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# Contents of the selected structural and non-structural compounds in antique wooden flooring

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**Abstract:** *Contents of the Selected Structural and Non-structural Compounds in Antique Wooden Flooring.* Wood durability is defined as its resistance to factors causing wood decomposition, that is the preservation of its qualities to a degree permitting its usage. Sets of antique wooden flooring dated to 1830s present a possibility of investigating to what extent the time that has passed since the wooden flooring was installed, together with the variable environmental conditions, such as variable air temperature and humidity, possible moisture or UV radiation, have affected the content of the most important structural and non-structural compounds of the wood under investigation. In order to specify this, tests were carried out to analyse the extractive compound content by using a chloroform/ethanol azeotropic mixture (93:7 w/w), cellulose isolated by the Kürschner-Hoffer method, holocellulose content with sodium chlorite, lignin according to the Polish Standard and the 1% NaOH soluble substances.

*Ke words:* old wood, flooring, chemical content composition

## INTRODUCTION

The basic requirement for wooden floors is their durability. The flooring wood is exposed to various factors that cause its gradual wear. Among them there are biological factors (fungi, insects, bacteria, algae, lichens and others), chemical factors (acids, bases, salts, aerosols), physical factors (fire, high temperature, light, radiation) and physical and mechanical factors (changes in humidity, low temperatures, mechanical forces) [Ważny 1977]. As a result of those factors, the wood loses its initial durability.

Wood durability is defined as the period of its resistance (that is, the preservation of its properties to a degree permitting its usage) to the factors causing wood decomposition [Krzysik 1974]. Theoretically, wood durability is unlimited if the external factors are eliminated [Vorreiter 1949]. Due to the fact that durability decreases as a result of operation of complex and always individual sets of factors that operate jointly on a particular, individual object [Jędrzejewska 1972], it is difficult to predict or investigate it. Usable durability is defined as the time during which the object preserves its properties in normal conditions of usage.

Wooden flooring durability depends, most of all, on the properties of the material of which it was manufactured, that is the wood species, its structure and chemical content, as well as the characteristics of the environment in which it is located [Kozakiewicz and Matejak 2000]. It has been proved that the time is less important for wood durability [Kollmann 1951, Dzbeński 1969, Kraińska 1988].

For this reason, the research takes into account the influence of the climate of manor house interiors in relation to the external climate, the manner of heating the room, number and activity of the people residing in there and the hygroscopic materials present there. Similarly, the importance of the floor's structure was taken into account, together with the manner and quality of its installation, as well as the usage conditions and the maintenance measures.

The paper includes the identification of chemical content of flooring samples taken from 19$^{th}$ century manor houses that were exposed to the detrimental operation of time. We were interested in the changes of the chemical content of wood produced by climatic factors and by the manner of flooring installation and maintenance. It is a pilot research forming part of a wider research programme concerning the relations between the physical and chemical wood properties and the factors determining its durability within the scope of material, surface finishing and microclimate of antique flooring [Różańska et al. 2011]. The changes will be tracked taking into account the history of each of the sites.

## WOOD AGING CHANGES IN RELATION TO THE LITERATURE

Natural wood aging [Holz 1981] is a process of irreversible changes in its appearance and properties as a result of prolonged operation of atmospheric factors.

Wood durability described by different researchers differs considerably within the scope of each single species [Vorreiter 1949, Kollmann 1951, Wanin 1953]. This is probably due to not having taken into account the process of sample acquisition or the place from which they were acquired, as well as the humidity of the samples and the differences in their density [Holz 1981]. It is well known that frequent changes in humidity are very harmful for the durability of wood. In accordance to Kozakiewicz and Matejak [2000], at constant wood moisture of up to 10%, wood durability is very high, e.g. the wood of Egyptian sarcophagi [Kozakiewicz 1999].

Opinions concerning the processes of natural wood aging are quite divided, but it is assumed that it oxidises because of them (cellulose and lignin decomposition [Unger 1988]) and its crystallinity rises in the function of a very long time [Fukada 1957]. Moreover, the research conducted in this respect is fragmentary due to the difficulties with material acquisition.

## WOOD ORIGIN

The chemical tests included wooden flooring from several manor houses of South-eastern Poland: Tarnowiec and Falejówka manor houses. Taking into account the design, structure and history of the sites, the samples acquired for wooden flooring element tests are estimated to be from 150 to 180 years old.

The mansion and park estate in Tarnowiec was built in the style of classicism in the 30s. It was partially destroyed during World War II and rebuilt in 1952. At that time, the lateral risalits were removed, a knee wall was added and the roof was changed. In accordance with the documentation, the changes did not affect the interior layout within the garden side, where an original wooden flooring set was preserved [Szczepaniak 2010, Bosak 2004, Rybowski 1955, Dubiel 1994]. This flooring is located on beams that are placed on a layer of sand.

The bricked building of the Falejówka manor house has a well preserved date, “1924”, on the dormer facade, referring probably to the building renovation during which it was given its present appearance, while the attic was adapted for bedrooms. The renovation included the rooms on the first floor and the central rooms of the front side [Bosak 2002, Śnieżyńska – Stolotowi and Stolot 1982]. In the garden side, in some of the rooms, oak tile flooring was preserved, whose structure and design is analogous to the Tarnowiec manor houses. The flooring is placed on a ventilated boarding supported by ceiling beams. After the war, the building served as a primary school. Since the 80s, the building has been abandoned and at this moment it is completely ruined (leaking roof, lack of rain water drainage system).

## CHEMICAL COMPOSITION

Dry wood is primarily composed of cellulose, lignin, hemicelluloses, and minor amounts (5-10%) of extraneous materials. Cellulose, the major component, constitutes approximately 50% of wood substance by weight (*Querqus* sp. 39.5-42.8%). It is a high molecular weight linear polymer.

Lignin constitutes 23-33% of the wood substance in softwoods and 16-25% in hardwoods (*Querqus* sp. 24.9-34.3%). Although lignin occurs in wood throughout the cell wall, it is concentrated toward the outside of the cells and between cells. Lignin is a three-dimensional phenylpropan polymer, and its structure and distribution in wood are still not fully understood.

The hemicelluloses are associated with cellulose and are branched, low molecular weight polymers composed of several different kinds of pentose and hexose sugar monomers. The relative amounts of these sugars vary markedly with species (*Querqus* sp. 19.0-25.5%).

Unlike the major constituents of wood, extraneous materials are not structural components species (*Querqus* sp. 3.8-6.1%). Both organic and inorganic extraneous materials are found in wood. The organic component takes the form of extractives, which contribute to such wood properties as color, odor, taste, decay resistance, density, hygroscopicity, and flammability. Extractives include tannins and other polyphenolics, coloring matter, essential oils, fats, resins, waxes, gum starch, and simple metabolic intermediates. This component is termed extractives because it can be removed from wood by extraction with solvents.

The inorganic component of extraneous material generally constitutes 0.2-1.0% of the wood substance, although greater values are occasionally reported [Fengel and Wegener 2003, Rowell 1984, Sjöström 1981, Stamm 1964, Wood Handbook 1999, Wagenführ and Scheiber 1985].

## MATERIALS AND METHODS

The floors are made preferably of older trees of high density, heartwood, with extractive compounds (resins, essential oils, tannins, fats). Technically, the best kind of wood is the oak ring-porous wood, taken from the heartwood. Floorings in the manor houses of South-eastern Poland.

Analyses were performed on oak wood (*Querqus* sp.), acquired from the flooring of the manor houses in Tarnowiec and Falejówka. Then, three samples were taken from each floor. After the selection, the samples were photographed, described and mechanically converted into sawdust. The sawdust was sorted with laboratory sieves in order to achieve the proper fraction passing through a 1.0 mm sieve and retained by a 0,5 mm sieve. Moisture content of wood samples were examined, next samples were extracted using the azeotropic mixture of chlorophorm and ethanol (93:7 w/w) [Antczak et al. 2006], and then and then analyzed carbohydrates and lignins [Krutul 2002, Kacik et al. 1999]. Following analysis were performed: holocellulose content using sodium chlorite, 1% NaOH soluble substances, cellulose content with the use of the Kürschner-Hoffer method, the lignin content in accordance to the PN-74/P50092 standard.

## RESULTS

It follows from its analysis and results presented in Table 1, the chemical composition of tested wood samples differs from the given in the literature [Fengel and Wegener 2003].

Tab. 1: Medium percentage share of structural and non-structural compounds in the tested wood samples. *hemicellulose content has been calculated from the difference between the content of holocellulose and cellulose

| Sample | Humidity [%] | Content in extracted wood [%] | | | | |
|---|---|---|---|---|---|---|
| | | Extractives | 1% NaOH soluble subst. | Lignin | Cellulose | Holocellulos e |
| Oak contemporary wood | x | 3.8-6.1 | 19.0-25.5 | 24.9-34.3 | 39.5-42.8 | 73.2-78.7 |
| Oak Falejówka | 5.6 | 2.3 | 27.6 | 25.0 | 40.9 | 75.1 |
| Oak Tarnowiec | 7.5 | 1.9 | 37.7 | 30.1 | 36.2 | 68.7 |

The analysis of samples of the Tarnowiec floor revealed that in comparison with the data found in the literature it contained an increased level of substances soluble in 1% NaOH. This may be attributed to a number of factors (presented in the part referring to literature) causing degradation and dissolution of the carbohydrates contained in the examined wood. Hemicelluloses, which have amorphous composition and relatively low level of polymerisation, not exceeding 200, are by far more exposed to degradation than celluloses, which are of crystalline-amorphous composition and their average level of polymerisation amounts to 9,000 – 10,000 reaching in extreme cases even 15,000 [Goring and Timell 1962, Fengel and Wegener 2003]. The polymerisation level of celluloses influences the durability of fibres. Therefore, the durability of wood and of any other cellulose materials depends on the level of polymerisation of the cellulose within it. The results reveal that it was the oak floor from Tarnowiec which displayed the greatest changes in the composition of polysaccharides, this relates to both substances soluble in 1% NaOH (significant increase) and to the reduced cellulose content, mainly in its amorphous part. It may have been caused by chemical factors, influence of the environment or physical factors, probably related to the impact of light. The exposure of carbohydrates to UV radiation results in the transfer of energy into the molecules and in a subsequent process of their degradation. The energy accumulated inside triggers the emergence of free radicals and the initiation of numerous chemical reactions. Among those there are: depolymerisation and homolytic cleavage of hydrogen atoms and hydroxyl and hydroxymethylene radicals. The main by-products include hydrogen, carbon oxide and carbon dioxide [Hon 1976]. The Tarnowiec oak floor has considerably less by-products, which may have been caused by their extraction and by the decomposition related to the passing of time and the lack of conservation.

The analysis of samples of the Falejówka floor revealed that the content of structural and non-structural wood components in these samples is very similar to the results of contemporary oak analysis. Such convergence may be attributed to the fact that the wood was provided with fine initial protection and was subsequently properly maintained. For this reason, one observes only minor increase of substances soluble in 1% NaOH. This, in turn, may be caused by low share of degraded β- and γ-cellulose and low share of its amorphous part. Lignin also influences the durability of wood and its mechanical (structural) properties.

The increased mass content of lignin results from the loss of carbohydrate components of the analysed wood.

The differences in composition of the analysed oak floors could have also been caused by the manner of floor assembly and isolation from the ground.

## CONCLUSION

The analysis of the presented data leads to the following conclusions:

The manner of use and maintenance of the oak floor, as well as the external (atmospheric) conditions, influence its chemical composition.

The comparison of samples of the Tarnowiec oak wood with the samples of the Falejówka floor revealed that the former contained much less celluloses, increased level of substances soluble in 1% NaOH and lignin, as well as decreased content of by-products (in relation to the data presented in the literature). This is possibly related to the manner of assembly which was different from the one applied in the Falejówka manor house, i.e. the floor was placed directly on the beams and was touching the sand (no ventilation), thus exposing it to additional degrading factors.

It seems that prolonged exposure to water, increased humidity and light may be the decisive factors causing degradation. These factors may cause hydrolysis and photolytic degradation of the carbohydrate components of wood. The hemicelluloses and the amorphous part of the cellulose are particularly vulnerable.

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**Streszczenie:** Trwałość drewna określa się jako jego odporność na działanie czynników powodujących rozkład drewna, czyli zachowanie swoich właściwości w stopniu pozwalającym na użytkowanie. Pochodzące z lat 30-tych XIXw. zespoły zabytkowych posadzek drewnianych dają możliwość ustalenia w jakim stopniu czas jaki upłynął od ułożenia posadzek drewnianych oraz zmienne warunki środowiskowe, w których skład wchodzą np. zmienna wilgotność i temperatura powietrza, ewentualne zawilgocenie, promieniowanie UV, wpłynęły na zmiany zawartości najważniejszych składników strukturalnych i niestrukturalnych badanego drewna. Aby to określić przeprowadzono analizy zawartości składników ekstrakcyjnych za pomocą mieszaniny chloroform – etanol 93/7 (v/v), celulozy wyodrębnionej metodą Kürschnera-Hoffera, holocelulozy przy użyciu chlorynu sodowego, ligniny wg. PN, substancji rozpuszczalnych w 1% NaOH.

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