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Influence of environmental factors on the surface condition of thermally modified ash wood in polyvinyl acetate adhesive joints

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Abstract. The aim of this work was to study polyvinyl acetate adhesive joints of "thermally modified ash/pine wood" concerning changes in the surface condition of thermally modified ash wood (correlated with changes in the strength of the samples) under prolonged exposure to external factors. Test samples of adhesive joints were placed on a test rack for external exposure. Every three months, they were removed to record destructive changes in the thermally modified wood surface using scanning electron microscopy, assess changes in wettability and the duration of water droplet penetration into the structure (by measuring changes in contact angles over time), and determine changes in the strength of the adhesive joints. It was established that photochemical damage to thermally modified ash wood is the "trigger mechanism" for its further degradation changes. Samples exposed during summer periods exhibited more pronounced destructive changes in the thermally modified surface and a significant decrease in the strength of adhesive joints (from 6.56 MPa to 6.05 MPa after the first cycle and from 5.93 MPa to 5.62 MPa after the second cycle). The study showed that due to a cascade of destructive mechanisms, the structure of thermally modified ash wood, after 24 months of exposure to natural conditions, sustained damage to a depth of 0.05-0.2 mm (while the strength of the adhesive joints decreased from 7.12 MPa to 5.13 MPa), the surface became more hydrophilic, which led to a reduction in the time required for water penetration into its structure. Accordingly, the contact angle on such the surface reached $\theta = 17°$ after 480 seconds, while on the surface of thermally modified ash wood, which was not exposed to natural factors, a similar value was reached only after 570 s

Keywords: external factors; temperature-humidity loads; solar radiation; scanning electron microscopy; destructive changes; contact angle; water droplet penetration

Introduction

Adhesive wood structures are widely used in the production of joinery-construction products, flooring, and various other applications. These structures can be utilised both indoors and outdoors. When exposed to outdoor conditions, they are subjected to various environmental factors that can negatively affect both the wood and the adhesive joints. To mitigate these effects, thermally modified (TM) wood – derived from less valuable or less commonly used species in the woodworking and furniture industries – is often used as the outer layer of such adhesive structures. This is due to its enhanced properties, investigated by D. Jones & D. Sandberg (2020) and A. Ugovšek *et al.* (2018), as well as its aesthetic appeal, as highlighted by A. Mastouri *et al.* (2023).

Ash wood (*Fraxinus excelsior* L.), in particular, is a hardwood species widely distributed across Europe – its high genetic diversity was studied by J. Meger *et al.* (2024), and it is a key forest-forming species in Ukraine, where its successful natural regeneration was examined by V. Tkach *et al.* (2020). Despite its favorable properties – uniform light color, flexibility, hardness, and load resistance – it remains underutilised in woodworking and furniture production, primarily due to challenges in drying and machining. Researchers J. Niklewski *et al.* (2023) assessed the impact of environmental stressors such as ultraviolet (UV) radiation, precipitation, temperature and humidity fluctuations, wind, and abrasive forces on wood, finding that these factors contribute to discoloration, loss of luster, and surface degradation through progressive fiber erosion, often resulting in cracking. O. Pinchevska *et al.* (2022)

confirmed that these environmental factors reduce wood's resistance to various biotic and abiotic agents, thereby compromising structural integrity and shortening the service life of ash wood – a conclusion also noted by J. Stocks *et al.* (2019). Therefore, as outlined in the review by S. Zelinka *et al.* (2022) on wood modification and functionalisation technologies, improving the properties of ash wood through thermal modification – a process involving heating at 160-240°C in low-oxygen conditions – is a justified and effective solution for extending its durability in outdoor applications.

The combination of unmodified and TM wood in adhesive joints offers new opportunities for the production of various carpentry-construction products, including façade elements, doors, window frames, flooring, gazebos, and more. However, the increased surface hydrophobicity of TM wood presents a challenge when bonding TM elements to unmodified wood. Since there are no adhesives specifically developed for TM wood, manufacturers often resort to using inexpensive but potentially hazardous urea-formaldehyde adhesives.

B. Kshyvetskyy *et al.* (2024), who investigated the formation of cohesive and adhesive strength in non-structured and structured polyvinyl acetate (PVAc) films, noted that due to environmental concerns and the need for strong, durable bonds, the shift toward the use of PVAc adhesives with D4 durability class is justified. Moreover, the relatively flexible PVAc adhesive seam can compensate for deformations caused by differences in the moisture expansion of the bonded materials. This provides partial improvement in the elastic-deformation behavior of the adhesive joint and helps absorb shock loads, thereby reducing the risk of structural damage. Research conducted by B. Kshyvetskyy *et al.* (2023) demonstrated that these advantages of PVAc adhesives are crucial for ensuring the strength of adhesive wood joints and that PVAc adhesives are suitable for bonding TM wood to unmodified wood, particularly in structures intended for outdoor use.

Polyvinyl acetate adhesive joints using TM ash wood and unmodified pine wood have become increasingly common. These structural solutions, particularly in the production of window frames for both standard and roof windows, promote the more efficient use of pine wood – a valuable species recognised for its excellent technological, functional, and aesthetic properties. Additionally, these solutions enhance the durability of constructions by protecting natural wood with a TM outer layer while simultaneously improving its thermal insulation properties, as TM wood has lower thermal conductivity compared to unmodified.

Considering that the adhesion of PVAc adhesives to the surfaces of different wood species and to TM wood – obtained through the thermal modification of certain species under specific treatment parameters – varies, additional information is needed on the strength of TM ash/pine wood adhesive joints, especially when used in outdoor conditions. D. Godinho *et al.* (2021) conducted a review on thermally modified wood exposed to various weathering conditions and noted that, during outdoor exposure, the surface of TM ash wood is subjected to a complex combination of environmental factors – primarily fluctuations in humidity, direct precipitation, UV radiation, temperature changes, and additional mechanical impacts such as wind and airborne dust.

However, to date, relatively little attention has been given to investigating the changes in the surface characteristics of TM ash wood during prolonged outdoor exposure, as well as the condition of the aged wood surface in terms of water penetration into its structure. It is assumed that extended environmental exposure increases the water permeability of TM ash wood surfaces, which may subsequently lead to a reduction in adhesive joint strength. Therefore, the relevance of this study lies in the need to obtain comprehensive information about the changes occurring in adhesive joints under extended exposure to external factors. This includes both the degradation of the TM ash wood surface and the partly associated decline in adhesive joint strength – an area where detailed data is currently insufficient.

The aim of this work was to study polyvinyl acetate adhesive joints of TM ash/pine wood concerning changes in the surface condition of TM ash (correlated with changes in the strength of the samples) under prolonged exposure to external factors.

Materials and Methods

Testing of "thermally modified ash/pine wood" samples in an open environment. The total number of "TM ash/pine wood" (TM-Ash/W-Pine) polyvinyl acetate adhesive samples, formed in accordance with the DSTU EN 205:2014 (2014) standard, was 225. They were divided into two groups: 25 TM-Ash/W-Pine control samples, used to evaluate the condition of TM-Ash surfaces and to determine the initial bonding strengths, respectively; and 200 TM-Ash/W-Pine test samples, used to assess changes in TM-Ash surface condition after exposure to atmospheric factors and to determine changes in bonding strengths.

To investigate the impact of environmental factors on the thermally modified ash (TM-Ash) surface condition and, simultaneously, on the strength of the adhesive joints, 200 TM-Ash/W-Pine test samples were installed on a test rack 1 meter above the ground following EN 927-3 (2006). The samples were positioned 20 mm apart to ensure air circulation and placed at a 45° inclination, with the thermally modified ash wood surface facing outward and oriented southward. The research was conducted in the Western region of Ukraine (Lviv, Ukraine: 49°50′17″ N, 24°01′23″ E) – an area with a moderately continental climate characterised by mild temperatures and high humidity. The samples were installed on the test rack in November, and the exposure lasted 24 months in total. A batch of samples (25 pieces) was removed from the test rack every three months to observe changes in the TM-Ash surface condition (denoted as TM-Ash^{n}, where $n = 3, 6, 9 \ldots 24$ months) and to determine the strength of the adhesive joints (denoted as TM-Ash^{n}/W-Pine, respectively).

Time-dependent water contact angle values measurement. TM-Ash surfaces from TM-Ash/W-Pine control samples and TM-Ash^{24} surfaces from TM-Ash^{24}/W-Pine test samples were cut to dimensions of 2 × 7 × 15 mm (thickness × width × length) for the surface wettability test. Using a syringe, a droplet of distilled water was placed at the center of the test surface. The experiment set-up consists of microscope, camera connected to a computer for image storage and processing. Sequential images of the droplet on the surface of the sample (in the direction of fibers) were obtained at regular intervals using the camera Casio Pro EX-F1. The contact angle values were determined from the images using an image analysis program (Fig. 1).

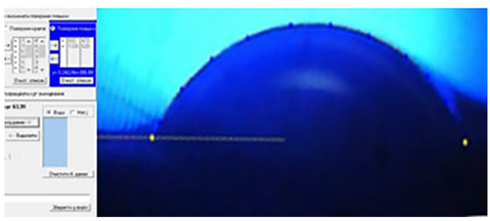

Figure 1. Determination of contact angle in image analysis program

Source: compiled by the authors

Scanning Electron Microscopy (SEM). Evaluation of the TM-Ash surface condition in TM-Ash/W-Pine control samples and the TM-Ash^{n}

surfaces of TM-Ash^n/W-Pine test samples (exposed to an open environment for $n = 3, 6, 9\ldots24$ months) was conducted using a scanning electron microscope (SEM, JEOL IT 500 LV, Japan). For this, 5 × 5 × 2 mm samples were cut from the TM-Ash and TM-Ash^n surface structures and coated with a thin layer of gold to improve conductivity before observation. The operating parameters of the scanning electron microscope were as follows: accelerating voltage (EHT) – 14.7 kV; working distance (WD) – 10.5–14.5 mm. SEM images were captured at 500 × magnification.

Results and Discussion

Control samples TM-Ash/W-Pine and test samples TM-Ash^n/W-Pine, which, according to the research methodology, were removed from the rack after exposure in natural conditions for *n* months, were used for research on changes in the strength of adhesive joints and changes in the thermally modified ash wood surface condition.

The average strength of the TM-Ash/W-Pine control samples was 7.12 MPa. These results indicate their reliability, as they correspond to the chipping strength of pine wood along the grain. The ability to form strong polyvinyl acetate adhesive joints made from thermally modified wood were confirmed by research of M. Mamonova *et al.* (2022). It was noted that, despite the decreased wettability of thermally modified wood, an increased penetration depth of PVAc adhesive into the structure of wood, treated at rather low temperatures of 180°C, was observed. The findings also suggest the possibility of forming an adhesive seam with the lower permissible limit of strength when joining thermally modified wood elements treated at 180°C, 200°C, and 220°C – with structures of lower permeability.

The change in the strength of the TM-Ash^n/W-Pine test samples occurred in stages, depending on the duration of their exposure to environmental factors. At the same time, it should be noted that the intensity of natural factors' effects depended on the season. As studies have shown, the most hazardous factors for such polyvinyl acetate adhesive compounds were ultraviolet radiation –its intensity being the highest in the summer period – along with elevated temperatures and humidity. According to observations made during the experiment, the adhesive joints of wood formed with polyvinyl acetate adhesive began to change their behavior. This was noticeable both visually, as slight flaking began to appear along the edges of the samples between the wood and the adhesive, and through a reduction in strength. For example, after the summer research period, the strength of the adhesive samples decreased significantly: the strength of the adhesive samples decreased from 6.56 MPa (TM-Ash^6/W-Pine samples) to 6.05 MPa (TM-Ash^9/W-Pine samples). A rather significant change in the strength of the samples was also observed during the second summer exposure period, when the strength of the samples changed from 5.93 MPa (for TM-Ash^{18}/W-Pine) to 5.62 MPa (for TM-Ash^{21}/W-Pine). It should be noted that, overall, the average strength of adhesive samples aged in natural conditions for 24 months decreased from 7.12 to 5.13 MPa. The above changes in the strength of adhesive joints occur under the cyclic action of humidity, temperature fluctuations, solar radiation, precipitation, etc., during exposure. Considering the final strength values of the adhesive samples, it can be concluded that adhesive joints unprotected from external environmental effects withstand the impact of natural factors while maintaining their operational capacity.

Control samples TM-Ash/W-Pine and test samples TM-Ash^n/W-Pine were also used to study changes in the surface condition of thermally modified ash wood. For SEM observations of TM-Ash and TM-Ash^n surfaces, three adhesive samples were selected from the total number of TM-Ash/W-Pine control samples, as well as from each batch of TM-Ash^n/W-Pine test samples (aged in natural conditions for *n* months). TM-Ash and TM-Ash^n surfaces were prepared for SEM observations according to the above method. No significant differences in the surface structures of the three duplicate samples from each batch were detected by SEM observations. Therefore, Figure 2 shows SEM images of only one sample.

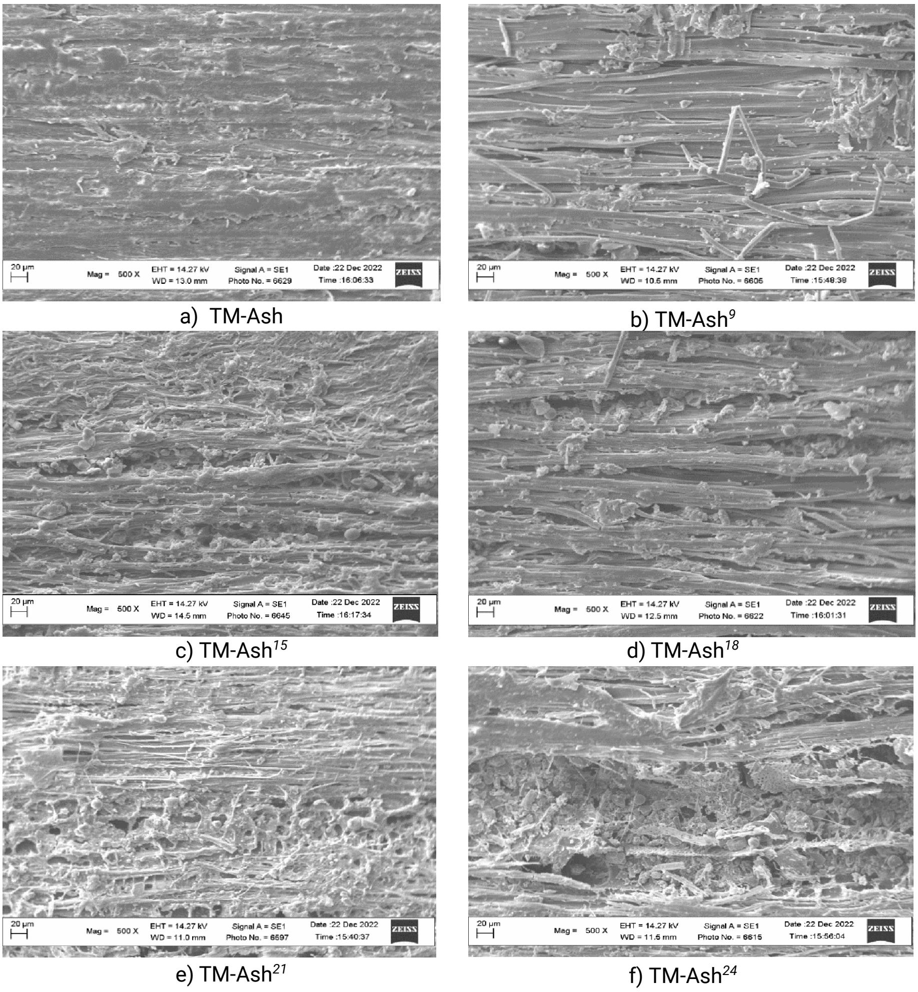

Figure 2. SEM images of TM-Ash and TM-Ashn surfaces at 500 × magnification
Source: compiled by the authors

As shown in Figure 2a, the TM-Ash surface is characterised by a relatively homogeneous and smooth structure, formed during thermal modification as the result of complex physicochemical transformations in the wood matrix under high temperatures, leading to a decrease in porosity and lignification. The TM-Ash surface element of the TM-Ash/W-Pine adhesive sample exhibited a brown color, as seen in Figure 3a. M. Gaff *et al.* (2023) emphasised the role of the breakdown of C = O and C = C bonds in hemicelluloses and lignin, which facilitates the formation of chromophoric structures responsible for the characteristic color changes in thermally modified wood.

It should be noted that no significant structural changes were observed on the surface of the thermally modified wood during the first nine months of exposure to natural conditions (as confirmed by SEM observations). However, over time, under the influence of various environmental factors, structural changes began to appear on the TM-Ash^{n} surfaces of adhesive samples (accompanied by a color shift – gradual graying was observed), which were recorded using SEM images presented in Fig. 2b-f. The first significant changes in the condition of the TM-Ash surface, as a direct indicator of the dynamics of wood degradation under the influence of environmental factors, were recorded in SEM images after nine months of exposure of adhesive samples to natural conditions. These changes were manifested in an increase in structural irregularities (Fig. 2b). This period corresponds to the highest average temperature (+25°C in July) and solar radiation, as well as the highest amount of precipitation (100 mm).

It can be assumed that intense ultraviolet (UV) radiation initiated the degradation process of the thermally modified wood surface through a series of photochemical reactions. Specifically, UV radiation accelerates surface oxidation, leading to the formation of functional groups such as carboxyl groups, and due to UV absorption, chemical reactions occur that result in the breakdown of lignin, which in turn contributes to increased surface wettability. Furthermore, the destructive effect of sunlight was supplemented by the action of other environmental factors. UV radiation also has a degrading effect on color pigments, leading to changes in the color of the thermally modified wood surface.

SEM images in Figure 2 illustrate further degradation changes in the thermally modified surface, with increasing intensity due to fluctuations in humidity and temperature, precipitation (rain, snow), and changes in wind force (with abrasive components such as dust). As a result, with prolonged exposure to natural conditions, the surface of thermally modified ash transformed into one with significant structural micro-irregularities.

Notably, substantial changes were observed in the TM-Ash^{21} surface (Fig. 2e), which had been exposed for two summer periods. The condition of the surface of the thermally modified ash wood at the final stage of research (TM-Ash^{24}) is presented in Figure 3b. The SEM images (Fig. 2f) reveal TM-Ash^{24} surface destruction extending into the wood structure. The measurements of the destructive surface changes indicated that the structure of thermally modified ash wood, after 24 months of environmental exposure, was damaged to a depth of 0.05-0.2 mm. However, no areas with deeper damage, such as crack formation, fractures, or fiber lifting, were detected. Therefore, the surface damage was classified as “superficial” due to the degree of erosion.

a *b*

Figure 3. The condition of the surfaces of the thermally modified ash wood at the initial and the final stages of research

Note: a) TM-Ash surface element of the TM-Ash/W-Pine adhesive sample; b) TM-Ash^{24} surface element of the TM-Ash^{24}/W-Pine adhesive sample

Source: compiled by the authors

The results of this study on changes in the surface condition of thermally modified ash wood under prolonged environmental exposure are consistent with findings reported by other researchers who studied the effects of natural outdoor weathering and accelerated aging on thermally modified wood of other species. Z. Vidholdová *et al.* (2023) investigated how thermally modified Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) changed in surface properties – such as color, roughness, and mold resistance – during 24 months of natural outdoor weathering. According to the authors, the surfaces of both thermally modified species gradually lost their original yellow-reddish hue and became increasingly gray, while surface roughness increased over time. The weathered wood was colonised by molds such as *Aspergillus niger* and *Penicillium brevicompactum*.

F. Kačík *et al.* (2025) examined the effects of accelerated aging on the lignin content in thermally modified spruce wood. Their findings indicated that the aging process results in a relative increase in lignin content, mainly due to the leaching of water-soluble extractives. Additionally, lignin in the aged samples exhibited a lower molecular weight compared to that in freshly thermally modified wood, indicating further degradation and the release of larger quantities of aromatic monomers.

Considering the structural changes observed on the TM-Ash[24] surface through microscopic analysis – characteristic of the final stage of environmental exposure – its wettability and the time required for complete water droplet penetration were investigated using the established methodology. The TM-Ash surface, which underwent similar testing, was chosen as a comparative surface.

The contact angles (θ°) were measured at the initial moments when water droplets came into contact with the TM-Ash and TM-Ash[24] surfaces after their spreading (Fig. 4a and Fig. 4b, respectively).

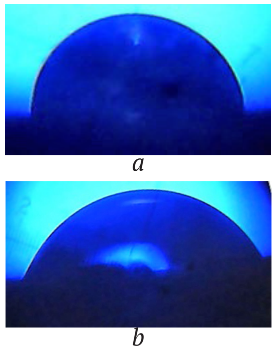

Figure 4. Water droplet
Note: a) on the TM-Ash surface; b) on the TM-Ash[24] surface
Source: compiled by the authors

Measurements taken after 1 second showed a contact angle of θ = 92° for the TM-Ash surface, which is characteristic of a hydrophobic surface. This is consistent with the effects of thermal modification, which increases the hydrophobicity of wood cell walls by removing hydrophilic and hydroxyl groups from hemicelluloses. In contrast, a contact angle of θ = 75° was observed for the TM-Ash[24] surface, indicating its hydrophilic nature (Fig. 5).

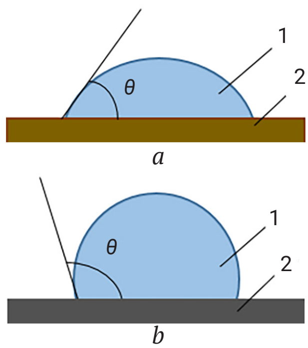

Figure 5. Hydrophilic and hydrophobic surfaces
Note: 1 – water; 2 – surface; 3 – contact angle (θ°)
Source: compiled by the authors

Figure 6 presents the contact angle vs. time data for the TM-Ash and TM-Ash*24* surfaces, considering all measurements. As can be seen from the graphical dependences, in general, long-term environmental exposure of thermally modified ash wood led to the decrease in contact angle values, indicating greater hydrophilicity of TM-Ash*24* surface.

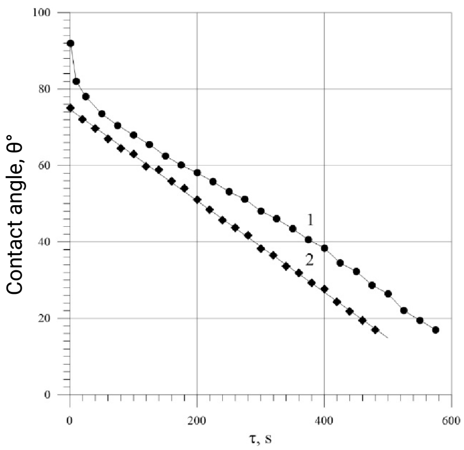

Figure 6. Dynamics of the change in the wetting angle over time for surfaces
Note: 1 –TM-Ash surface; 2 –TM-Ash*24* surface
Source: compiled by the authors

The contact angles and droplet volumes on both surfaces gradually decreased over time due to water penetration into the TM-Ash and TM-Ash24 structures. The results showed that the water droplets penetrated the TM-Ash*24* structure faster than the TM-Ash structure. Accordingly, the contact angle on the TM-Ash24 surface reached θ = 17° after 480 seconds, while on the TM-Ash surface after 570 seconds.

The shorter water penetration time in the TM-Ash*24* structure indicates reduced water resistance, potentially accelerate further destructive processes under the influence of external factors. Moreover, prolonged environmental exposure is expected to increase the water permeability of TM ash wood surfaces, leading to material swelling, negatively affecting its mechanical strength, and partial moisture ingress into the adhesive seam. This, in turn, may result in a decline in adhesive bond strength (Rabko *et al.*, 2021).

However, it should be noted that even with the accelerated water absorption observed on the TM-Ash24 surface, the total time required for droplets to penetrate the structures of both thermally modified samples is significantly longer compared to unmodified ash wood. Unmodified ash wood, being a ring-porous material, was used as the control in this study. The average time for complete droplet penetration was found to be 57 seconds, which aligns with the results reported by M. Žlahtič & M. Humar (2016), who noted that for various wood specimens, the contact angle could not be measured after 60 seconds because the droplets had fully penetrated the surface. The findings of this study regarding the reduced water penetration in TM ash wood are consistent with those reported by A. Lunguleasa & C. Spirchez (2025), who examined the effects of heat treatment on ash wood properties. Their results demonstrated a significant decrease in water absorption and swelling in samples treated at 185°C for 3 hours, compared to untreated wood.

O. Horbachova *et al.* (2025) investigated the swelling behavior of both untreated ash wood and thermally modified ash wood. Swelling was quantified as the percentage increase in size and volume resulting from moisture absorption, measured from the absolutely dry state to the fiber saturation point. The authors obtained results, showing that swelling varied considerably: for untreated ash wood, it was 7.49%, while for wood modified at 200°C, it was 1.75% relative to the initial dimensions.

Thus, as complex experimental studies of adhesive samples have shown, environmental factors negatively affect both the adhesive joint of thermally modified ash wood and non-modified pine bonded with PVAc adhesive composition with the degree of water resistance D4, as well as the surface of thermally modified ash wood when unprotected. Such studies are important because manufacturers offer various constructions and products (facade elements, doors, window frames, terrace decking, gazebos, etc.), where the combination of thermally modified ash wood and pine is achieved through bonding with PVAc adhesives. In particular, window frames and doors with an outer layer made of thermally modified ash wood, which provides better protection against moisture and biological degradation, offer significant advantages in terms of energy efficiency, durability, and aesthetic appeal. However, they serve as a barrier between external and internal environments. In such constructions installed in buildings, the adhesive joint is protected from direct exposure to external factors, while the surfaces of thermally modified and unmodified wood are subjected to different climatic conditions. As a result, the external environment is characterised by dynamic and unpredictable weather fluctuations, playing a crucial role in the durability of the thermally modified surface, whereas the internal environment maintains relatively stable climatic conditions. Therefore, further research remains essential to predict the long-term behavior of adhesive joints and the surface of thermally modified wood in such constructions to ensure their proper service life.

Conclusions

It has been established that prolonged exposure to cyclic temperature-humidity loads and solar radiation over 24 months caused a decrease in the strength of "thermally modified ash/pine wood" polyvinyl acetate adhesive joints from 7.12 MPa to 5.13 MPa. Samples exposed during summer periods exhibited a significant decrease in the strength: from 6.56 MPa to 6.05 MPa after the first cycle and from 5.93 MPa to 5.62 MPa after the second cycle.

Using scanning electron microscopy, the dynamics of destructive changes on the surface of thermally modified ash wood due to external factors were recorded over 24 months. It was found that photochemical damage to thermally modified ash wood acts as a "trigger mechanism" for further destruction of the surface condition under the influence of external factors, including fluctuations in humidity and temperature (narrowing and expansion of the material's structure), precipitation (moisture penetration into the material), changes in wind force, and the presence of abrasive components in the form of dust (surface wear).

The study revealed that the structure of thermally modified ash wood, subjected to environmental conditions for 24 months (TM-Ash^{24}), was damaged to a depth of 0.05-0.2 mm due to a cascade of destructive mechanisms. The surface damage was classified as "superficial" due to the degree of erosion. The results of the study showed that water droplets penetrated such a structure faster than the structure of thermally modified ash wood, which was not exposed to natural factors (TM-Ash). Accordingly, the contact angle on the TM-Ash^{24} surface reached $\theta = 17°$ after 480 seconds, while on the TM-Ash surface after 570 seconds. The decrease in water penetration time into the TM-Ash^{24} structure indicates the reduced water resistance of this material, which can potentially accelerate further destructive processes under the influence of external factors.

The information on the surface destruction dynamics of thermally modified ash wood and changes in adhesive joint strength is comprehensive and useful for predicting the durability of polyvinyl acetate adhesive joints in TM-Ash/W-Pine. The research results indicate that TM-Ash/W-Pine adhesive joints (using thermoplastic polyvinyl acetate adhesives with with durability class

D4) should not be used in natural conditions with an unprotected surface of thermally modified wood and exposed adhesive joint areas.

It is crucial that a direction for further research has been outlined regarding the strength of TM-Ash/W-Pine adhesive joints under two different climatic environments (indoor climatic conditions and outdoor exposure). The obtained results will have practical significance in ensuring the effectiveness of adhesive bonding and enhancing the overall reliability of structures combining thermally modified and unmodified wood.

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Conflict of Interest

None.

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Вплив факторів зовнішнього середовища на стан поверхні термомодифікованої деревини ясеня у полівінілацетатних клейових з'єднаннях

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Анотація. Метою роботи було дослідження полівінілацетатних клейових з'єднань «термічно модифікована деревина ясеня/сосна» щодо змін стану поверхні термічно модифікованої деревини ясеня (що корелюються із зміною міцності зразків) за умов тривалого впливу зовнішніх факторів. Тестові зразки клейових з'єднань розміщувалися на стенді для зовнішньої експозиції. З тримісячною періодичністю вони вилучалися із стенду для фіксування деструктивних змін поверхні термічно модифікованої деревини за допомогою скануючої електронної мікроскопії, оцінки змін її змочуваності та тривалості проникнення крапель води в структуру (шляхом фіксування зміни значень кутів змочування в часі), а також встановлення змін міцності клейових з'єднань. Встановлено, що фотохімічне пошкодження термічно модифікованої деревини ясеня є «пусковим механізмом» її подальших деструктивних змін. Зразки після літніх періодів експозиції, характеризувалися більш вираженими деструктивними змінами термічно модифікованої поверхні та суттєвим зниженням міцності клейових з’єднань (від 6,56 МПа до 6,05 МПа після першого циклу та від 5,93 МПа до 5,62 МПа після другого). Дослідження показали, що внаслідок каскаду деструктивних механізмів, структура термічно модифікованої деревини ясеня після 24 місяців витримки в природних умовах, зазнала поверхневих пошкоджень на глибину 0,05-0,2 мм (в той час як міцність клейового з’єднання зменшилась з 7,12 МПа до 5,13 МПа), поверхня стала більш гідрофільною, що призвело до скорочення часу проникнення води в її структуру. Відповідно, кут змочування на такій поверхні досягнув θ = 17° вже через 480 с, тоді як на поверхні термічно модифікованої деревини ясеня, що не піддавалася впливу природним факторам, аналогічного значення було досягнуто лише через 570 с

Ключові слова: зовнішні фактори; температурно-вологісні навантаження; сонячна радіація; скануюча електронна мікроскопія; деструктивні міни; кут змочування; проникнення крапель води