Modern Materials and Wooden Housing Construction Technologies

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Abstract. Wood-based products application systems are directly harmonized with its properties. Currently, frame construction of cottages, residential and economic objects is becoming more and more developed. In such systems, an important factor of their effective operation is high-strength and wear-proof wooden elements usage, high-quality insulation and its installation methods.

The article considers modern methods of solid wood technological processing to give it new physical, mechanical, exploitation and aesthetic properties. The main stages of processing, technological and ecological requirements related to the process of wood processing are described. The basic advantages, disadvantages and application of modified wood, Thermally modified wood and nanowood are formulated.

Research findings of seamless welded shells based on polyethylene foam used for heat - hydro - vapor insulation of buildings with wooden frame systems are presented. It is established that the tensile strength in the longitudinal direction of the material is 80-92 kPa, and 29-32 kPa for the weld. The moisture content of wooden structures is 7.7–7.8 percent. Rotten manifestations were not found on the wooden frame, which confirms the feasibility of using these insulation systems for the construction of wooden frame buildings.

1. Introduction

Wood, as a building material, is one of the most requested natural materials owning to its availability, resource renewability and environmental safety. Due to its properties, it is widely used in industry, construction and various sectors of the national economy. Thereat, much attention is paid to the strength and mechanical properties of wood, its appearance and color scheme. However, it also has certain disadvantages which often limit the even wider usage of wood [1-3].

The main disadvantage of natural wood is low physical, mechanical and exploitation characteristics and a linear dimensions instability. Therefore, physical and mechanical properties improving is one of the main tasks in the modern world woodworking industry. Modern research is aimed at studying new methods and technologies of influence on natural wood in order to improve it, that is, to change the main properties for the better. To give the new properties, various technological methods to influence the raw material are used and obtain the new properties that wood acquires. Wood processed in accordance with the exploitational requirements is called technical wood [4-6].

Wood-based products application systems are directly harmonized with its properties. Currently, frame construction of cottages, residential and economic facilities is becoming more and more developed. In such systems, high-quality insulation and its installation methods are an important factor of their effective operation. One of such solutions is the technology of appliance foamed rolled
polyethylene TEPOFOL, based on the possibility of obtaining a seamless heat - hydro - and vapor-insulating shell. Individual rolls of polyethylene foam are fixed to the structure, connected in a lock and welded with hot air [7-9].

In our article, we will focus only on some of the most used ways of solid wood technological processing in order to give it new properties. One of the solutions to the problem of changing the properties and basic physical and mechanical properties of wood is polymer modification. Technological processes of wood modification are developed and applied all over the world [10-12].

Taking into consideration the fact that wood is a material consisting of cell walls, voids and cavities, the modification process can be divided into chemical and physical. The first one includes various types of wood processing, including chemical substances that, under certain conditions, change the composition and properties of the material of the wood cells walls. The second one includes methods (for example, wood pressing or filling wood cavities with other materials) that reduce the content volume of wood cell cavities, as well as changes in the mutual orientation of different cells groups relatively to each other.

An important problem in these processes is to find new modifying materials (modifiers) that can give wood products a complex of necessary properties. In the capacity of such materials, it is proposed to use impregnating makeups based on urea-formaldehyde, alkyd, alkyd-urethane and acrylic resins and acids.

The basic requirements to them is ecological compatibility, the ability to penetrate deeply into the wood, to create high-quality decorative coating that does not require further coating materials, to discharge a function of an antiseptic, that is particularly important for floor coverings, which are often exposed to moisture, a short time of processing and curing, low cost.

2. Materials and methods
Performed studies have shown that the process of wood modification is significantly influenced by the modifying substance viscosity and the method of impregnation on the depth of penetration of the impregnating composition of different temperatures of wood layers. With a decrease in polymer viscosity, there is a noticeable increase in the mass weight gain of the polymer, especially with an additional vacuuming method. It should also be noted that during impregnation, the permeability of wood along the fibers is several hundred times greater than across fibers, and the higher the viscosity of the impregnating agent is, the less its percentage will penetrate into the wood in the direction across the fibers, i.e. into the wood layer [13].

In addition to the significant strength increasing polymer-modified wood compared to the original natural wood has a complex of improved properties, namely:

Modified wood is a material with predefined properties. Therefore, if the customer wishes, it is possible to produce modified products with the required set of properties.

Polymer-modified WPC wood is characterized by the following properties: volume swelling decreases from 15% to 3-4%; strength increases by 4-6 times (except for the strength of static bending and shear parallel to the grain - they are 1.5 times); wear resistance of WPC is 2-3 times higher; durability in aggressive environments (sea water, mineral fertilizers solutions, acids and alkalis solutions); resistance to rotting increases by 2-3 times.

The fire-proofing properties of modified wood depend on the impregnating polymers. Modified wood also acquires a fire resistance 2-3 times greater than natural wood.

The polymer that fills the wood cavities facilitates to increase its biostability. Even at 5% content of phenol-alcohols modified wood obtains almost absolute resistance to wood-attacking fungi.

The increased chemical resistance of modified wood is explained by the delayed diffusion of an aggressive agent into the wood (the colmatung-clogging effect of the polymer); and the increased resistance of the polymer.

The slowed moisture diffusion in the modified wood and the reduced humidity level causes its increased weather resistance and form stability. In the open air, the humidity of natural wood varied
during the year from to 23%, of modified 5-8%. Thus, humidity deformations and stress were 4-5 times less in modified wood than in natural wood.

The processing method as described above has shown good results in improving the physical and mechanical properties of wood, but it is quite expensive and time-consuming. In addition, some of these substances are admitted to be harmful to the environment. Therefore, chemical processing of wood is on the decline in Finland, especially due to the increase of environmental valubles.

Thermomodification is another method of processing wood to improve its physical and mechanical properties based on a constantly controlled temperature treatment during production. As a result of heat treatment, the wood structure changes, changing a number of its chemical, physical and mechanical properties [14, 15].

In the first stage, the temperature of wood is quickly raised to 100 °C by means of heat and steam. Then is slowly raised up to 130 °C. At the same time, the wood is dried, the moisture content is reduced to almost zero. The presence of steam in the chamber prevents cracks appearing in the wood. Under the influence of high temperatures and steam, the wood becomes more elastic. At the second stage, the actual heat treatment takes place. After drying, depending on the final assignment of the product, the temperature in the chamber increases to 180-220 °C and wood is keeped for 2-4 hours. The moisture content of wood is reduced to almost zero. At the final stage, the temperature in the chamber is reduced using water spray systems. The final moisture content of wood is important for its performance characteristics. Therefore, when the temperature reaches 80-90 °C, the wood is again moistened so that the moisture content in it reaches an acceptable level of 5-7%. Depending on the timber species and heat treatment temperature, the cooling phase lasts 5-15 hours. When performing the process of wood thermodification, the costs are only 25% higher than for conventional lumber drying.

As a result of heat treatment, wood’s resistance to moisture and its biological stability are improved. At the same time, extracts of various substances are removed from the wood, as a result, the wood becomes lighter, its equilibrium moisture content decreases, and the thermal insulation capacity increases by the three times. At the same time, wood's stiffness decreases and its strength properties deteriorate slightly. The surface of heat-treated wood becomes very dense, so, for example, its gluing is complicated.

Under the influence of heat treatment, the wood surface always darkens. In case of unsuccessful carrying out the process of heat treatment, the risk of cracking increases. Internal cracking of wood was previously considered the greatest disadvantage of heat-treated wood, especially when the material was later submitted to mechanical processing. Herewith, the drying time increases, despite the use of conventional, well-absorbed in wood PVAc adhesives. On the other hand, paint stays on the surface of heat-treated wood better. Protecting the end parts of wood elements with paint or stitching them with strips is also important for heat-treated wood to prevent water absorption along the fibers.

The technological properties (durability, low hygroscopicity and dimensional stability) of thermal wood make it possible to use it in various directions. No chemicals are used in the production process. Heat-treated products are therefore exclusively natural and environmental friendly. The thermal modification process does not require chemical additives or other additional components.

In the early twenties of our century, a method was developed to improve significantly the physical and mechanical characteristics of wood by impregnating it with an aqueous solution of arabinogalactan and dihydroquercetin from the “extract” of siberian larch.

During the drying process of siberian larch, an aqueous extract, which contains dihydroquercetin molecules encased in a shell of arabinogalactan macromolecule (reaching up to 15% of the wood weight) is extricated from its wood. This unique material with the size of complex particles of about 20 nm after modification is used to impregnate timber of various species with natural polymers to give it new properties. Its solutions have a low viscosity, easily penetrate the capillary systems of plant and animal tissue. It has the properties of an antipyrene [16-18, 22].

The wood nanocomposite or nanowood can be included to a completely new class of materials, namely the nanocomposites based on porous materials or porous nanocomposites.
natural polymer allows for deep biochemical polymerization of the solution with the surfaces of micro and macropores of natural wood in the form of a nanoscale film, evenly over the entire volume of the sample.

The main difference between nanoprocessing of natural wood and all existing methods of processing with flame retardants and antisepctics is the depth and uniformity of the impregnating compounds distribution throughout the volume of the processed body due to the effect of vacuum "pressing" the solution inside the porous body of wood. Herewith, the depth of impregnation and processing reaches 20-25 mm from the surface layer. Consequently, during the drying, impregnation and nanoprocessing process of lumber with thickness up to 50mm, a complete 100% uniform impregnation is achieved, followed by an adsorption and uniform formation of a nano-sized film on the surfaces of micro and macropores throughout the wood body while obtaining (forming) a wood nanocomposite. Due to the fact that the applied solution and the impregnable natural wood have a common related biological basis, the nanowood does not lose its natural ecological properties after processing. Wood nanocomposite is absolutely non-toxic, does not emit any harmful substances and chemical elements during exploitation.

3. Results

Experimental studies on the possibility of using rolled foamed polyethylene in insulation systems of wooden frame buildings were conducted in the following areas: testing of thermal properties of the material and products; testing of mechanical characteristics of products, including the strength of the weld; determining the properties of insulation systems in building conditions, including the assessment of humidity and possible rotten damage to the wooden frame [19-21].

Longitudinal tensile strength tests were performed in accordance with the standards. It was found that the tensile strength in the longitudinal direction for products with a metallized coating is 80-92 kPa, without a metallized coating 80-87 kPa, and for a weld 29-32 kPa.

To assess the heat-protective qualities of an external wall made of a wooden frame with insulation of a foamed polyethylene canvas, an experimental determination of the resistance to heat transfer was conducted on a determined wall part in accordance with the standards "Buildings and structures". The sensors were installed both on the inner surface and on the outer surface of the wall (pic. 1).

![Figure 1. Installation of temperature and heat flow sensors.](image)

The results of experimental determinations of the external wall resistance made of a wooden frame with a foam polyethylene insulation canvas were: thermal resistance of 2.96 m²C/W, heat transfer resistance of 3.12 m²C/W. The determined humidity of wooden structures was 7.7–7.8% - at the level of equilibrium humidity values. Rotten manifestations of wood frame were not detected, which confirms the feasibility of using these insulation systems for the construction of wood frame buildings.

4. Discussion

One of the ways to use thermal wood as a structural material for external facade cladding, which is not afraid of any fluctuations in temperature or humidity, in the form of a terrace board and garden paths.
Thermal wood suits excellent for saunas and baths cladding. When finishing yachts - as a deck board, trimming, as interior elements. Resistance to moisture makes it possible to use it for finishing, which is located close to water: the area next to the pool, interiors of the water parks, baths, artificial reservoirs, etc.

The use of wood in construction is becoming more and more popular. Up until recently, the natural disadvantages of wood as a building material were eliminated by chemical treatment. The result was a product that looked like wood, but was not an example of environmental cleanliness. As such, the European Union in early 2004 introduced a ban on the use of chemically treated wood. Thus, the use of thermal wood in construction as an environmentally friendly material is very popular and relevant today.

Thermal wood has an exceptional functionality for use as a floor in that places where conventional wood requires constant protection and care. Verandas, terraces, patios, outdoor summer kitchens, gazebos, balconies, areas around swimming pools, jetties, bridges, piers, garden paths and sidewalks, porches, landscape solutions and layouts of outdoor recreation areas – wherever the wood needs to maintain its size and geometry at any changes in humidity and temperature, while not being subjected to rot, fungus and mould.

The improvement of physical, mechanical, technological and explotational properties of nanowood is manifested in an increase in density and strength by 10-25% due to the strengthening of the micro and macropores walls with a polymer crystalline water-insoluble film and, as a result, in a decrease in cracking formation, hydrophilicity and gas permeability of wood.

The resulting material can be used for the production of nanostructured building materials: wall and load-bearing structures, beams, furniture panels, various profiles, window and door blocks. Currently, this method of processing is not widely used in industry, but currently the plant for deep processing of conifer into high-quality products based on nanotechnology is under construction in Novokuznetsk.

5. Conclusions
The conducted analysis showed that when choosing new technologies in the field of wood processing, as well as improving methods and techniques of processing, using modern technologies, the following requirements must be met: technology and protective materials must prevent wood combustion and smouldering, must not cause corrosion of wood-contacting metal parts and details, must reduce the hydrophilic (hygroscopic) properties of wood, must be environmentally safe for people and animals, must not emit harmful substances, they should improve the physical and mechanical properties of wood and, at least, should not affect its useful natural properties.

The conducted research, which results are presented in the article, have shown that one of the promising options for using modified wood products are frame structures. To create seamless insulation shells mounted on such structures, it is permissible to use rolled polyethylene foam. The absence of rotting damage to the wooden frame and the thermal characteristics that meet the standards confirm the feasibility of using these insulation systems for the construction of wooden frame buildings.

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