λ is the coefficient of thermal conductivity of the wall, W/(m·°C).

In the paper [3], the solution of equation (1) is given considering the initial and boundary conditions (2)-(5), and the thermophysical characteristics for a flat sample are determined – Table 1:

Table 1. Formulas for finding the thermophysical characteristics of solid materials

Thermal activity coefficient	$b = \frac{2q\cdot\sqrt{\tau}}{\sqrt{\pi}\cdot\Delta T_n}$
Temperature conductivity coefficient	$a = \frac{1}{4\cdot\tau_2}\left(\frac{x}{B}\right)^2$
Thermal conductivity coefficient	$\lambda = b\cdot\sqrt{a}$
Specific heat capacity	$c = \frac{\lambda}{a\cdot\rho}$

where ΔT_n is the temperature difference between the heater and the reverse side of the sample, °C; B is the argument of the error integral function; ρ is the material density, kg/m³.

Results and Discussion

To establish the thermophysical characteristics of materials, namely common pine wood, thermally modified common hornbeam and reed, the features of the heat transfer process from the heating source are studied (Fig. 1).

The characteristics of the heater are as follows: an electrical insulation plate measuring 100×100 mm with a thickness of 1 mm, a winding made of nichrome wire, the resistance of which is 84 Ohms. During the experiment, a voltage of 24.6 V was applied. To partially reduce heat consumption around the perimeter, the installation was placed in a thermal-insulating plate.

The studies on finding the temperature level and induction rate of heat transfer through a wall sample, which includes common pine wood and thermally modified common hornbeam wood, as well as thermal insulation from reeds, were performed on the equipment and according to the methodology described above. The results of thermal conductivity are presented in Figures 3, 4.

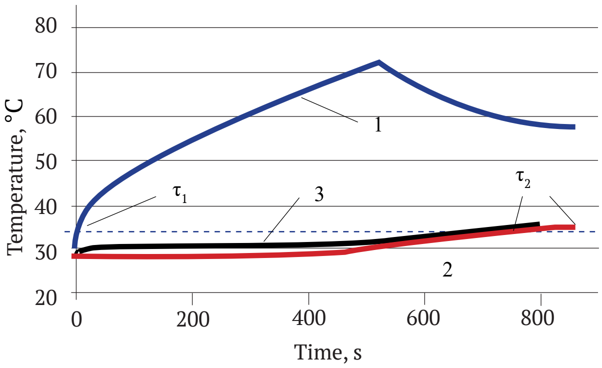

Figure 3. The results of thermal conductivity tests: 1 – heating curve, 2 – temperature level from the back surface of common pine wood, 3 – temperature level from the back surface of thermally modified wood. Points τ_1 correspond to the average temperature of the heating curve and τ_2 – to the average temperature value on the reverse surface

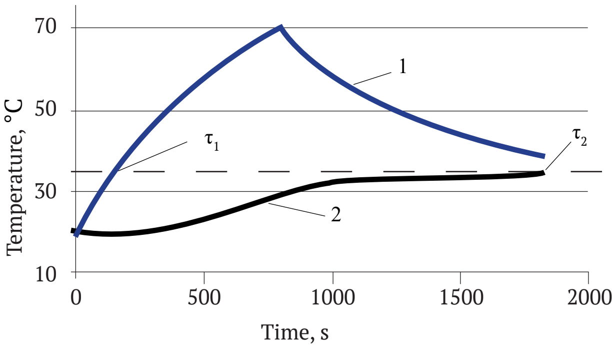

Figure 4. Results of tests of thermal conductivity of reeds: 1 – heating curve, 2 – temperature level from the back surface of reeds. Points τ_1 correspond to the average temperature of the heating curve and τ_2 – to the average temperature value on the reverse surface

Analysis of Figure 3 and Figure 4 shows that heating with heat transfer along the thickness of the sample began immediately when it was brought to the surface of the heater. However, on the reverse side of the wall, a slight increase in temperature was recorded in the period over 800 s. For the reed sample, the time to reach the temperature on the reverse surface surpassed 1900 s. That is, when using reeds as thermal insulation, it was found that the thermal conductivity of this sample is described by a prolonged heat transfer, namely, the heat transfer is inhibited by the air barriers formed in the reeds, which allows influencing the thermal insulation.

Based on the results of the measured temperature using the method given above, the thermophysical characteristics of wood and reed materials were calculated (Table 2).

Table 2. Thermal insulation properties of wood and reed

Material name	Thickness, mm	Weight, g	Calculated parameters					
			Density ρ, kg/m³	Thermal activity, W·s/(m·K)	Temperature conductivity, m²/s	Thermal conductivity λ, W/(m·K)	Heat capacity, kJ/(kg·K)
Pine wood 150×150 mm	19.8	214	475	18.7	$0{,}19\cdot10^{-6}$	0.0082	90.8
Thermally modified hornbeam wood, 150×150 mm	20.0	308	684	18.7	$0{,}15\cdot10^{-6}$	0.0073	71.2
Reed 150x150 mm	26	133	172.7	11.5	$0{,}039\cdot10^{-6}$	0.0022	337.2

When figuring out the thermal insulation properties of materials, it was found that the thermal conductivity of wood does not exceed $0.19\cdot10^{-6}$ m²/s, whereas for reed, this value decreases by almost 5 times. The thermal conductivity of the wood sample did not exceed 0.0082 W/(m·K), and for the reed product it is 0.0022 W/(m·K). Furthermore, the heat capacity of wood corresponds to a value within 70÷90 kJ/(kg·K), and the value of heat capacity for a reed product is 337.2 kJ/(kg·K), respectively. Thus, these materials correspond to the values of the thermal insulation material [19].

The calculation of the thermal parameters of the outer wall is based on finding the following basic values – the required heat transfer wall resistance R_0^r and the wall thickness δ determined on its basis [20].

Finding of R_0^r:

$$R_0^r = \frac{n\cdot(t_{in}-t_{out})}{\Delta t_{in}\cdot a_{in}}, \tag{6}$$

where n is the coefficient that depends on the position of the outer wall to the environment, ($n=1$); t_{in} is the calculated value of the internal air temperature taken according to the house design standards, °C, ($t_{in}=18$°C); t_{out} is the calculated outdoor temperature in winter, taken as the average daily value of the 5 coldest days, °C, ($t_{out}=-20$°C); Δt_{in} is the standard temperature difference between the indoor air temperature and the temperature of the inner surface of the wall, °C, ($\Delta t_{in}=7$°C); a_{in} is the heat transfer coefficient of the inner surface of the wall, ($a_{in}=7.5\cdot1.163$ W/m²·°C).

Thus:

$$R_0^r = \frac{1\cdot(18-(-20))}{7\cdot7.5\cdot1.163} = 0.62\ \mathrm{m}\cdot\frac{\mathrm{K}}{\mathrm{W}}.$$

The estimated wall thickness is calculated according to the following formula [20]:

$$\delta_p = \left[R_0^r - \left(\frac{1}{a_{in}} - \frac{1}{a_{out}}\right)\right]\cdot\lambda\,, \tag{7}$$

where a_{out} is the heat transfer coefficient of the outer surface of the wall (per the DBN B.2.6-31:2016 [20]), ($a_{out}=20\cdot1.163$ W/m²·°C); λ is the coefficient of thermal conductivity of the wall material.

The coefficient of thermal conductivity is found according to the following formula [20]:

$$\lambda = \lambda_{nom}\cdot K_p\cdot K_x, \tag{8}$$

where λ_{nom} is the nominal value of the coefficient of thermal conductivity; found by a diagram constructed from experimental data for pine wood across the fibres depending on temperature; $\lambda_{nom}=0.45$ W/(m²·K); K_p is a coefficient that considers the basic density of wood; $K_p=1.11$ at δ=550 kg/m³; K_x is the coefficient that considers the vector of heat flow; $K_x=1$.

Hence,

$$\lambda=0.45\cdot0.87\cdot1=0.39\ \mathrm{W/(m^2\cdot K)},$$

$$\delta_p = \left[0.62 - \left(\frac{1}{7.5\cdot1.163} - \frac{1}{20\cdot1.163}\right)\right]\cdot 0.39 = 0.204\ \mathrm{m}.$$

Thus, the thickness of the house wall will be 0.20 m (wall width) (Fig. 5).

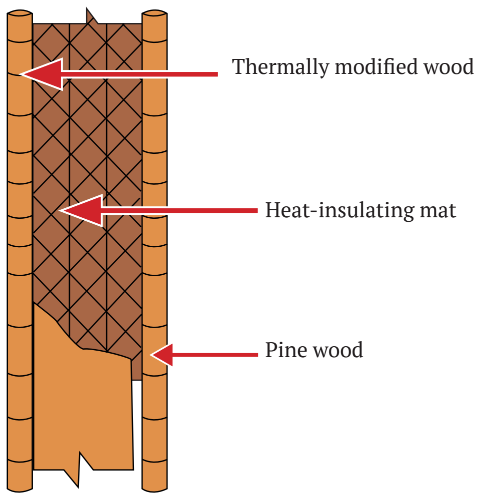

Figure 5. Scheme of thermal insulation of the house wall

Based on consumer demand, there are increased requirements for the appearance of thermal-insulating materials used for furnishing premises, therefore the use of natural thermal-insulating materials is more effective. Thus, thermomodified wood with increased weather resistance is reliable for the manufacture of external structures, and it is advisable to use reed as a thermal-insulating material.

Thermal conductivity through the wall of the building is considered as the process of heat energy transfer from the room to the outside and occurs until the temperature balance, which follows from the obtained results (Table 2). This phenomenon is caused by the formation and application of large and coupled pores in the material structure and the use of materials with low volume weight. Furthermore, the heat transfer is influenced by the following factors: the nature of the material and its structure, the degree of porosity, the nature of the pores, humidity and the average temperature at which heat transfer occurs. Thermal insulation products must meet the following requirements: have stable thermal insulation indicators, be environmentally safe and resistant to atmospheric fluctuations. This coincides with the results in [8; 9], where the authors associate the effectiveness of thermal insulation with the use of natural low-density materials. However, unlike in [14; 15], the data obtained by the authors of this study regarding the influence of natural and sustainable fibres of wood cellulose and straw of cereal crops allow stating the following:

– the main parameter for suppressing thermal conductivity is both the density and porosity of the material, since low values of these properties inhibit heat transfer;

– substantial influence on inhibition of heat transfer upon using natural materials is exercised towards the formation of a thermal insulation structure resistant to destruction under temperature and humidity fluctuations.

The obtained results are of practical importance, as they allow for a reasonable approach to figuring out the required amount of thermal insulation materials and products in a building structure. From a theoretical standpoint, this allows asserting the determination of the mechanism of inhibition of heat transfer by the wall, which constitutes a certain advantage of this study.

However, the calculated results indicate an ambiguous effect of natural materials on changes in thermal conductivity. This uncertainty imposes some restrictions on the use of the results obtained, so in the future it is necessary to conduct added experiments to identify the time from which a sharp jump in thermal conductivity begins. Thus, it will be possible to figure out the factors influencing the heat exchange process.

Conclusions

Thermal insulation properties of wood and reed materials were calculated based on thermophysical dependences. The coefficient of thermal conductivity of wood reaches 0.0082 W/(m·K), and for a reed product, this coefficient is 0.0022 W/(m·K). Therewith, the thermal conductivity does not exceed $0.19 \cdot 10^{-6}$ m^2/s, while the heat capacity of wood is within 70÷90 kJ/(kg·K), and the heat capacity of a reed product is 337.2 kJ/(kg·K), respectively, which refers them to thermal-insulating materials.

The speed of the heat transfer between the elements of the structure made of wood and reed lies in the formation of air pores. The inhibition of heat transfer in the material is caused by the lack of air movement in the air pores.

In the future, it is necessary to conduct added experiments to obtain updated data. It is necessary to create conditions sufficient for the qualitative conduct of the heat transfer and detect the time point at which the drop in heat resistance begins. Such detection allows investigating the transformation of the surface of the material based on thermally modified wood and reed, moving towards low temperature with increasing transfer time. This also allows finding those variables that substantially affect the beginning of the transformation of this process.

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Моделювання теплопровідності дерев'яної стінки з очеретяним теплоізоляційним матом

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Анотація. Проблема застосування природних будівельних матеріалів в малоповерховому будівництві полягає в забезпечені їх довговічності при експлуатації в умовах атмосферного коливання, а також у забезпечені теплоізолювальних властивостей. Мета проведених досліджень полягає у визначені теплоізолювальних властивостей матеріалів, зокрема, термічно модифікованої деревини граба (зовнішня поверхня будівлі), деревини сосни (внутрішня поверхня будівлі) та теплоізоляційного шару з очерету, що дозволяють обґрунтувати ефективність застосування їх у будівництві. В роботі використано комплексний метод дослідження, що полягав у визначені теплоізоляційних властивостей матеріалів та обґрунтуванні їх доцільності у будівництві. За теплофізичними залежностями розраховано теплоізоляційні властивості матеріалів з деревини та очерету, зокрема, коефіцієнт теплопровідності для деревини сягає 0,0082 Вт/(м·К), а для виробу з очерету становить 0,0022 Вт/(м·К). При цьому температуропровідність складає не більше 0,19·10-6 м2/с, теплоємність деревини знаходиться в межах 70÷90 кДж/(кг·К), а теплоємність для виробу з очерету складає 337,2 кДж/(кг·К) відповідно, що відносить їх до теплоізоляційних матеріалів. Практична цінність отриманих результатів полягає у тому, що обґрунтовано метод становлення теплоізоляційних характеристик будівельних матеріалів через визначення фізичних і теплофізичних властивостей та розширити сферу застосування виробів і будівельних конструкцій з деревини і очерету

Ключові слова: природні будівельні матеріали, деревина і очерет, теплоізоляційні вироби, теплопровідність, теплофізичні властивості