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## **THE STATE OF PRESERVATION OF ARCHAEOLOGICAL WOOD UNCOVERED IN THE GROTTA FOUNDATIONS OF THE RETAINING WALL OF THE PALACE MUSEUM IN WILANÓW**

*The following paper presents the results of the examination of archaeological wood from excavations carried out in the gardens of Wilanów Palace. The main purpose of the research work was to determine its state of preservation. In order to accomplish this, chemical and physical examinations were carried out on wood samples taken from the level of the grotto foundations.*

**Keywords:** waterlogged archaeological wood, chemical analyses, physical analysis, European Spruce, archaeology, Wilanów Palace

### **Introduction**

In the course of excavations, relics of material culture made from various species of wood are found at various types of archaeological sites. During archaeological work, architectural remains, elements of constructions, waterworks and plumbing systems, as well as minor objects such as vessels or ornaments, are unearthed. During underwater archaeological work, boatbuilding relics – dugout boats, stave boats and ships are discovered.

The state of preservation of wooden relics depends more on the conditions in which they were kept until the moment of their discovery, than on the duration of their deposition in archaeological layers. The type of used wood and the conditions the objects were in have a considerable impact on their degradation. Of considerable significance for the speed and scale of decay of wood tissue is the type of environment and its pH value, oxygenation, moisture, temperature, the presence of microorganisms, and sometimes also seasonal changes in con-

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ditions [Witomski 2009]. Wooden archaeological relics found in different types of wet natural environments are subjected to other degradation factors. The process of wood degradation proceeds more slowly under anaerobic conditions, occurring in swamps and peatbogs.

Examination of the samples taken from the elements of the construction uncovered at the level of the foundations of the retaining wall of Wilanów Palace's grotto allowed researchers to determine the state of preservation of the construction wood making up the elements of the retaining wall's foundations. This was possible to achieve owing to the fact that the stratigraphy of the lower terrace of the residential garden was established, according to which all the wooden objects were located in the same cultural layers. Determining the wood species – spruce, which did not occur in the Mazovia Region when the retaining wall was constructed (17th c.) – suggests that it could have been brought from the south of Poland as construction material, an assumption corroborated by historical sources which refer to other construction materials used for the building of the retaining wall [Starzyński 1976].

In the year 2003, an archaeological survey commenced inside the garden complex, conducted by the National Centre for Historical Monument Studies and Documentation (currently the National Heritage Board of Poland). The need to conduct the excavations was prompted by the beginning of the renovation of Wilanów Palace and the revitalization of the gardens constituting an integral part of the palace complex. The goal of the archaeological research was to determine the location of the compositional elements of the garden – their form and scale at the different stages of the complex's development.

The retaining wall is already visible on a copy of the oldest plan of the King's property, drawn by Adolph Boy in 1682 [Hanaka 2005]. The process of the wall's construction is also described several times in the letters of architect Augustyn Locci to King Jan III Sobieski [Sikora 2005]. During the excavations, it was concluded that the wall had been erected in a surprisingly inexpert manner. This applies especially to the construction of the bow of the arcade foundations, of the joints between the different sections and the way the formwork was done.

## Material and methods

The grotto foundations were built as an escarpment-based construction. The palace-garden complex is situated on the floodplain terrace of the Vistula River valley, which accounts for the high water table present in the area. The grotto foundations were embedded in narrow trenches, delving ca. 5.10–5.20 m n.p.w<sup>1</sup>. Wood samples for the examination of the state of preservation were obtained from construction element [622], unearthed at the level of the foundations, in trial pit 60.

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<sup>1</sup> Meters above Wilanow level.

The function of the construction [622] is not clear. It consists of long piles of 120 cm in length, set at a 45° angle relative to the face of the wall, embedded beneath the footing of the foundations.



**Fig. 1. Work at the grotto foundations – South-East; a fragment of construction [622] is visible, trial pit 60. [photo Michał Aniszewski]**  
*Rys. 1. Prace przy fundamentach Groty – SE, widoczny fragment konstrukcji [622], sondaż 60. [fot. Michał Aniszewski]*

Undoubtedly, this construction appeared before the creation of the wall itself. It may have originally functioned as a formwork designed to protect the ditch from earth slides during the bricklaying. Driving a row of piles into the natural layers found beneath the construction level may have also served to demarcate the construction line, defining the position of the foundations and the eastern wall of the grotto.

Wood samples for physical and chemical analysis were extracted from the construction element [622], excavated at the level of the foundations, in trial pit 60. After excavation and documentation work in the grotto's retaining wall was concluded, one of the most easily extractable piles was obtained. It was moved to the Department of Wood Protection at Warsaw University of Life Sciences for laboratory analysis. A piece of ca. 50 cm in length was cut out, from which samples

for chemical and physical tests were prepared. The tests allowed researchers to determine the structural and non-structural substance content, hardness and shrinkage. The results and the subsequent analysis based on a comparison of the values obtained with other results and norms were to determine the state of wood preservation.

In order to conduct the chemical analysis and to indicate the moisture content of the wood, the samples were mechanically fragmented and fractionated using a sieve. In order to conduct physical analysis, rectangular blocks of three different sizes were prepared. The study was conducted in the research laboratories of the Department of Wood Protection at Warsaw University of Life Sciences.

The first analysis conducted was the determination of the species of wood used to assemble the construction [622]. The macroscopic characteristics of the material under examination were: a glossy surface, a bright yellow color, the absence of a tinged heartwood, as well as clearly visible growth rings and resin canals. These traits are characteristic of the wood of European Spruce (*Picea abies* (L.) H. Karst). For the botanical identification of the wood, samples with an average moisture content of 11.1% were used. The analysis of the structure of the wood was performed using three anatomical cross-sections: transverse, tangential and radial. The indication of the species was carried out on the basis of the analysis of the anatomical elements, observed under an Olympus BX41 microscope. Visible in the microscopic image of the transverse cross-section were tracheids arranged in regular rows, as well as longitudinal resin canals, their epithelial cells made of thick, ligneous walls. No medullary rays were observed. In the tangential cross-section, transverse resin canals were visible, surrounded by heterogeneous, single row, fusiform medullary rays. In the radial cross-section, 1–4 simple cross-field pits were noted, as well as longitudinal tracheids, distributed in radial rows, while the thickness of the walls of the cells increased towards the growth limit. Visible on the radial walls of the tracheids were infundibuliform cavities arranged in a single row.

The microscopic images unambiguously confirmed the assumption based on the macroscopic characteristics of the material, that the samples extracted from the construction element [622] were in fact European Spruce wood (*Picea abies* (L.) H. Karst).

The identification of the wood species (spruce) which did not occur in the Mazovia Region in the 17th century, may suggest that it was brought from the south of Poland, together with other construction materials used for the building of the retaining wall – information concerning the importing of construction materials can be found in written sources [Starzyński 1976].

The examination of the state of preservation of the wood was conducted using the following test procedures:

1. Determination of the basic technical parameters of the wood was conducted for:

- the absolute moisture content: this was determined through the oven-dry method on dried samples (12 samples measuring  $20 \times 20 \times 20$  mm);
  - the density of the wood: this was determined using the stereometric method according to the procedure of the PN-77/D-04101 [1997] standard (12 samples);
  - linear shrinkage in the radial and tangential directions: this was determined on the basis of the methodology of the PN- 82/D-04111 [1982] standard (6 samples measuring ca.  $30 \times 30$  mm and a thickness of 5 mm);
  - the examination of the resistance of the compressive strength along the fibers: this was performed in accordance with the procedure of the PN-79/D-04102 [1979] standard (12 samples measuring  $30 \times 20 \times 20$  mm);
  - the measurement of the hardness of the wood using the Brinell method: this was carried out with the use of Brinell's hardness tester within the range of a 60 daN load (12 samples measuring  $30 \times 20 \times 20$  mm);
2. The chemical analyses were carried out for:
- the determination of non-structural substance content: this was carried out in the process of extraction in the Soxhlet apparatus using a chloroform and ethanol mixture [chloroform-ethanol (93:7)v]. The percentage of extractive substance content was calculated on the basis of the ratio of the extract mass to dry sawdust (3 samples);
  - the determination of cellulose content in the wood: this was performed using the Kürschner-Hoffer method [Krutul 1994] (3 samples);
  - the lignin content in the studied samples: this was determined according to the methodology of the Polish PN-74/P50092 standard (3 samples);
  - the determination of the content of the substances soluble in the analyzed wood: this was performed with the use of 1% sodium hydroxide [Krutul 1994] (3 samples);
  - the determination of alpha-cellulose content: this was carried out using the gravimetric method [Krutul 1994] on the cellulose mass obtained earlier using the Kürschner-Hoffer method (3 samples);
  - holocellulose content: this was determined according to the methodology described by Krutul [1994] (3 samples);

The values obtained were subsequently compared with test results for modern wood, available in written sources. The indication of the state of preservation of historic wood determines the proper method for any future conservation.

## Results and discussion

**Table 1. Physical properties of archaeological wood from Wilanów and modern European Spruce wood (*Picea abies* (L.) H. Karst)**

*Tabela 1. Cechy fizyczne archeologicznego drewna z Wilanowa oraz współczesnego drewna świerka pospolitego (*Picea abies*) (L.) H. Karst)*

European Spruce Wood ( <i>Picea abies</i> ) (L.) H. Karst <i>Drewno świerka pospolitego (<i>Picea abies</i>) (L.) H. Karst)</i>				
Physical properties of wood <i>Cechy fizyczne drewna</i>		Archaeological wood <i>Drewno archeologiczne</i>	Modern wood according to Krzysik [1974] <i>Drewno współczesne Krzysik [1974]</i>	Change in relation to modern wood <i>Zmiana w odniesieniu do drewna współczesnego [%]</i>
Density of wet wood <i>Gęstość drewna mokrego</i>	[kg/m <sup>3</sup> ]	920	–	–
Density of dry wood <i>Gęstość drewna suchego</i>		421	330–470–680	–10.4
Absolute moisture content <i>Wilgotność bezwzględna</i>	[%]	146	157	–7
Linear shrinkage in the radial direction <i>Skurcz liniowy w kierunku promieniowym</i>		2.99	3.6	–16.9
Linear shrinkage in the tangential direction <i>Skurcz liniowy w kierunku stycznym</i>		6.22	7.8	–20.3
Compressive strength <i>Wytrzymałość na ściskanie wzdłuż włókien</i>	[MPa]	37.5	30–43–67	–13
Brinell's hardness <i>Twardość Brinella</i>		39.7	32	+26.8

The test results shown in the tables for the various parameters of the wood under examination did not diverge substantially from the values determined for modern wood. The density of the archaeological spruce wood differed from the average density of modern spruce by 14%, although it was still within the range of values considered “normal” for this species of wood. An improvement in certain parameters was even noted, namely the decrease in the absolute moisture of the wood by 7% compared to modern wood, as well as a decrease in the linear shrinkage by 17–20%. The resistance to compressive strength decreased by 13%, while Brinell's hardness increased by 27%.



**Table 2. Average structural and non-structural substance content [%] in archaeological wood from Wilanów and in modern European Spruce Wood (*Picea abies*) (L.) H. Karst)**

**Tabela 2. Średni [%] udział substancji strukturalnych i niestrukturalnych w drewnie archeologicznym z Wilanowa oraz we współczesnym drewnie świerka pospolitego (*Picea abies*) (L.) H. Karst)**

European Spruce Wood ( <i>Picea abies</i> ) (L.) H. Karst <i>Drewno świerka pospolitego (Picea abies) (L.) H. Karst</i>			
Structural and non-structural substances <i>substancje strukturalne i niestrukturalne</i>	Archaeological wood <i>Drewno archeologiczne</i>	Modern Wood according to Prosiński [1969] <i>Współczesne drewno Prosiński [1969]</i>	Changes in relation to modern wood <i>Zmiany w odniesieniu do drewna współczesnego [%]</i>
	Content <i>Zawartość [%]</i>		
Cellulose <i>Celuloza</i>	50.6	61.47	-18
Alpha-cellulose (portion in cellulose) <i>Alfaceluloza (zawartość w celulozie)</i>	73.7	–	–
Lignin <i>Lignina</i>	31.6	28.85	+9
1% NaOH Soluble substances <i>Substancje rozpuszczalne w 1% NaOH</i>	9.3	11.65	-20
Holocellulose <i>Holoceluloza</i>	74.2	–	–
Non-structural substances (extractives) <i>Substancje niestrukturalne (ekstrakcyjne)</i>	4.6	3.06	+50

The 18% decrease in the cellulose content and in 1% NaOH soluble substances – small molecule sugars with a simultaneous retention of a good quality of cellulose (a high alpha-cellulose content) was indicative of only slight degradation processes in the wood, caused, under anaerobic conditions, mainly by chemical factors. The increase in the lignin content should be explained by its lack of decay. The increase in the content of extractives may be the effect of the accumulation of various types of deposits, typical for archaeological wood.

Physical and chemical analysis of the material samples taken from the construction element [622] indicated a good state of preservation of the object dating, based on archaeological study and written sources, to the late 17th century.

The parameters of the archaeological spruce wood, dated as 300 years old, were close to the values characteristic for modern material of this species. This was the result of the deposition of the wood in anaerobic layers which preserved it from degradation agents. The grotto foundations, with the creation of which the pole construction [622] is undoubtedly connected, are partly dug into the natural geological strata of an argillaceous structure with decaying plant elements. The spruce piles were driven in beneath the foundation footing; they were found beneath the water table level, a fact which caused additional protection for the archaeological wood.

## Conclusions

1. The state of preservation of archaeological wood, discovered during archaeological fieldwork conducted in the grotto of the retaining wall of the palace-and-park complex at Wilanów, was determined.
2. A slight degradation of the archaeological wood in anaerobic layers was found.
3. The structural and non-structural substance content was similar to that of modern wood.
4. Construction elements [622] were subjected to slow hydrolysis which did not significantly influence the percentage of structural and non-structural substances in the wood tissue.
5. A decrease in the content of aliphatic compounds (ca. 18% of cellulose and ca. 20 % of hemicellulose) was found in comparison with modern wood.
6. The technical parameters of the archaeological wood were close to the values for modern spruce wood.
7. Resistance to the compressive strength of the examined wood was only 13% lower than that of modern wood.
8. Anaerobic layers had a „conservational” effect on archaeological wood.

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### List of standards

**PN-74/P50092** [1974]: Oznaczenie zawartości ligniny

**PN-77/D-04101** [1977]: Drewno. Oznaczanie gęstości

**PN-79/D-04102** [1979]: Drewno. Oznaczanie wytrzymałości na ściskanie wzdłuż włókien

**PN-82/D-04111** [1982]: Drewno. Oznaczania skurczu i spęcznienia

## STAN ZACHOWANIA DREWNA ARCHEOLOGICZNEGO ODKRYTEGO PRZY FUNDAMENTACH GROTY MURU OPOROWEGO PAŁACU W WILANOWIE

### Streszczenie

W niniejszym opracowaniu przedstawiono wyniki badań drewna archeologicznego, pochodzącego z wykopalisk prowadzonych na terenie ogrodu Pałacu w Wilanowie. Głównym zamierzeniem pracy było określenie jego stanu zachowania. W tym celu przeprowadzono badania chemiczne i fizyczne próbek, które pobrano z fragmentu konstrukcji odkrytej na poziomie fundamentów Groty. Otrzymane wartości porównano z wynikami badań drewna współczesnego, dostępnymi w literaturze. Określenie stanu zachowania zabytkowego drewna determinuje odpowiednią metodę ewentualnej konserwacji. Próbkę drewna do badań chemicznych i fizycznych pobrano z elementu konstrukcji [622], odkrytej na poziomie fundamentów, w sondażu 60. Funkcja konstrukcji [622] nie jest jednoznacznie określona. Jej elementami są pale o długości około 120 cm, ustawione pod kątem około 45° względem lica muru, wbite poniżej stopy fundamentu. Po zakończeniu prac wykopaliskowych i dokumentacyjnych w Grocie muru oporowego wydobyto jeden z najłatwiej dostępnych pali. Określenie gatunku drewna – świerka, nie występującego w owym czasie (w XVII w.) na Mazowszu – sugeruje, że jako materiał konstrukcyjny mógł on być sprowadzony z południa Polski, co znajduje potwierdzenie w źródłach historycznych w odniesieniu do innych materiałów budowlanych użytych do konstrukcji muru oporowego.

Badania chemiczne i fizyczne próbek materiału pobranego z elementu konstrukcji [622] wskazują na dobry stan zachowania obiektu datowanego na podstawie badań archeologicznych i tekstów źródłowych na koniec XVII wieku. Parametry zabytkowego, archeologicznego drewna świerka, liczącego około 300 lat, są zbliżone do wartości charakterystycznych dla współczesnego surowca tego gatunku. Jest to wynikiem zalegania drewna w warstwach beztlenowych, które zabezpieczyły je przed czynnikami degradacji. Fundament Groty, z budową którego niewątpliwie związana jest konstrukcja palowa [622], jest częściowo wkopany w naturalne warstwy geologiczne o gliniastej strukturze z elementami gnijących roślin. Świerkowe pale wbite poniżej stopy fundamentu, znajdują się one poniżej poziomu wód gruntowych, co stanowiło dodatkowe zabezpieczenie dla zabytkowego drewna.

**Słowa kluczowe:** mokre drewno archeologiczne, badania chemiczne, badania fizyczne, świek europejski, archeologia, Pałac w Wilanowie

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