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Survey of the Designs of Wooden Architectural Monuments

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Abstract. The article describes a method for examining the material of monument structures using physico-chemical studies. The surface of samples of wooden structures was investigated by electron microscopy. The study of the capillary structure of wood was determined by kinetic changes in water adsorption. The possibility of destruction of wood structures in time was determined by the mycological method. Wood samples were taken for examination from the following monuments of wooden architecture: The Kremlin of Rostov the Great; Kizhe Reserve Museum; St. Nicholas Church in the village of Llava; piles of the Assumption Cathedral STSL; Seraphim-Diveevo monastery.

1. Introduction

Monuments of wooden architecture are the cultural heritage of the world community [1-3]. Especially valuable with elegant unique architecture are the monuments of wooden architecture of Russia. To preserve the monuments of wooden architecture in time, it is necessary to periodically conduct a survey of structures. When restoring structures, it is necessary to determine the degree of their preservation and to predict their durability. To solve these problems, a physicochemical method was developed with the participation of mycological studies.

The main component of the polymer composite of wood is the ligno-carbohydrate complex (LUK). Cellulose and lignin are combined into a spatial polymer structure containing reactive hydroxyl groups. Preservation of wood strength is determined by the invariability of the chemical composition and structure of the onion. The presence of organic carbon-containing polymers in wood causes the exposure of wooden structures and wood products to biocorrosion. In the presence of biodegradable fungi, the destruction of wood occurs, which increases with wood moisture more than 18% [4]. For a reasonable determination of the durability of structures containing viable spores (FS) of biodegradable fungi, it is necessary to control the change by chemical analyses.

Cellulose and stucco (components of onion), as well as changing the structure of wood by electron microscopy. The strength of the samples depends on changes in the capillary structure of wood. Changing the capillary structure of wood affects strength and durability. This change was determined by the difference in water sorption.

2. Methodology

We had samples of designs of wooden architecture monuments from the Kremlin of Rostov the Great, the Kizhi Museum, a house on Moscow's Small Vasilyevsky Lane. The duration of operation of buildings and structures of these objects is 100, 150, 350, 400 and 1000 years. There were also wood samples from the pile foundations of the Assumption Cathedral of the Holy Trinity St. Sergius Lavra and piles of the Stables yard of the Rostov Kremlin; St. Nicholas Church from the village of Llava, Arkhangelsk Region, wooden beams on the floor of the Bishop's Hotel of the Seraphim-Diveevo Convent, etc.

Mycological studies were carried out to determine the type of biodegradors on wood samples and quantitatively determine viable spores by direct sowing of wood samples on solid agar nutrient media, followed by counting the number of viable spores of fungi per 1 sq.cm and determining the species composition of the community. Wood samples were placed on the surface of sterile wort agar and Saburo medium in Petri dishes and incubated at a temperature of 27-28°C and relative humidity of 90% for a week or more. The types of fungi were determined according to [5, 6], using the recommendations set forth in [4, 7].

As a physico-chemical studies, a chemical analysis of the wood composition was carried out for the Classon lignin content using the Komarov method, and cellulose was determined according to the Kürschner – Heffer method [8]. The method of IR spectroscopy was used to determine the chemical changes in the components of LAA [9]. The structure of wood was studied by electron microscopy [10].

3. Results and its discussion

The results of the mycological analysis of wood samples are shown in table 1. The kinetics of water sorption by the wood of the monuments made it possible to determine the changes associated with the specific surface of the sample material.

Table 1. The quantity of viable spores of fungi on wood samples.

No	Wood sampling location	Microorganisms (MO) detected in the sample		The number of FS per 1 sq. cm	The concentration of MO in 1 g of sample (total number)
		Wort Agar	Saburo Medium		
1	Seraphim-Diveevo Convent. Bishop's hotel. Wood floor beam	Ophistoma sp. Aspergillus niger; Aspergillus flavus; Penicillium cyaneo-fulvum; Penicillium biforme.	Ophistoma Aspergillus Penicillium Yeast Lypomyces	178	5·104
2	Kizhi. Seregin House	Aspergillus niger; Ophistoma; Aspergillus flavus; Fusarium; Serpula lacrimans	Serpula Actinomyces Lypomyces Yeast	126	4·103
3	Church of St. Nicholas, the village of Llava, from the eastern wall of the altar outside	Trichoderma viride; Trichoderma koningii; Cladosporium herbarum; Ophistoma	Penicillium Aspergillus Yeast Lypomyces Rodotoruba	214	9·105
4	STSL. Assumption Cathedral,	Aspergillus niger; Mucor hie ta Us Ophistoma, Fusarium	Yeast Lypomyces	193	2·107

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	wooden foundation piles	Penicillium capculatum			
5	Maly Vlasyevsky Lane, Building 4. Part of the wall in the attic.	Penicillum biforme; Penicillum cyaneo-fulvum; Aspergillus glaucus; Aspergillus niger; Stemphylium sp;	Penicillum Yeast Lypomyces Candida Rhodotoruba	112	8·103
6	Piles of the Rostov Kremlin.	Penicillum chryso-genum; Penicillum capculatum; Aspergillus glaucus; Ophistoma; Fusarium	Penicillum Aspergillus Yeast	102	3·104
7	Rostov the Great. Stable yard. Depth 2.5 m. Pile.	Penicillum biforme; Cladosporium, Penicillum rugulosum, Fusarium	Penicillum Yeast Lypomyces	67	5·102

In the presented wood samples, mold fungi were revealed (5 species of Penicillum, 3 species of Aspergillus, Fusarium); biologically damaging - Trichoderma, Cladosporium, Mucor; wood-destroying Ophistoma serpula stemphylium; yeast and yeast-like fungi Candida, Lypomyces, Rodotoruba. The concentration of viable spores in the wood of damaged structures ranged from 67 to 214 sp./sq.cm. As is known from literary sources, the concentration of FS above 80 sp./sq.cm creates a dangerous situation [9]. The dependence of compressive strength along wood fibres on the number of viable spores is shown in Figure 1.

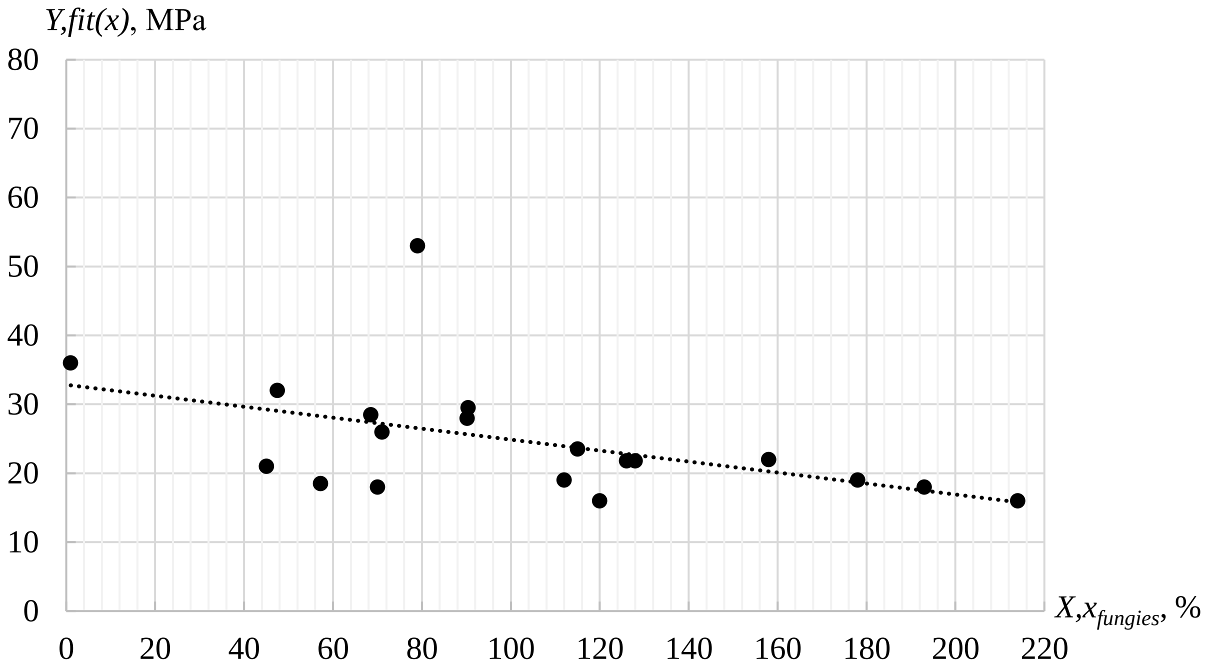


Figure 1. The dependence of the compressive strength along the wood fibres on the number of viable spores per sq.cm (the smallest strength of the samples is 1.3.4, table 1).

As shown by mycological studies, samples of the Bishop's hotel (floor beam) of the Seraphim-Diveevo monastery are more susceptible to biocorrosion. The outer wall (eastern) of the St. Nicholas Church, the village of Lavlya, wooden piles of the Assumption Cathedral STSL.

Wood adsorption of monuments of wooden architecture. Wood is a sorbent with a branched capillary-porous structure. Kinetic curves of sorption of woody water of various monuments are shown in Figure 2.

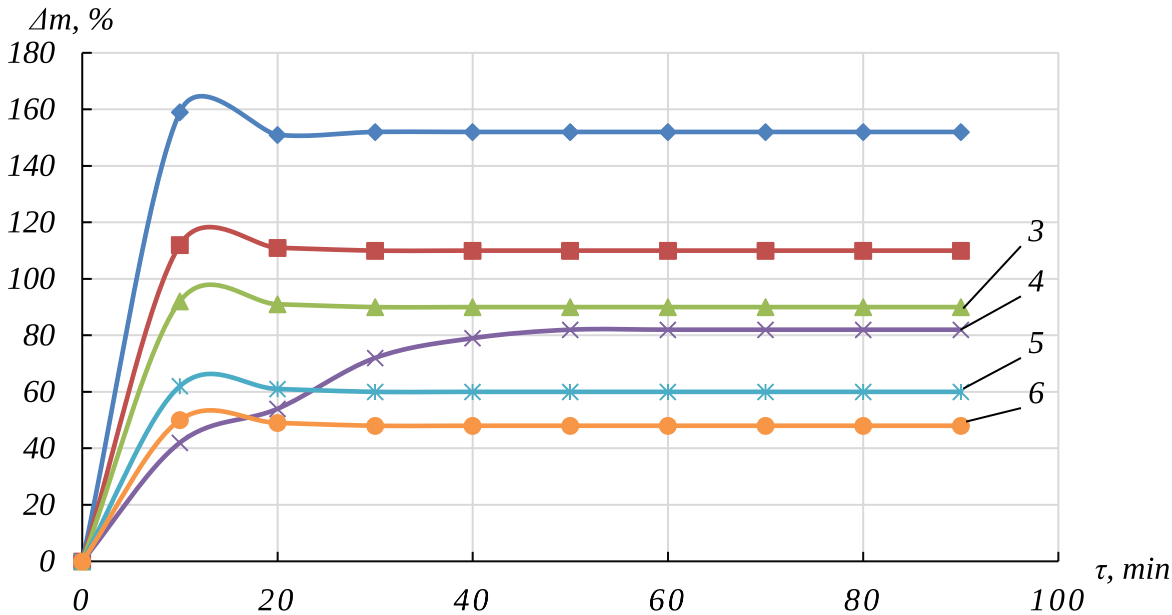


Figure 2. Kinetic water sorption curves of woody monuments of wooden architecture:
1 - source wood; 2 - eastern wall of the Nikolaev church; 3 - Bishop's hotel; 4 - Assumption Cathedral STSL; 5 - piles of the Rostov Kremlin; 6 - piles of the Rostov Kremlin (depth 2.5 m).

Structural failure (other than force impacts) begins from the surface. Destruction leads to "loosening" of the surface layer of wood [11]. Water absorption, water adsorption increases. One of the indicators of the destruction of the surface of a layer of a structure is the quantity A, the limiting value of adsorption. Of all the samples studied, the largest sorption of water is at the outer eastern wall of the St. Nicholas Church. (Figures 3-4).

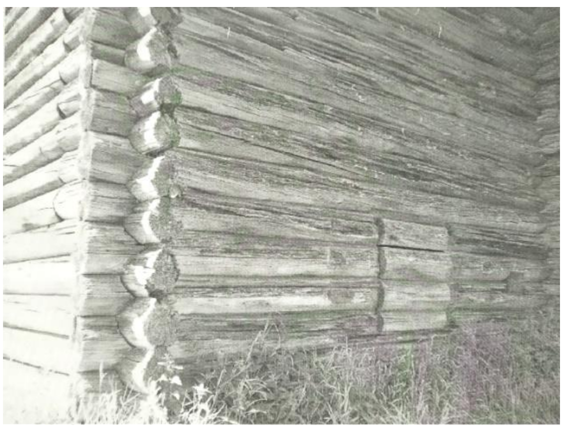
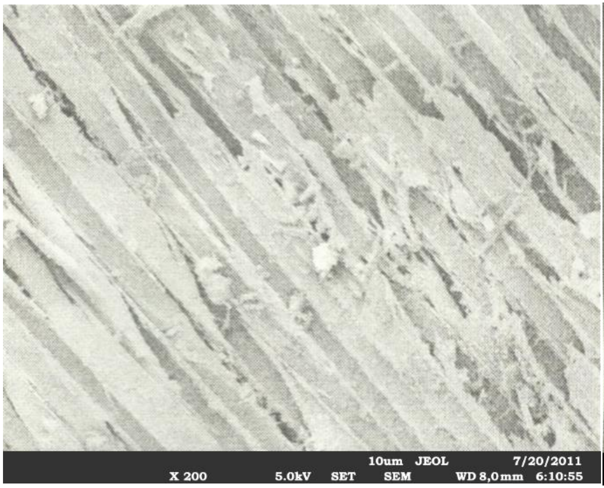
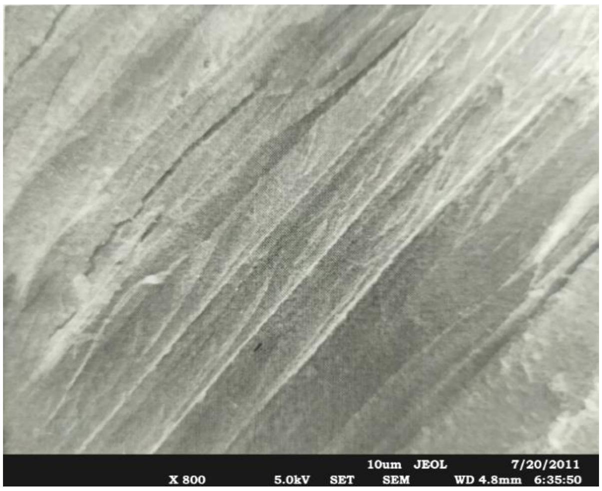


Figure 3. The outer eastern wall of the St. Nicholas Church, Arkhangelsk region, Primorsky district, the village of Lavlya (1581-1584).



a)

b)



c)

d

e)

Figure 4. The destruction of wood fibers on the eastern outer wall of the St. Nicholas Church (a - uv. 200x times; b - uv. 800x times); violation of the lignin matrix of the eastern outer wall of the St. Nicholas Church (c- in - at. 800x times; d - at. 2000x times; e - at. 6000x times).

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4. Conclusions

The most objective method of examining wooden structures of monuments is physico-chemical studies and studies of mycological destruction of the material. Inspection of the designs of wooden architecture monuments showed once the largest internal change in the structure of wood samples: Nikolskaya Church, the village of Llava, from the eastern wall; wooden piles of the foundation of the Assumption Cathedral STSL; floor beams of the Seraphim-Diveevo nunnery, Bishop's hotel. During restoration, these objects should be treated with reinforcing antiseptic compounds, for example, the composition "Mipor".

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