Compressive Strength Along and Across Wood Fibers Modified by a Polymer Composition with a Nanostructured Filler

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Abstract Today, the main materials for the construction of buildings and structures are concrete, brick, wood, and metal. Improving their strength and operational characteristics is a priority task of modern scientific research. The use of thermochemical modification of wood makes it possible to improve its physical and mechanical characteristics. The paper presents a method of thermochemical modification of wood with polymer compositions based on dimethacrylic polyester and based on dimethacrylic polyester with the introduction of carboxylated CNTs. The method of testing samples for compression along and across fibers is shown, as well as the dependences of "load and strain" are shown, the strength values of samples and so on are found, and the results are statistically processed.

An increase in strength has been established an increase in the compressive strength of the modified scaffold along the fibers - 43%, across the fibers - 58% compared to the reference one was found.

Keywords Wood · Polymer · Nanostructured fillers · Strength

1 Introduction

Wood is one of the most important materials used in construction and other areas of the national economy [1, 2]. Along with its advantages - high strength, hardness, low thermal conductivity, chemical resistance, wood also has significant disadvantages - anisotropy, high porosity and hygroscopicity, and a tendency to bio-damage, which significantly reduces the service life of wooden structures and products [3–10].

To reduce the impact of wood приscavenging during itsи use, the modification process is used [11–14]. Modification is understood as the process of directed changes

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N. Vatin et al. (eds.), *Proceedings of MPCPE 2022*, Lecture Notes in Civil Engineering 335, https://doi.org/10.1007/978-3-031-30570-2_22

in the physicomechanical, thermophysical, tribotechnical, and biochemical properties of wood in relation to the operating conditions of wood products [15–17]. Modified wood has increased strength, durability, biostability, lower moisture and water resistance, as well as higher resistance to aggressive environments and other improved properties compared to natural wood [18–21].

The optimal method of wood modification is its thermo-chemical modification - under the influence of temperature using polymer materials [22–24]. ПPolymers, including those that do not have protective properties, when introduced into wood, increaseт its chemical and biological resistance, strength, hardness, and durability. Polymer compositions can act both on the surface and completely or partially penetrate the wood structure, they help to increase the resistance of modified wood to water, ultraviolet radiation and biological pests.

Polymers used for wood modification should have a number of properties - low viscosity, low evaporation, and polarity for better penetration into the capillary structure of wood and physical and chemical interaction with wood components. After curing, the modifier must have high resistance to water, acids, and alkalis, be strong under static and dynamic loads, and be environmentally friendly. Polyester resins and compositions based on them have all these properties.

A number of studies have been conducted on the introduction of nanostructured fillers into the polymer matrix and the use of the resulting compositions for wood modification [25–27]. The introduction of nanomaterials into wood improves its properties, due to their unique characteristics. [28–31]. Due to their size, nanostructured fillers penetrate deeply into the wood, helping to improve its properties.

2 Methods

In the framework of the presented study, an enlarged technique for modifying wood with a polymer composition and a comparative analysis of the results of testing standard samples for compression along and across fibers are presented.

For each of the corresponding series of tests, the research methodology proposed in the current norms of the Russian Federation was used.

For compression tests three series of five samples in each were formed for testing on the raw material. Series 1 – samples from "reference" wood (samples #1–5), series 2-samples from wood modified with dimethacrylic polyester (samples #6–10), series 3 – wood modified with dimethacrylic polyester with carboxylated carbon nanotubes (samples # 11–15).

Preparation for testing includes the following tasks:

1. Production set of samples of "reference" wood is made. For compression tests along and across fibers, samples are made in the form of a rectangular prism with a base of 20 × 20 mm and a length along the fibers of 30 mm.
2. Production set of samples of modified wood was made (fritters No. 6–15)

A low-viscosity polymer composition based on hot-cured polyester resins is used as the matrix. Samples No. 6–10 are modified with a polymer composition based on dimethacrylic polyester and dry hardener (0.25 mass parts). Samples No. 11–15 are modified with the following composition: liquid resin based on a new dimethacrylic polyester, dry hardener (0.25 parts by weight), surfactant (OP – 10) in the amount of 0.5 parts by weight), carboxylated carbon nanotubes (CNTsof the Taunit-M series) (0.5 parts by weight). The structural elements are evenly dispersed over the volume of the composition for 15 min by an ultrasonic dispersant with an ultrasonic wave frequency of 30 kHz.

Samples of reference wood in a bathoй with a polymer composition are placed in a mobile unit for vacuum infusion. The sample impregnation time is 30 min, and the vacuum pressure is 90 kPa.

After impregnation, the samples are transferred to a drying laboratory шshelf, where they are cured at t = 1–00 °C for 60 min.

3. Before testing, the images are conditioned at a temperature of (20 ± 2) °C and relative humidity of (65 ± 5)% for 24 h.

The samples were tested on an electromechanical bursting machine REM-100-A-1. To perform the test, the fritter is placed in a compression testing device. The sample is loaded evenly with a constant loading speed or a constant speed of movement of the loading head of the machine 4 mm/min.

A general view of the samples during the crumple test along the fibers is shown in Fig. 1. A general view of the samples during the crumple test along the fibers is shown in Fig. 2.

A general view of the samples during the cross-fiber crease test is shown in Fig. 2.

a) b) c)

Fig. 1 Samples of wood when tested for compression across fibers: a) series 1; b) series 2; c) series 3

a) b) c)

Fig. 2 Wood samples tested for compression along the fibers: a) series 1; b) series 2; c) series 3

3 Results and Discussion

The results of testing samples at compression and across the fibers and compression and along the fibers of the samples are shown in Figs. 3, 4, respectively.

The destruction of the samples during compression along the fibers was plastic in nature with the formation of a characteristic "fold" in the form of individual wood fibers that lost their stability.

The results obtained from the results of destructive studies wood samples have a significant spread of values due primarily to the anisotropy of wood. The value of wood strength is found by the formula 1

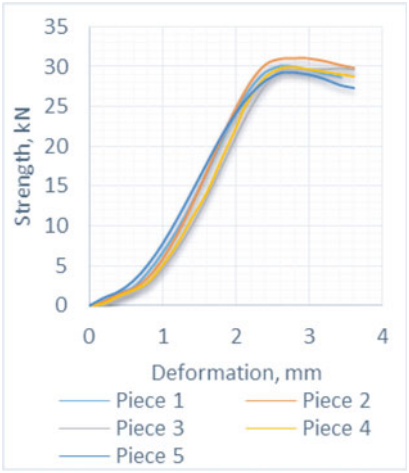
$$\sigma = \frac{P_{\max}}{a \cdot b} \tag{1}$$

where P_{max} is the maximum load, kN;

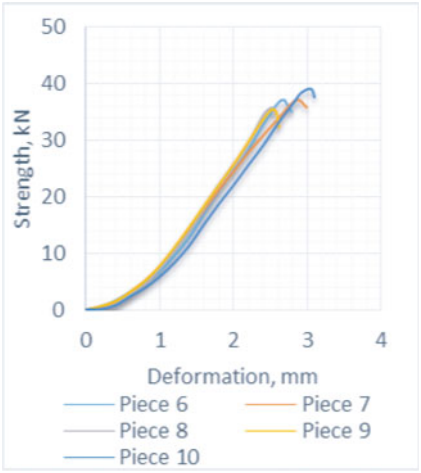
a and b are the cross-sectional dimensions of the sample, see.

The lowest values of the wood strength limits of series 1,2,3 were obtained by statistical processing of tests based on probability theory and are shown in Table 1.

Based on the data obtained, it can be concluded that the increase in compressive strength along the fibers of wood modified with a polymer composition is 23%, and wood modified with a polymer composition with carboxylated carbon nanotubes is 43%. The increase in the conditional compressive strength along the fibers of wood modified with a polymer composition was 3.5%, and wood modified with a polymer composition with carboxylated carbon nanotubes was 58%.



a)



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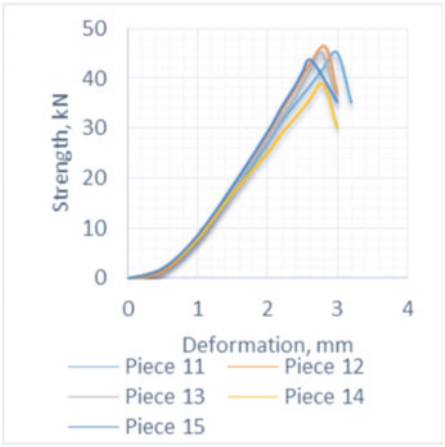

c)

Fig. 3 Changes in the strength of pine wood during compression testing along the fibers: a) series 1; b) series 2 c) series 3

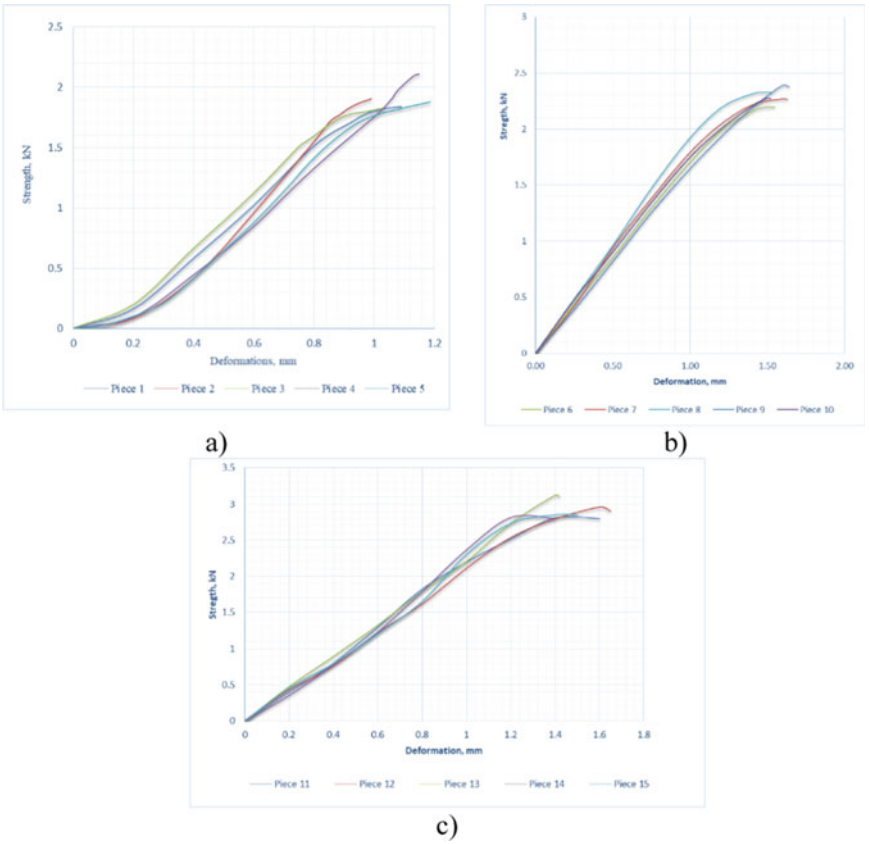

Fig. 4 Change in the conditional tensile strength of pine wood when tested for compression across fibers: a) series 1; b) series 2; c) series 3

Table 1 The lowest value of the wood strength limits of series 1, 2, 3

	Compression along the fibers		Compression across the fibers	
	The lowest strength value, kgf /^{cm2}	Accuracy indicator of the obtained cf. value	The lowest strength value, kgf /^{cm2}	is an indicator of the accuracy of the obtained cf. value mean value
Series 1	611.93	2.27%	26.41	4.67%
Series 2	752.24	2.35%	35.63	2.88%
Series 3	878.01	1.50%	41.70	3.94%

4 Conclusions

Based on the results of the presented study, the following conclusions can be drawn:

1. The proposed method of wood modification can significantly improve its physical and mechanical properties. The increase in compressive strength along the fibers reaches 23%, across the fibers-35%. By introducing carboxylated carbon nanotubes into the polymer compositions нанотрубок, it is possible to achieve an increase in compressive strength along the fibers-43%, and across the fibers-5–8%.
2. The optimal composition for wood modification is a composition of liquid resins based on dimethacrylic polyester, dry hardener (0.25 mass parts), surfactants (OP-10) in the amount of 0.5 mass parts), carboxylated carbon nanotubes (CNT of the Taunit-M series) (0.5 mass parts).
3. Modified wood has improved operational parameters, namely, increased resistance to biological pests, chemical influences, and moisture.

Acknowledgements The study was carried out using the equipment of the interregional multispecialty and interdisciplinary center for the collective usage of promising and competitive technologies in the areas of development and application in industry/mechanical engineering of domestic achievements in the field of nanotechnology (Agreement No. 075-15-2021-692 of August 5, 2021).

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