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# The Influence of Climatic Aging on the Performance of Wood-Based Panels

Ekaterina Pakhomova [1], Sergey Emelyanov [2*], Viktor Yartsev [3], Vladislav Danilov [3], Pavel Monastyrev [3]

[1] *Dean of the Faculty of Construction and Architect, Southwest State University, Russian Federation.*

[2] *Rector of the Southwest State University, Southwest State University, Russian Federation.*

[3] *Institute of Architecture, Construction and Transport, Tambov State Technical University, Russian Federation.*

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**Abstract**

The purpose of this work is to experimentally determine the climatic effects on the performance of wood-based panels using the methodology developed on the basis of the thermo-fluctuation concept of material aging. This methodology makes it possible to determine the durability of the material by taking into account the simultaneous action of temperature, time, and mechanical stress, as well as additional external influences. The experiments were conducted on particleboard, fiberboard, and plywood. The following climatic effects were studied experimentally in specialized laboratory facilities: high humidity, thermal aging, and UV-irradiation. As the evaluation indicators of the performance characteristics of wood boards were selected, water absorption, swelling rate, thermal expansion, penetration strength, and bending strength. From a theoretical point of view, the value of this work lies in demonstrating a methodology for determining the performance characteristics of particleboard, fiberboard, and plywood, which is highly accurate by considering these characteristics together rather than separately. From a practical point of view, this paper contains experimental results that allow us to judge the characteristics of the wood boards. It has been proven that exposure to UV rays and heat aging causes the binder between the filler particles to break down, and moisture is detrimental to the filler. The thermo-fluctuational constants obtained in the course of the study make it possible to predict the durability of the materials in question over a large range of operating parameters.

*Keywords:* Fiberboard; Chipboard; Thermal Fluctuation; Panels; Plywood.

## 1. Introduction

One of the main methods of residential or small commercial structure construction is the use of wooden structures. Wood frame construction is popular partly because of its economical technology and wide availability of materials. Currently, there is an active replacement of natural wood with its modernized artificial analogs, wood composites. The reason for this is both the general development of scientific and technological potential and economic development [1]. Wood composites are usually considered to be wood modified by polymers [2]. Such materials include particleboard, fiberboard, and plywood, which are considered in this paper. It is also worth noting that the list of such materials is quite wide, but those considered in this paper are the most common around the world.

All building materials are exposed to external influences (moisture, exposure to low and elevated temperatures, ultraviolet, etc.) during operation. The impact of external factors can lead to the aging of building materials, i.e., a change in their structure, as well as the deterioration of their operational properties (strength, heat resistance, etc.) [3, 4].

* Corresponding author: bvv001@mail.ru

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In world practice, when studying the strength characteristics of particle boards, fiberboard, and plywood, maximum strength values were obtained under various types of loading (transverse bending, compression, stretching, punching, etc.) under normal conditions [3–5]. Currently, the physical and mechanical characteristics of wood slabs with modernizing additives affecting fire resistance, moisture resistance, etc. are being studied [6–13]. Due to the wide availability of such materials, the possibility of using such materials in seismic areas is being studied [14]. It is also worth noting that researchers in some countries are studying the properties of adapted types of wood slabs for local raw materials [15–18]. For example, the use of bamboo filled with modernizing additives [19]. It should be noted that some attempts were made to study the long-term strength of particle boards, fiberboard, and plywood, but without taking into account the joint work of various influencing factors [20–22]. The material is exposed to prolonged loads in combination with the effects of temperature and humidity influences, atmospheric influences, and solar radiation in the process of manufacturing and operation at the same time, and it must be comprehensively studied as well.

This work is based on the basic ideas of the thermo-fluctuation concept, which considers the failure of the structure (destruction of chemical bonds) due to the joint work of the energy of thermal motion of atoms and the work of an external force. This principle was developed by S.N. Zhurkov and was further significantly refined by Soviet and Russian scientists. Accounting for the durability of materials based on this concept is currently a rather labor-intensive method, but it has high accuracy. Because of its high labor intensity, this method is still under development and is currently used only in post-Soviet countries, especially in Russia [23].

Currently, in the thermo-fluctuation concept, the durability of the material is described by the following formula:

$$\tau = \tau_m \cdot exp\left[\frac{U_0-\gamma\cdot\sigma}{R}\cdot\left(T^{-1}-T_m^{-1}\right)\right] \tag{1}$$

where τ is the durability of the material or the time before the onset of one of the limiting states, [s]; R is universal gas constant, [kJ/mol·K]; σ is stress, [MPa]; T is temperature, [K]; $\tau_m$ is minimum fracture time of a solid, characterized by the oscillation period of a particular kinetic unit (atom, group of atoms or segments), [s]; $U_0$ is maximum activation energy of the destruction process, which is determined by the bonding energy preventing the loss of body integrity, and in metals is close to the sublimation energy; in polymers, it is close to the activation energy of the thermo destruction process, i.e., the maximum activation energy of destruction is numerically close to the activation energy of interatomic bond decay in solids, [kJ/mol]; γ is a structural-mechanical constant characterizing the efficiency of the mechanical field when the load is applied to the body [kJ/(mol·MPa)]; $T_m$ is the limiting temperature of existence at which the chemical bonds of the polymer are destroyed in a single thermal fluctuation, [K].

Fracture of solids is a process that is thermally active over time and constantly evolving. The formula contains the multiplier "$exp(U/kT)$". This multiplier is the inverse of the Boltzmann factor. The task of this multiplier is to provide a description of the rate of standard physical and chemical processes. Such processes include: chemical reactions, diffusion, evaporation, phase transitions, etc. In view of the fact that the rate of the named processes accelerates with increasing temperature, such processes are called thermo active [24]. Such processes are performed if the system is metastable. The elements in such a system pass from one state to another by means of thermal fluctuations, overcoming the energy barrier expressed by the "U" value. At the moment when the mechanical load is established, the acceleration of breaking intermolecular and interatomic bonds begins. Since the applied load has a certain direction, the process cannot be stopped because mechanical destruction occurs by the elementary act of breaking intermolecular and interatomic bonds. This phenomenon is called the mechanothermal process. This process proceeds over time, which, in turn, increases the number of thermal fluctuations. In connection with the above, we can say that time does not play a large role but only increases the number of thermal fluctuations required for the transition from one energy state to another [25, 26].

## 2. Materials and Methods

A set of studies, including six types of experiments, was carried out in this work to explore the influence of climatic factors on the operational properties of wood slabs. These experiments include determining the effects of increased humidity, UV irradiation, and thermal aging by evaluating the parameters of water absorption, swelling rate, thermal expansion, penetration strength, and transverse bending strength. Figure 1 shows a block diagram of the study.

### 2.1. Methodology for Determining the Effect of UV Irradiation and Thermal Aging on the Water Absorption Process

The first experiment is aimed at identifying the possibility of breaking bonds in a material under the influence of ultraviolet irradiation and thermal aging. This dependence is revealed when studying the absorption of liquid media by the material and its swelling. The choice of water as a liquid medium is due to the high influence on the characteristics of wooden composites. In addition, water is the most common liquid medium. In view of this, the study is carried out with its application.

Determination of the resistance of wood slabs to ultraviolet radiation is carried out in a special camera of artificial photoaging. The process of thermal aging is carried out by heat treatment in a drying cabinet. Figure 2 shows an artificial photo aging chamber and a drying oven.

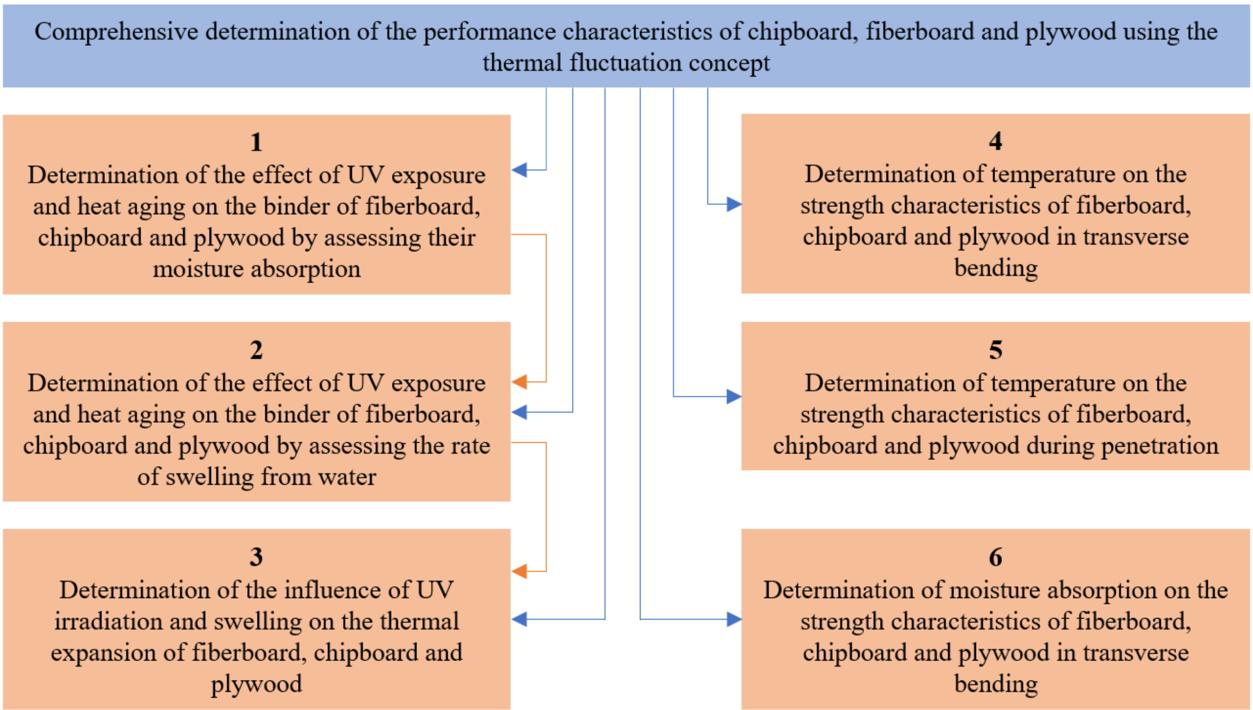



**Figure 1. Block diagram of the research methodology**

(a) (b)

**Figure 2. Artificial photo aging chamber (a), and drying cabinet (b)**

Water absorption is determined by the formula:

$$B = \frac{m_н - m_к}{m_н} \cdot 100 \quad (2)$$

where $m_н$ is the sample mass before the test, [kg]; $m_к$ is the sample mass after staying in water, [kg].

The swelling of the material in thickness is determined by a similar formula:

$$B = \frac{c_н - c_к}{c_н} \cdot 100 \quad (3)$$

where $c_н$ is the height of the sample before the test, [mm]; $c_к$ is the height of the sample after its stay in the water, [mm].

Tests were conducted in water at temperatures of 20, 40 and 60 $^oC$ before and after exposure to UV irradiation and heat aging. UV irradiation and heat aging were performed for 50 hours for each sample. Samples of size 20×20×20 mm were used for the experiments.

## 2.2. Method for Determining the Effect of Ultraviolet Irradiation and Thermal Aging on the Swelling Rate

The second experiment determines the effect of ultraviolet irradiation and thermal aging on the swelling rate of wood slabs. The determination of the swelling rate is determined by rearranging by grapho-analytic differentiation of the graphs of the effect of thermal aging and UV irradiation on swelling into the coordinates of the logarithm of the swelling rate from the inverse temperature. The Arrhenius equation is used to describe them:

$$w = w_0 \cdot exp\left(-\frac{E}{RT}\right) \quad (4)$$

where $w$ is swelling rate, [%]; $w_0$ is pre-exponential multiplier, [%/c]; $E$ is activation energy of swelling, [kJ/mol]; $R$ is universal gas constant, [kJ/mol·K]; $T$ is temperature, [K].

## 2.3. Methodology for Determining the Effect of Ultraviolet Irradiation and Swelling on Thermal Expansion

The third experiment is aimed to identify the effect of ultraviolet irradiation and swelling on the thermal expansion of wood slabs. Dilatometric studies make it possible to determine not only the temperatures of phase transitions, but also to investigate the influence of various factors on them (molecular weight, thermal background, heating rate, etc.). The type of dilatometric curves in the transition region depends on the structure of macromolecules and the supramolecular structure of the polymer, which makes it possible to study the nature of transitions in copolymers, branched and cross-linked polymers, in polymer-polymer and polymer-low molecular weight substance systems, etc.

At elevated temperatures and soaking, the dimensions of building structures change, causing significant thermal or humidity loads in the material. The research consists in constructing dilatometric graphs based on experimental data [10]. The experiment is carried out on a linear dilatometer at a constant heating rate of 1.65 $^oC$/min. The tests are carried out in a free state, after ultraviolet irradiation and after soaking in water. According to the obtained curves, the coefficient of linear thermal expansion is determined by the formula:

$$\alpha = \frac{1}{l_0} \cdot \frac{\Delta l}{\Delta T} \quad (5)$$

where α is coefficient of linear thermal expansion, [1/$^o$C]; $l_0$ is initial sample length, [мм]; $\Delta l$ is elongation of the sample [mm] when the temperature changes by the value of ΔT [$^o$C].

Since the dependencies are not linear, they are divided into linear sections, where for each section is the coefficient of linear thermal expansion. Then this coefficient is averaged and taken as common for the entire graph. Figure 3 shows the optical dilatometer.

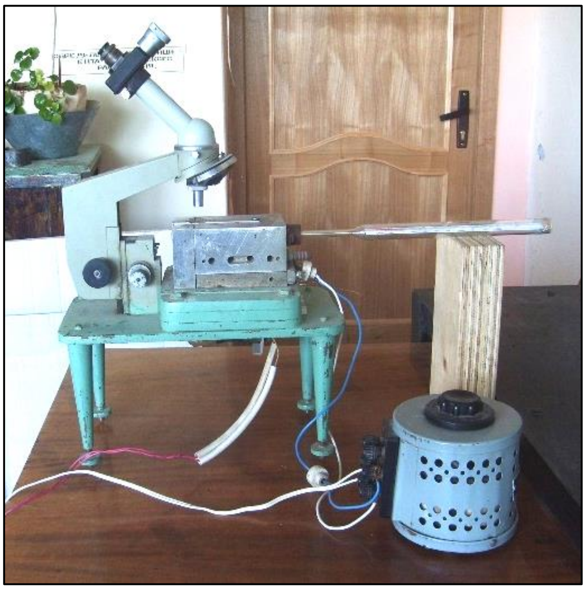


**Figure 3. Optical dilatometer**

## 2.4. Method for Determining the Effect of Temperature on Transverse Bending Strength

The fourth experiment determines the effect of temperature on the strength of wood slabs before and after UV irradiation. The test consists in transverse bending of the elements of wood slabs at various constant temperatures (20, 30, 40, 50 and 60 $^o$C) before and after UV irradiation. The samples are loaded stepwise on a six-position stand (Figure 4). This stand consists of frame, which is made of channels. On the support platform of the frame, two roller supports are installed at a distance from each other equal to the span of the beam (50 mm). The sample is placed on roller supports and loaded using a loading device. The increased temperature is created by rod electric heaters. To reduce heat loss and create a directed heat flow to the support platform, a casing is installed and fixed to the frame. The temperature is set by a laboratory autotransformer and regulated by a potentiometer in the range 0... 300 °C and additionally controlled by a thermometer with an accuracy of ± 1 °C. It should be noted that the thermocouple and the thermometer ball are located in the zone of destruction of the working part of the sample. To eliminate mechanical vibrations during the destruction of samples, a damping device was used – a container filled with sand.

**Figure 4. Six-position stand**

### 2.5. Method for Determining the Effect of Temperature on Penetration Strength

The fifth experiment shows the patterns of behavior of wood slabs during melting. The tests are carried out in the mode of specified constant stress before and after ultraviolet irradiation at different temperatures (20, 40, and 60 °C). The experiment is carried out using a lever installation with a long lever length. The depth of the dive is recorded by the hourly indicator. The constants of thermal oscillations describing the introduction of the indenter into the surface of the material were obtained during standard grapho-analytic rearrangements. Based on the experimental data obtained, graphs are constructed in lgt – σ coordinates. The next step is the standard permutation of a family of fan-shaped straight lines into lgt - 1000/T coordinates. The constants tm and Tm are determined by the pole of these lines. The constants $U_0$ and g are found from a graph constructed in the coordinates $U_0 - \sigma$. The constant $U_0$ is the value formed along the ordinate axis ($U_0$, kJ/mol) by the intersection point of the line, and g is the angular coefficient of the line taken with the opposite sign.

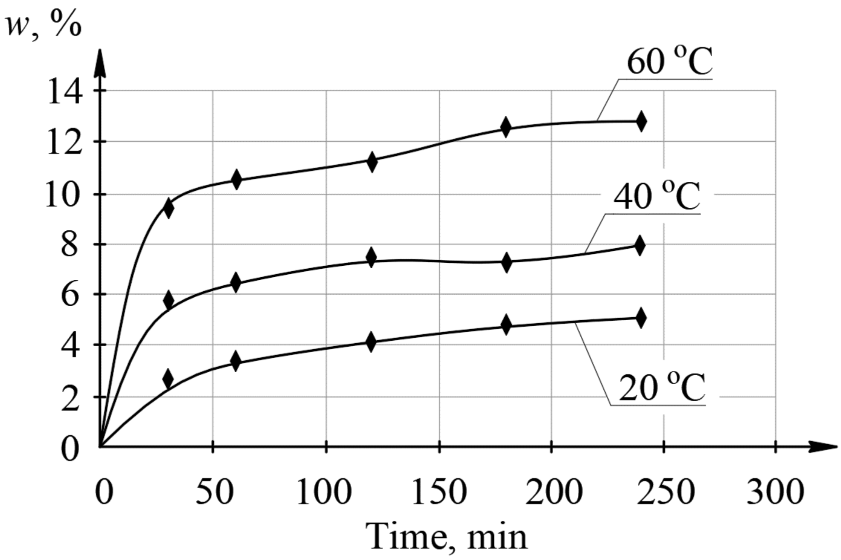
### 2.6. Method for Determining the Effect of Moisture Absorption on Transverse Bending Strength

The sixth experiment is aimed at studying the effect of humidity on the durability of wooden slabs. Pre-soaked samples in water for 1 hour. Then their bearing capacity is determined during transverse bending on a six-position stand, in the mode of constant set temperatures and stresses. Then, according to the experimental data obtained, a graph is plotted in the coordinates of the logarithm of the durability of the voltage.

## 3. Results and Discussion

### 3.1. Effects of UV Irradiation and Thermal Aging on Water Absorption

Water significantly affects the physical and mechanical characteristics of wood materials. The tests were carried out in water at constant temperatures (20, 40, 60 °C) before and after exposure to thermal aging and ultraviolet irradiation. Based on the results obtained, kinetic curves were constructed in the coordinates of water absorption from the exposure time in water and swelling from the exposure time in water. The curves have an exponential shape. Figure 5 shows graphs of water absorption of fiberboard, chipboard and plywood without external influences, Figure 6 shows graphs of swelling.

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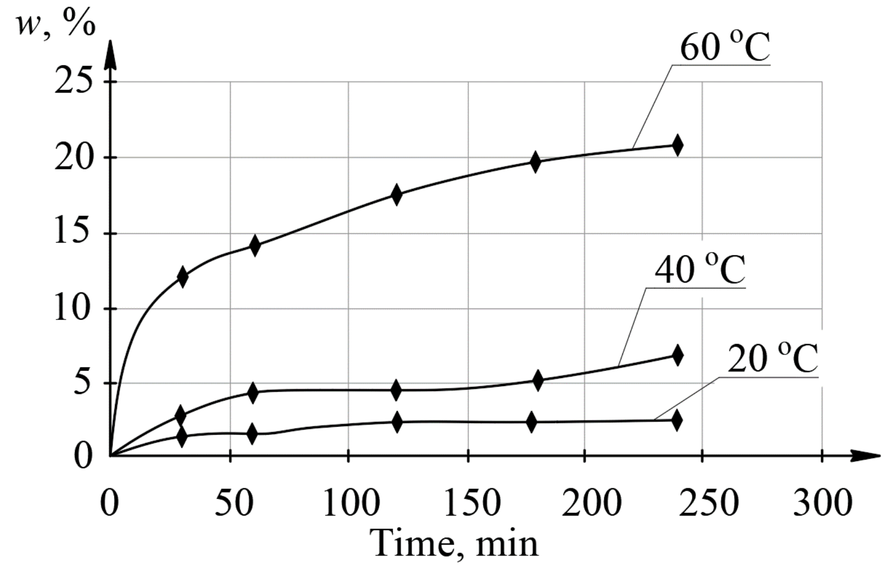


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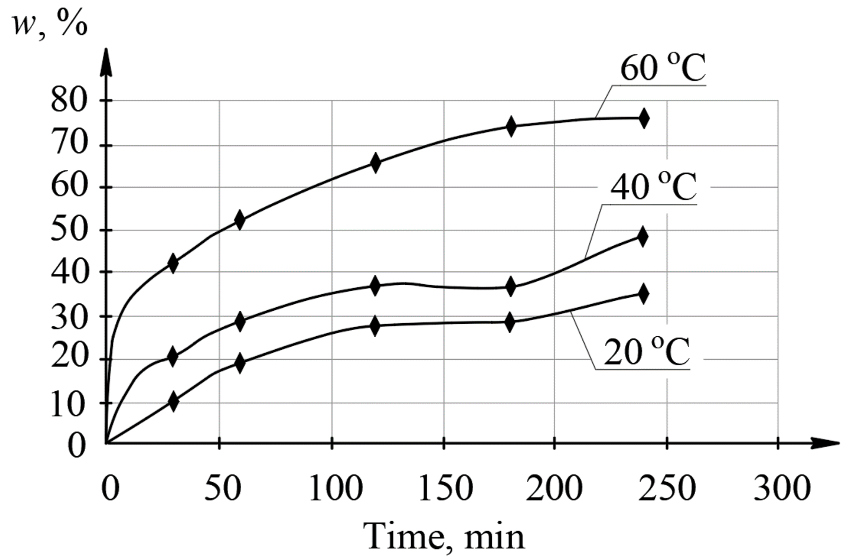
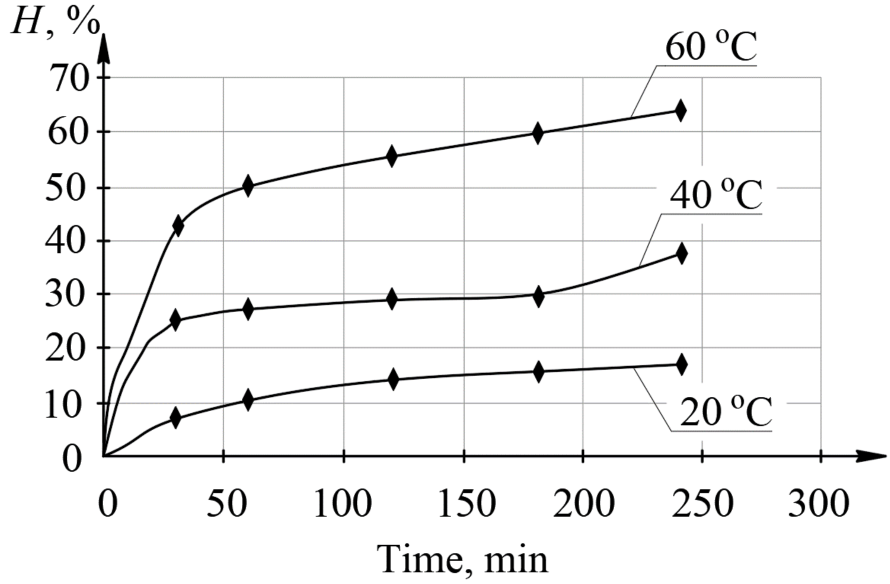



(c)

**Figure 5. Water absorption of wood boards without external influence:-a - chipboard; b - fiberboard; c – plywood**

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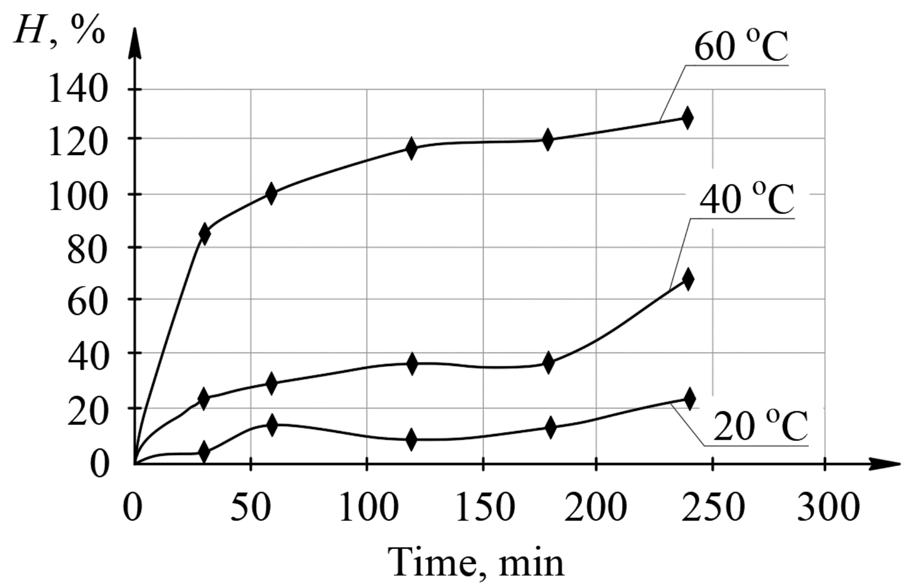


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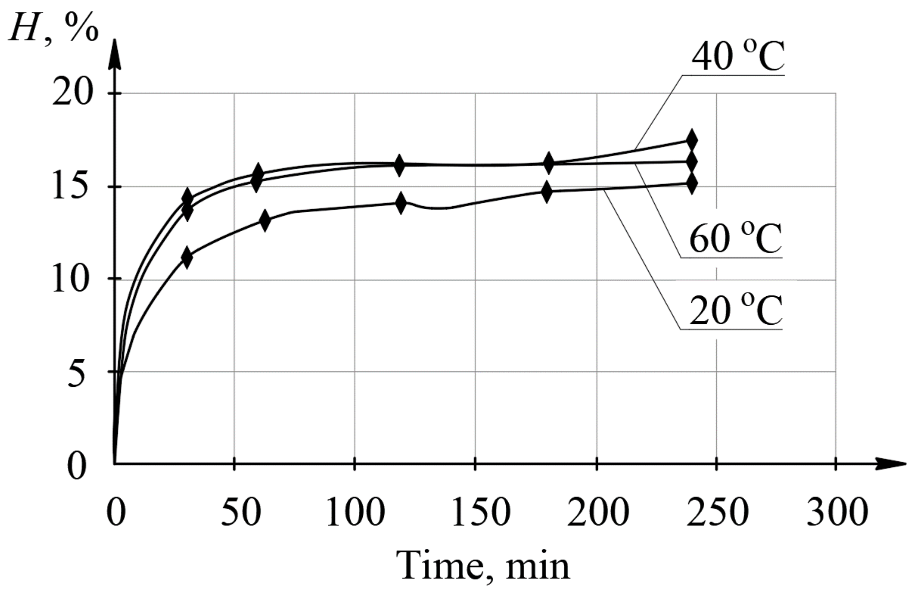


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**Figure 6. Swelling of wood slabs without external influence:**

Due to the fact that the nature of the curves does not change under the influence of thermal aging and ultraviolet irradiation, the results obtained are shown in Tables 1 and 2.

**Table 1. Effect of thermal aging and UV irradiation on water absorption of wood boards**

| Material | Impact time, (min) | Type of exposure | Water absorption at ambient temperature, [%] | | |
|---|---|---|---|---|---|
| | | | 20 °C | 40 °C | 60 °C |
| Chipboard | 0…24 | Without exposure | 0…5 | 0…8 | 0…13 |
| | | UV irradiation | 0…4 | 0…7 | 0…10 |
| | | Heat aging | 0…7 | 0…9 | 0…12 |
| Fiberboard | 0…24 | Without exposure | 0…3 | 0…7 | 0...21 |
| | | UV irradiation | 0…2 | 0…10 | 0…15 |
| | | Heat aging | 0…4 | 0…8 | 0…12 |
| Plywood | 0…24 | Without exposure | 0…35 | 0…50 | 0…75 |
| | | UV irradiation | 0…45 | 0…55 | 0…70 |
| | | Heat aging | 0…45 | 0…64 | 0…75 |

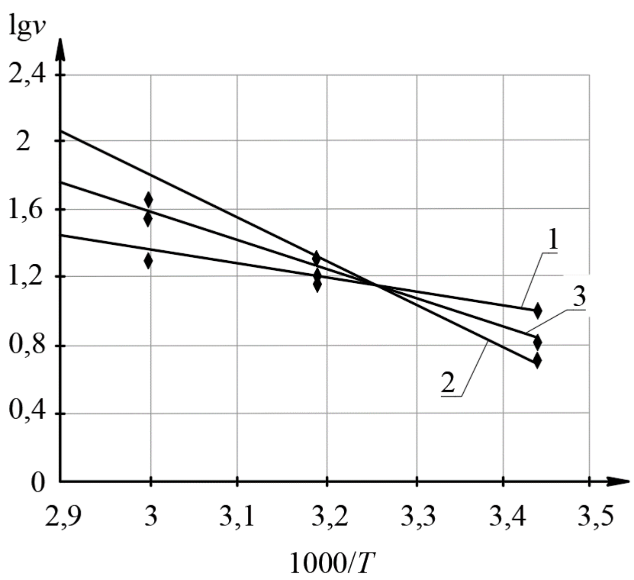
**Table 2. Effect of thermal aging and UV irradiation on wood board swelling slabs**

| Material | Impact time, (min) | Type of exposure | Swelling at ambient temperature, [%] | | |
|---|---|---|---|---|---|
| | | | 20 °C | 40 °C | 60 °C |
| Chipboard | 0…24 | Without exposure | 0…16 | 0…38 | 0…62 |
| | | UV irradiation | 0…17 | 0…32 | 0…60 |
| | | Heat aging | 0…21 | 0…42 | 0…63 |
| Fiberboard | 0…24 | Without exposure | 0…22 | 0…67 | 0…130 |
| | | UV irradiation | 0…10 | 0…70 | 0…98 |
| | | Heat aging | 0…17 | 0…48 | 0…78 |
| Plywood | 0…24 | Without exposure | 0…15 | 0…16 | 0…17 |
| | | UV irradiation | 0…9 | 0…10 | 0…13 |
| | | Heat aging | 0…12 | 0…11 | 0…11.2 |

Based on the above results, it was found that the processes of swelling and water absorption occur most strongly at the initial site (for 50 ... 100 minutes), after which they slow down or stabilize. At the same time, the speed of the processes is strongly influenced by the temperature of the water. Thus, when heated to 60 °C, the water absorption value of wood boards increases from 2 (plywood) to 5 (fiberboard) times. After thermal aging and ultraviolet irradiation, the behavior of wood boards and plywood in water changes. So, at room temperature after thermal aging, the amount of water absorption increases by 1.3-1.5 times. And after exposure to ultraviolet radiation, they behave differently: the water absorption of plywood and fiberboard increases slightly, and chipboard decreases. When water is heated to 60 °C, a drop in the value of their water absorption is a characteristic of all materials both after thermal aging and after ultraviolet irradiation. At the same time, chipboard and plywood are characterized by the lowest water absorption after exposure to ultraviolet radiation, and for fiberboard - thermal aging. When swelling, the materials behave in a similar way. From the results obtained, it follows that in wood slabs, under the influence of ultraviolet irradiation and thermal aging, there is a violation of the bonds between the filler particles. As a result, materials become less susceptible to the action of water.

### 3.2. Results of Determining the Effect of UV Irradiation and Thermal Aging on the Swelling Rate

To determine the characteristics of water absorption of wood slabs, the dependences of the swelling rate on the reverse temperature were constructed (Figure 7). It can be seen from the figures that straight lines were obtained as a result.

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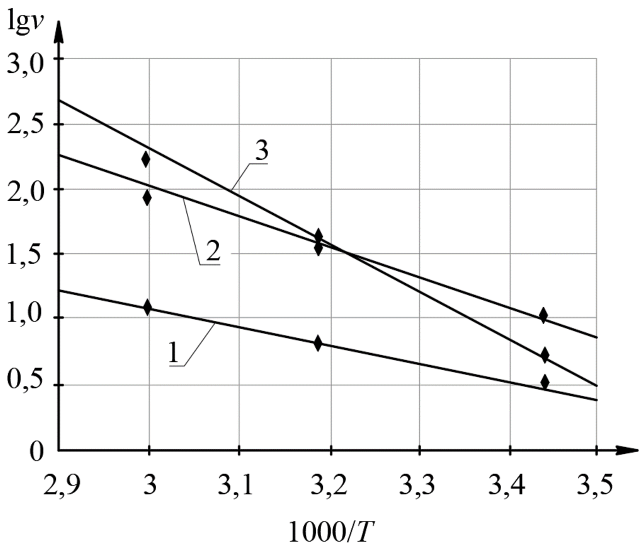


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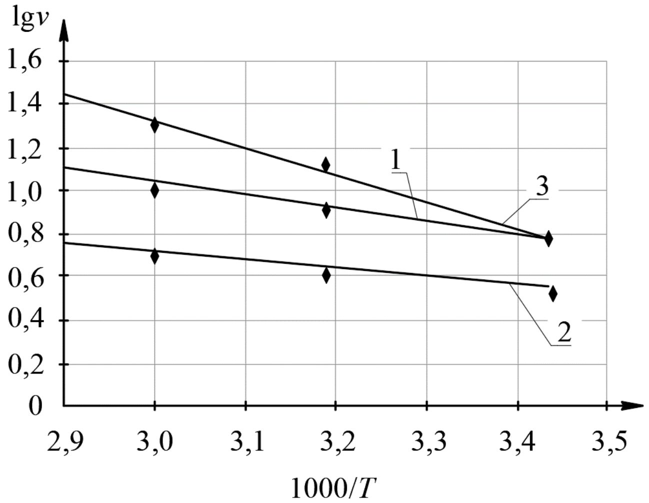



(c)

**Figure 7. Dependence of the swelling rate of wood slabs in water on the reverse temperature: a - chipboard; b - fiberboard; c – plywood (1 - without exposure; 2 - UV irradiation; 3 - thermal aging)**

The preexponent is determined by extrapolating this straight line to the ordinate axis (swelling rate), and the activation energy of this process is defined as the tangent of the angle of inclination of the straight line. The results obtained are presented in Table 3.

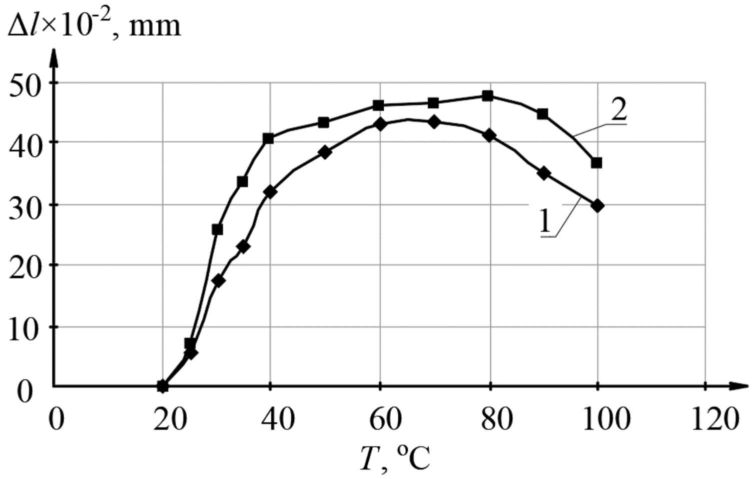
**Table 3. Values of physical constants of swelling of wood slabs**

| Material | Type of exposure | E, kJ/mol | lgv | E/lgv |
|---|---|---|---|---|
| Chipboard | Without exposure | 13.7 | 3.4 | 4.03 |
| | UV irradiation | 43.97 | 8.6 | 5.11 |
| | Heat aging | 30.74 | 6.65 | 4.63 |
| Fiberboard | Without exposure | 26.35 | 5.3 | 4.97 |
| | UV irradiation | 61.47 | 7.65 | 8.04 |
| | Heat aging | 35.13 | 11.55 | 3.04 |
| Plywood | Without exposure | 19.96 | 2.5 | 7.98 |
| | UV irradiation | 19.96 | 2.2 | 9.07 |
| | Heat aging | 21.95 | 4.6 | 4.77 |

It can be seen from the table that the constants characterizing the swelling rate vary depending on the type of wood slab and the impact. Moreover, thermal aging is the most dangerous for plywood and fiberboard, and ultraviolet irradiation is for chipboard. So, for fiberboard E and lgv is 2 times more than for chipboard. In plywood, these values have an intermediate value. To assess the degree of climate impact, consider the E/lgv ratio. It can be seen from the table that all the studied wood slabs are highly resistant to ultraviolet radiation. The data obtained make it possible to predict the rate of swelling of wood slabs after exposure.

### 3.3. Results of Determining the Effect of UV Irradiation and Swelling on Thermal Expansion

The behavior of wood slabs in the free state when heated at a given rate before and after ultraviolet irradiation and swelling in water was also studied. The results are shown in Figures 8 & 9, and Table 4.

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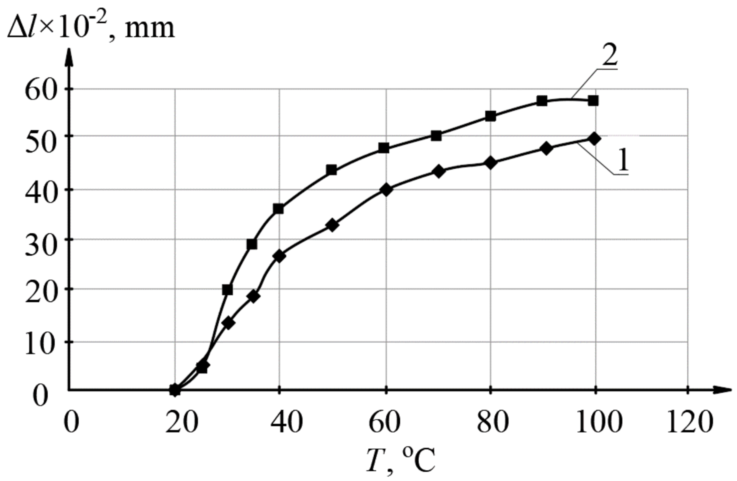


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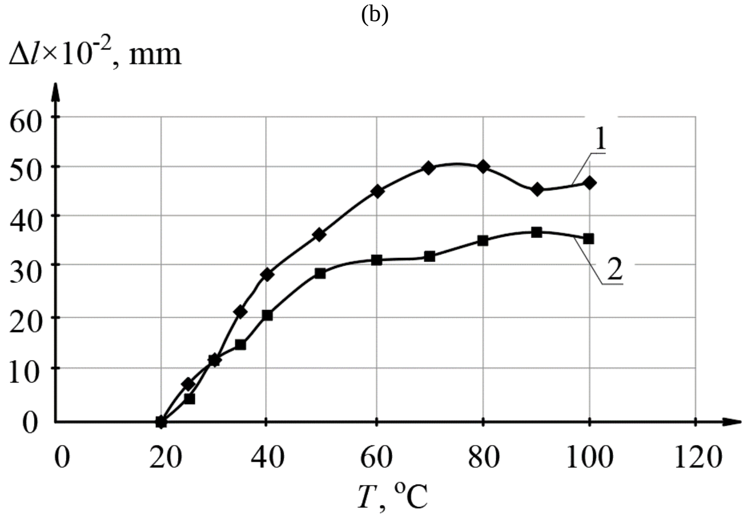


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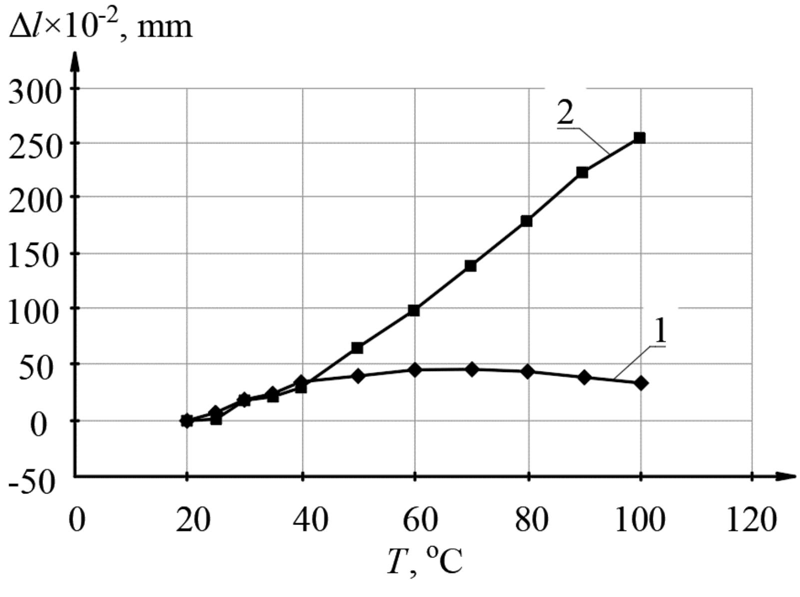
**Figure 8. The effect of UV irradiation on the linear thermal expansion of a wood slab:a - chipboard; b - fiberboard; c – plywood (1 - without exposure; 2 - after UV irradiation)**

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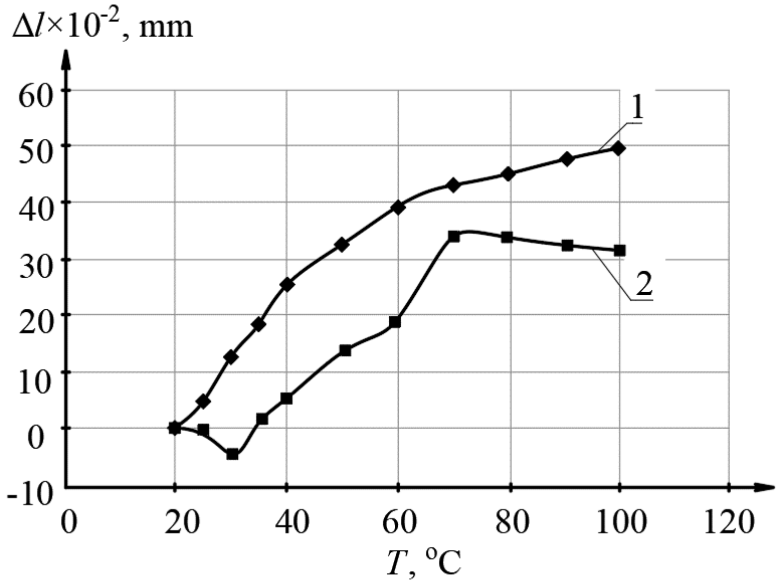


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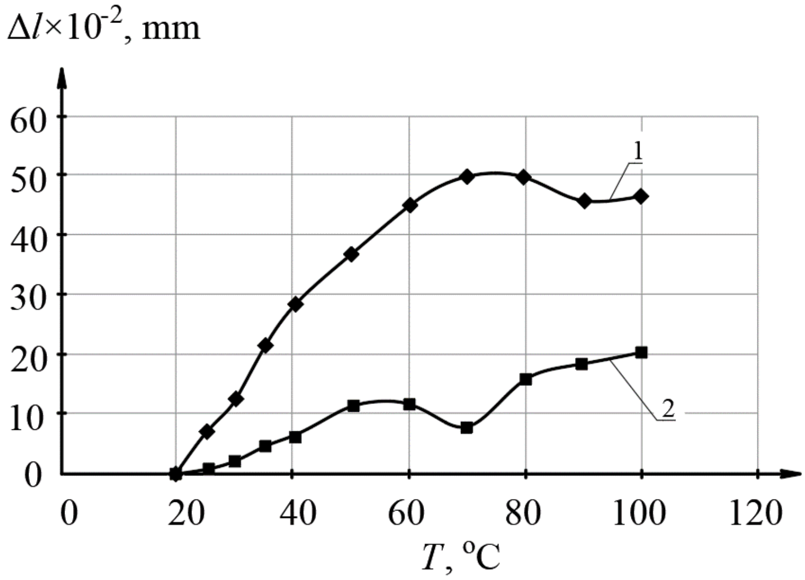



(c)

**Figure 9. The effect of swelling on the linear thermal expansion of a wood slab: a - chipboard; b - fiberboard; c – plywood (1 - without exposure; 2 - after swelling)**

**Table 4. Values of coefficients of linear thermal expansion of building composites**

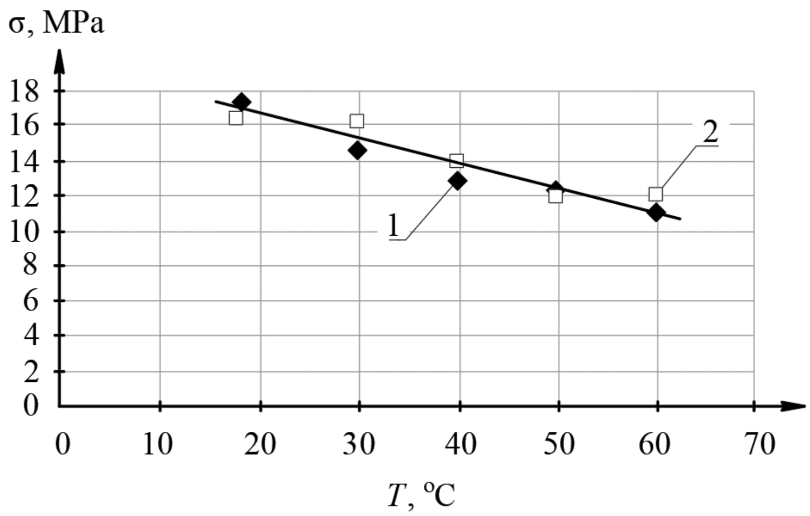
| Material | Type of exposure | Coefficient of linear thermal expansion $\alpha \times 10^{-6}$, 1/°C |
|---|---|---|
| Chipboard | Without exposure | 76 |
| | UV irradiation | 109 |
| | Swelling | 781 |
| Fiberboard | Without exposure | 121 |
| | UV irradiation | 167 |
| | Swelling | 111 |
| Plywood | Without exposure | 131 |
| | UV irradiation | 99 |
| | Swelling | 61 |

The coefficients of linear thermal expansion are determined by the obtained curves. From the data obtained, it can be seen that exposure to ultraviolet radiation increases the coefficient of linear thermal expansion for fiberboard by 1.3 times, and for chipboard by almost 1.5 times. For plywood, on the contrary, there is a decrease of 1.2 times. After soaking, the coefficient of linear thermal expansion of the chipboard increases by 10 times, which is associated with the destruction of the physical bonds of this material. For fiberboard, on the contrary, the coefficient value decreased by 1.1 times, and for plywood - by 2.2 times.

### 3.4. Results of Determining the Effect of Temperature on Transverse Bending Strength

Structural transitions after photoaging were determined, which are characterized by transition temperatures: for plywood, these are temperatures of 40 and 70 °C. After ultraviolet irradiation, the transition temperature shifts to a higher temperature range (50–90 °C). This is due to the layered structure of the material. In fiberboard, the transition points do not shift because the fibers in this material are oriented. The particle board had three transition points before external influences: at temperatures of 40, 60, and 80 °C. After ultraviolet irradiation in the range of 40–80 °C, the point disappears, i.e., the structure of the material in this temperature range is leveled. There is a resorption of internal stresses.

Experimental results of the influence of temperature on the strength of wood slabs before and after ultraviolet irradiation are shown in Figure 10.

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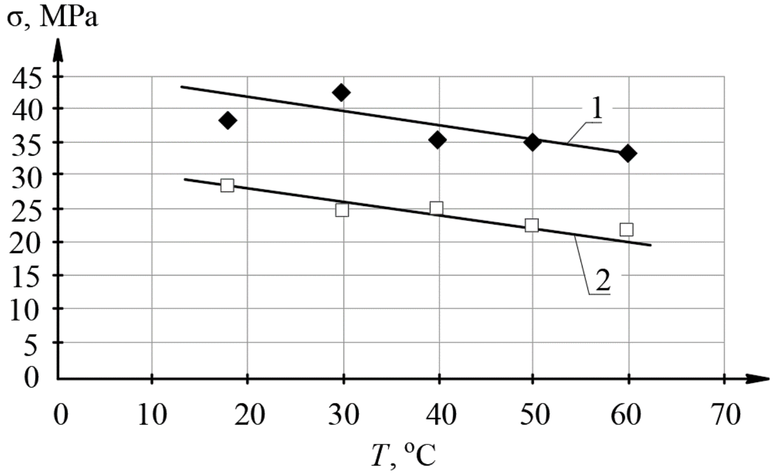


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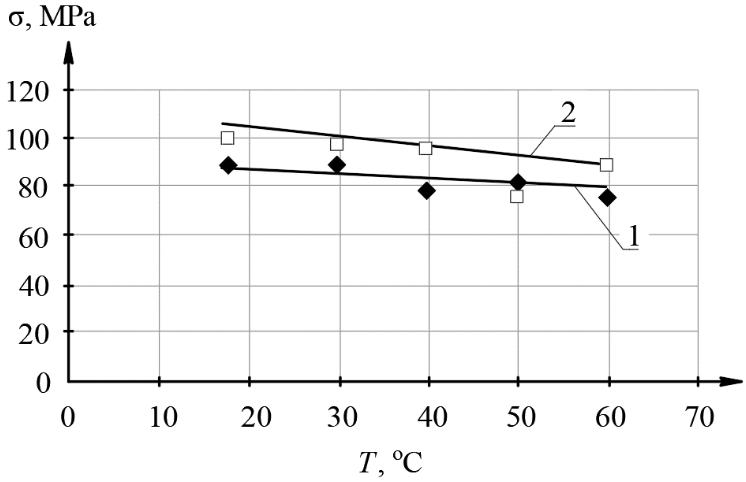



(c)

**Figure 10. The effect of temperature on the strength of wood slabs before and after UV irradiation: a - chipboard; b - fiberboard; c – plywood (1 - without exposure; 2 - after UV irradiation)**

It can be seen from the figure that after ultraviolet irradiation, the strength of the fiberboard is significantly reduced. Ultraviolet has a negative effect on the emulsion of rosin and paraffin, which are part of the binder of the fiberboard; the bond between the fibers weakens, and they begin to work as free. Thus, the load required for the destruction of the material is reduced. On the contrary, in plywood, the strength increases after exposure to ultraviolet radiation. This is due to the so-called shielding effect: the upper veneer protects the polymer layer from destruction, and the wood itself becomes stronger after exposure to ultraviolet radiation. The short-term strength of chipboard practically does not change after UV irradiation: the structure of the material becomes more homogeneous, the binder loses strength, and the filler, consisting of sufficiently large chips, acquires strength.

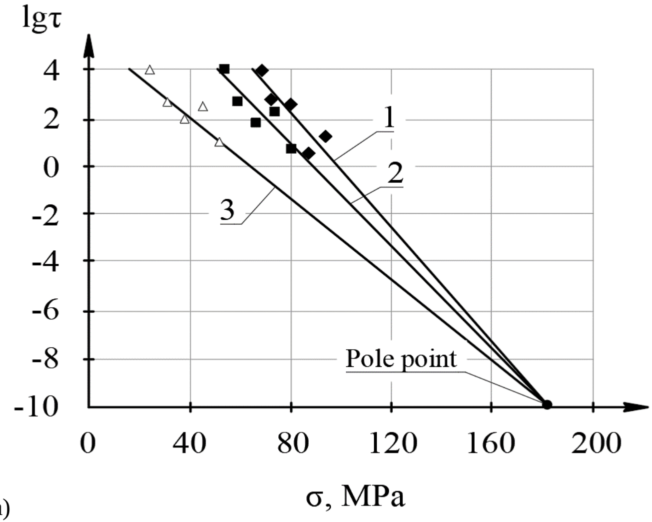
Based on the data from the graph, the temperature of destruction of wood slabs without load application and the limit voltage at a temperature equal to zero are calculated (Table 5). The value of the limit temperature without the application of a load is obtained by interpolation along the abscissa axis. The value of the breaking voltage at zero temperature is obtained by interpolation along the ordinate axis.

**Table 5. The value of the fracture temperature of plywood without load application and the value of the limiting voltage at a temperature equal to zero when exposed to UV radiation and without exposure**

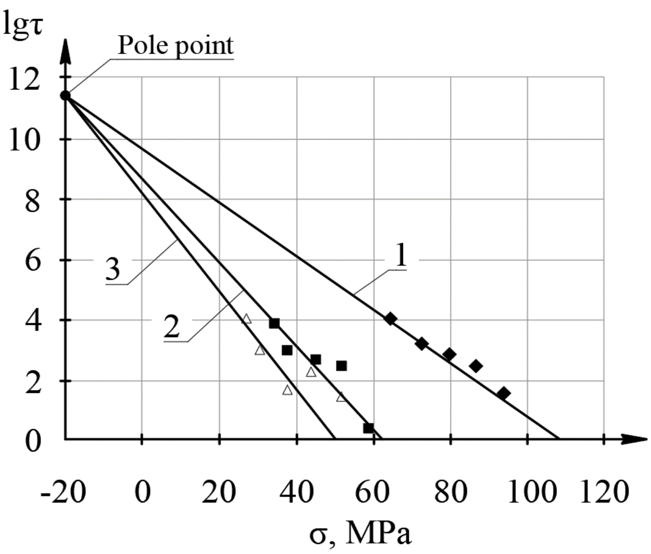
| Material | Type of exposure | t, ºC, at σ = 0 MPa | σ, MPa, at t = 0 ºC |
|---|---|---|---|
| Chipboard | Without exposure | 137 | 19 |
| | UV irradiation | 137 | 19 |
| Fiberboard | Without exposure | 196 | 48 |
| | UV irradiation | 172 | 32 |
| Plywood | Without exposure | 212 | 100 |
| | UV irradiation | 237 | 119 |

### 3.5. Results of Determining the Effect of Temperature on Penetration Strength

The study of the patterns of behavior of wood slabs during melting was carried out only for particle boards and fiberboard. The results of penetration tests at temperatures of 20, 40, 60 ºC in the coordinates lg τ – σ without external influences and after exposure to UV radiation are shown in Figures 11 and 12.

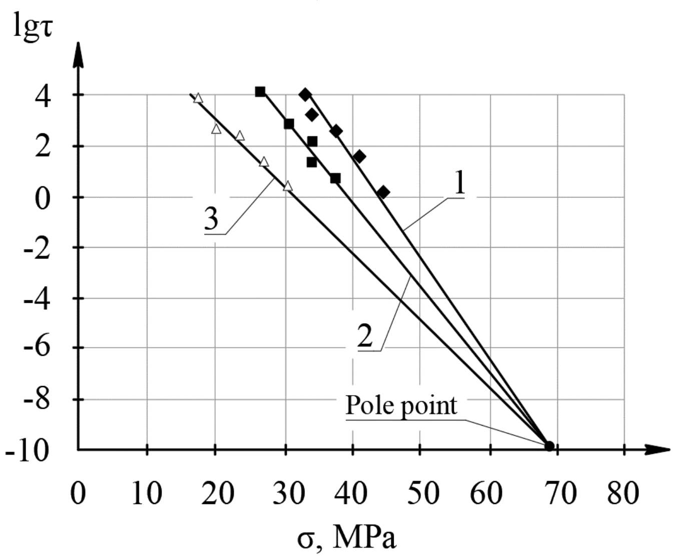



(a)

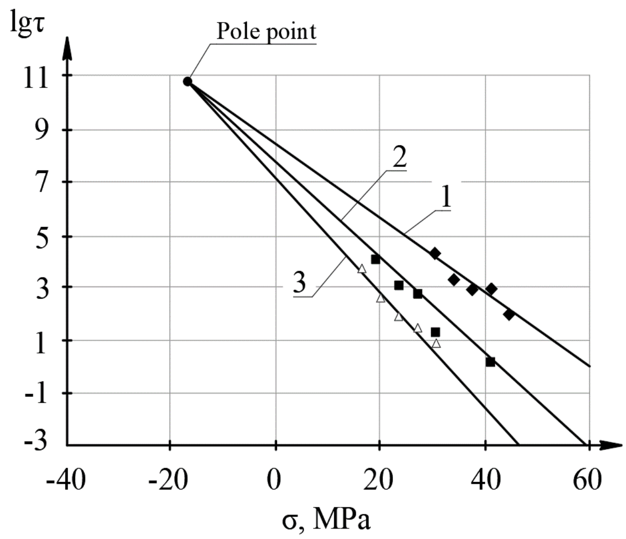



(b)

**Figure 11. Dependence of the logarithm of durability on voltage and temperature for chipboard: a - without external influences; b - after UV irradiation (1 – at 20 ºC; 2 – at 40 ºC; 3 – at 60 ºC)**




(a)




(b)

**Figure 12. Dependence of the logarithm of durability on voltage and temperature for fiberboard: a - without external influences; b - after UV irradiation (1 – at 20 ºC; 2 – at 40 ºC; 3 – at 60 ºC)**

The dependences of the logarithm of the velocity on the inverse temperature for wood slabs both before and after exposure to ultraviolet radiation are linear and converge at one point. This confirms the temperature fluctuation characteristic of the deformation of wood slabs during melting. After ultraviolet irradiation, the dependencies take the form of reverse rays. As a result of grapho-analytical rearrangements of these graphs, the constants of thermal oscillations are calculated, which are shown in Table 6.

**Table 6. The value of thermal fluctuation constants of wood slabs during penetration before and after exposure to UV radiation**

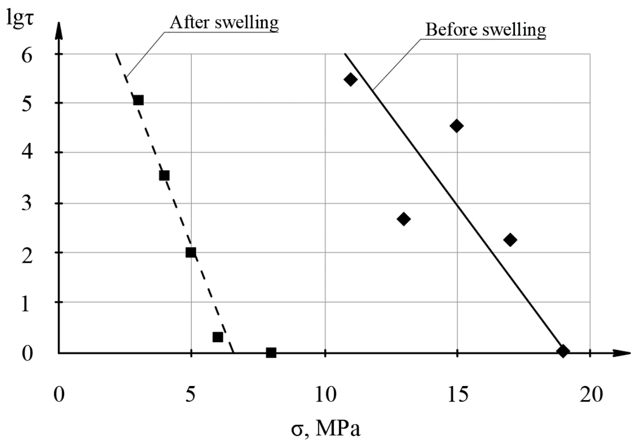
| Materials | Type of exposure | Thermal fluctuation constants | | | |
|---|---|---|---|---|---|
| | | $\tau_m$, sec | $T_m$, K | $U_o$, kJ/mol | γ, kJ/(MPa×mol) |
| Chipboard | Without exposure | $10^{-10}$ | 455 | 68 | 6.47 |
| | UV irradiation | $10^{7}$ | 260 | 12 | -3.33 |
| Fiberboard | Without exposure | $10^{-10}$ | 476 | 175 | 1.83 |
| | UV irradiation | $10^{11.5}$ | 253 | -22 | 0.32 |

These constants characterize the introduction of the indenter into the surface of the material during melting. As can be seen, ultraviolet irradiation causes significant changes in these constants.

When studying the effect of UV irradiation on the nature of the introduction of a solid indenter during penetration, thermal oscillation constants were obtained, which allow us to judge the degree of influence of this type of aging on durability. It is established that after 50 hours of photoaging in wood slabs, the constants of thermal oscillations change, accompanied by the transformation of the direct beam (the dependence of the logarithm of durability on voltage) into the reverse.

### 3.6. Results of Determining the Effect of Moisture Absorption on Transverse Bending Strength

In order to study the effect of water on the durability of wooden slabs, long-term tests were carried out. The experimental data obtained in lgτ – σ coordinates are shown in Figure 13.




(a)

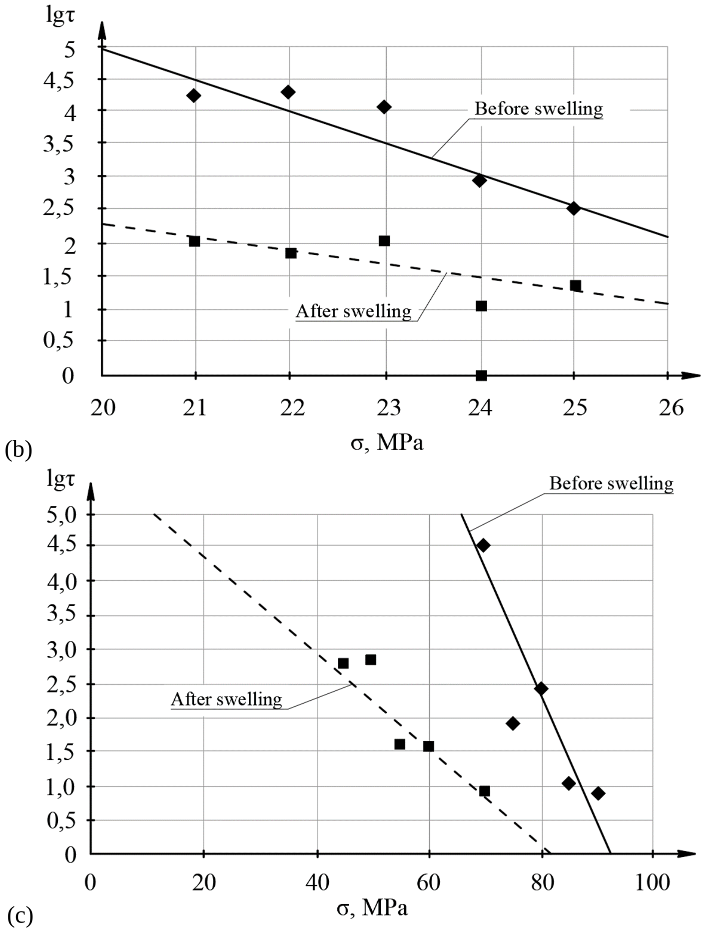



**Figure 13. The dependence of the logarithm of durability on the voltage for wood slabs before and after swelling for 1 hour a - chipboard; b - fiberboard; c – plywood**

It can be seen that the nature of the dependencies before and after exposure to water remains, but for all materials, there is a significant loss of durability and strength.

Humidity has a very significant effect on the durability of plywood. His strength dropped by about 4.5–5 times. Chipboard products should be insulated from contact with moisture, as the load-bearing capacity of this material drops sharply on impact. The most moisture-resistant material turned out to be fiberboard, which has the least decrease in durability and strength.

## 4. Conclusion

Studies of the effects of thermal aging and UV irradiation on the physical and mechanical characteristics of wood composites have shown that the deleterious effects of these influences destroy the binders, namely polymer-enhancing additives. This is confirmed by the fact that after exposure to UV irradiation and thermal aging, there is a decrease in the density of the material and consequently in its susceptibility to water. This also proves a general decrease in the strength of wood composites, namely resistance to transverse bending and penetration. The influence of water also impairs performance, but the deleterious effect is not on the binder but on the filler wood. It has been proven that UV irradiation and thermal aging have different effects, as the obtained swelling constants are different from each other. The results of this study show that a comprehensive approach to the study of performance characteristics is the most optimal solution. The application of the thermos-fluctuation concept increases the accuracy of the results since taking into account the operating parameters at different temperature ranges makes it possible to give a much more accurate prediction of the durability of materials. Thus, the considered efficiency indicators considerably deteriorate at high temperatures as compared to low ones. This pattern confirms the basic postulate of the thermos-fluctuation concept that higher temperatures cause much higher energy fluctuations in interatomic bonds and require much less mechanical energy from the outside to break them. The results of this study prove the validity of the proposed methodology for studying the performance characteristics of wood composites. Therefore, further research on the performance characteristics of wood composites, which were not involved in this study, is needed for future studies. In addition, to increase validity, it is necessary to conduct full-scale tests in addition to laboratory studies, which will include the study of real performance characteristics in different climatic zones.

# 5. Declarations

## 5.1. Author Contributions

Conceptualization, E.P., and S.E.; methodology, S.E., V.Y., and V.D.; formal analysis, S.E.; resources, V.Y., V.D., and P.M.; data curation, E.P., and S.E.; writing—original draft preparation, E.P., and S.E.; writing—review and editing, E.P., S.E., V.Y., V.D., and P.M. All authors have read and agreed to the published version of the manuscript.

## 5.2. Data Availability Statement

The data presented in this study are available in the article.

## 5.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

## 5.4. Conflicts of Interest

The authors declare no conflict of interest.

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