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# The chemical composition of oak wood after prolonged influence of variable weather conditions

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**Abstract:** Analyses of oak heartwood chemical composition were performed. Analyzed wood originated from trees after prolonged influence of variable weather conditions. Results were compared with those obtained on the basis of native oak heartwood. Changes in distribution of extractives and lignin on the cross-section were stated, while distribution of cellulose and 1% NaOH soluble substances were similar to native wood.

*Keywords*: oak wood, heartwood, extractives, cellulose, lignin, 1% NaOH soluble substances

## INTRODUCTION

Wood undergoes partial degradation under the influence of external abiotic and biotic factors. This process depends on wood kind, species, structure and chemical composition. Wood durability is the period of wood resistance against degrading factors, when wood keeps its initial properties what allows exploitation.

Factors destroying wood are divided on chemical, physical and biological. Acidic or alkali solutions, sunlight and the oxygen from the air are chemical ones. Physical are atmospheric falls and changes of air temperature and relative humidity. Wood, under the influence of humidity variations, swells and shrinks what causes cracking. Fractures enable the penetration of wood by the air, water and fungus, what causes the destruction of wood chemical components. Bacteria and fungus belong to biological factors of wood degradation. Dependent on species, wood under the influence of different atmospheric factors may be exploited from a few to dozens of years, while wood used outdoors but under the roof, may fulfill parameters of exploitation during 20 – 150 years. Wood stored under the roof in buildings prevented from stains but not heated may survive hundreds of years. This time could be prolonged to 1000 – 2000 years when chamber is heated in winter and the temperature is approximately constant. However, slow oxidation process follows in wood components during this time, what leads to their degradation.

Wood of heartwood species at the age of physiological maturity is the most durable. This mean 100 – 140 year old wood. Durability increases also with the density of wood. The presence of extractives, such as tans, fats, resins, waxes and others raises wood durability.

Krutul and Kozakiewicz (1997) and Krutul and Makowski (2003) examined oak heartwood gained from vertical construction element of barn covered off with gable straw roof, which was in the first class of biological hazard before roof destruction, and, after roof destruction, following 20 years in the second class of biological hazard. Content of extractives, soluble in ethanol – benzene $(1:1)_v$, in wood from the internal part of examined beam, was similar to the value determined for native wood. Wood from the beam surface underwent destruction as a result of external factors action. Destruction in the highest part of analyzed element was stated up to 50 mm inside. Two species of lichens were observed on the beam sufrace: *Hypogymnia physodes* (L.) Nyl. and *Cladonia fimbriata* (L.) Fr. (Krutul and Kozakiewicz 1997). Surface was grey and strongly cracked, what is related to 25 % decrease of alpha-cellulose content, as well as decrease of cellulose and extractives content (ethanol-benzene solution and cool water) in relation to pith adjacent heartwood. Wood inside examined beam saves its durability, what is confirmed by similar cellulose content in relation to native oak heartwood.

Living cells contents is the least resilience for destructive factors action. Among cell wall components, pectins undergo destruction at first, then hemicelluloses and cellulose. Lignin is the most resilience, because it contains phenol groups which inhibit the development of microorganisms. Oak heartwood is saturated with tans which are natural antiseptics and that is why it is resilient for biotic factors influence (Krzysik 1984, Kraińska 1988, Prosiński 1984). Lichens are pioneer organisms decomposing wood. They consist on two symbiotic components – fungus and alga. Fungus covers alga with its hyphae protecting it against drying, while alga delivers for fungus nutrients produced in assimilation process (Lipnicki and Wójcik 1995). Wood under the influence of atmospheric falls is settled by fungus, alga, bacteria and moss.

The aim of this paper is to analyze the changes of chemical components content in oak heartwood gained from well crane pillar and compare with the results obtained from the analysis of native wood (examined right after cutting of the tree).

## MATERIALS AND METHODS

The part of oak heartwood from well crane pillar, where crane neck lays, was taken for analysis. The crane pillar had been actively exploited for 70 years, then it has been lied for next 30 years on the ground in Wyłudki village in Podlaskie province. Analyzed element was stored until the studies beginning at the temperature of 20 °C and relative humidity of cca. 60 %.

The presence of *Hypogymnia physodes* (L.) Nyl. and *Pleurozium schreberi* (Dzwonkowski 2004) was stated on the beam surface after inspection. *Hypogymnia physodes* (L.) is leave thallus, rosette of irregular with the diameter of 3 – 5 cm, loosely connected with the base and belongs to the IV class in the lichen scale. *Pleurozium schreberi* is the loose turf with green, yellow-green or pale-green color. Straight twigs of gametophyte grow most often in one surface and stalk leaves are thick placed, with dimensions 2.5 mm x 1.4 mm, oval shape. Leave edge may be serrated in upper part. These species testify of long lasting atmospheric conditions impact. Following zones were marked out on the cross-section of examined pillar: pith adjacent wood (I), middle wood (II) and outer wood (III). Pillar was sampled with the drill and then milled with the laboratory beater. Samples were fractionated on sieves and 0.49 – 1.00 mm fraction was taken for analysis.

The research included the examination of: moisture content using the drying store-weight method according to the PN-77/D-04100 standard; cellulose content using Kürschner-Hoffer method; lignin content using Tappi T-222 method; content of 1 % NaOH soluble substances (after Krutul 2002). Results were related to the sample mass after extraction with ethanole-benzene (1:1) solution.

## RESULTS AND DISCUSSION

Fig. 1 presents values of extractives content in examined beam. Outer wood contains 27 % and 22 % more of extractives in relation to, respectively, pith adjacent wood and middle wood. In native heartwood (just after tree cutting) pith adjacent wood contains 17 % more of extractives in relation to the outer heartwood and 6 % more in relation to middle heartwood. Results of analysis of extractives distribution on the cross-section of examined element are similar to results obtained by Krutul and Kozakiewicz (1997), concerning changes in oak heartwood gained from vertical construction element of barn. Extractives content in outer wood is 15 % higher in relation to pith adjacent wood and 8 % higher in comparison to middle wood. Action of various weather conditions causes the increase of extractives content in outer and middle wood in relation to pith adjacent wood.

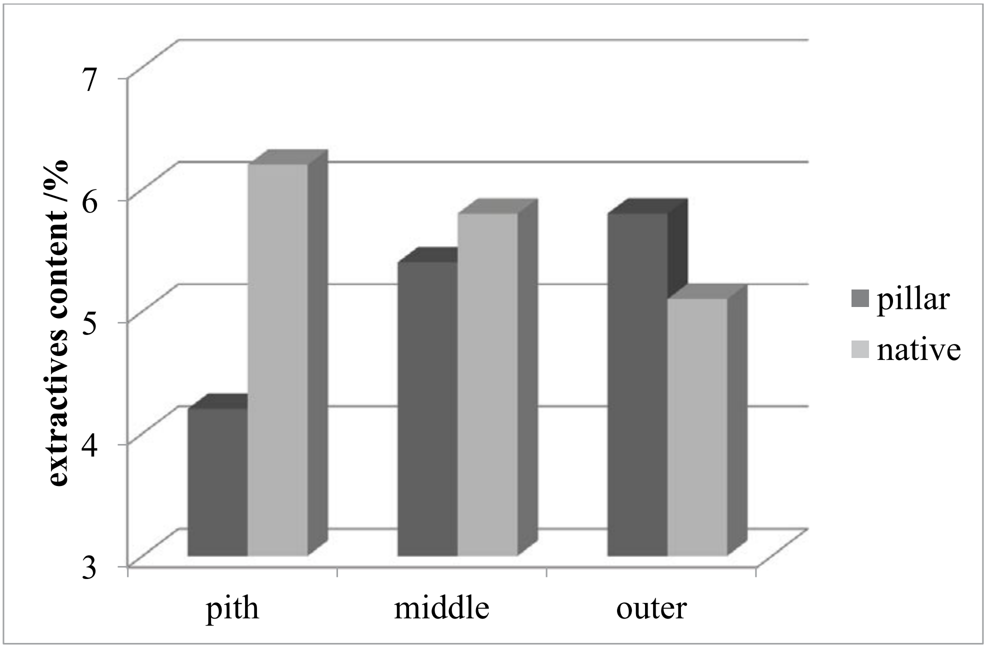


Fig. 1 Extractives content on the cross-section of analyzed beam and native wood

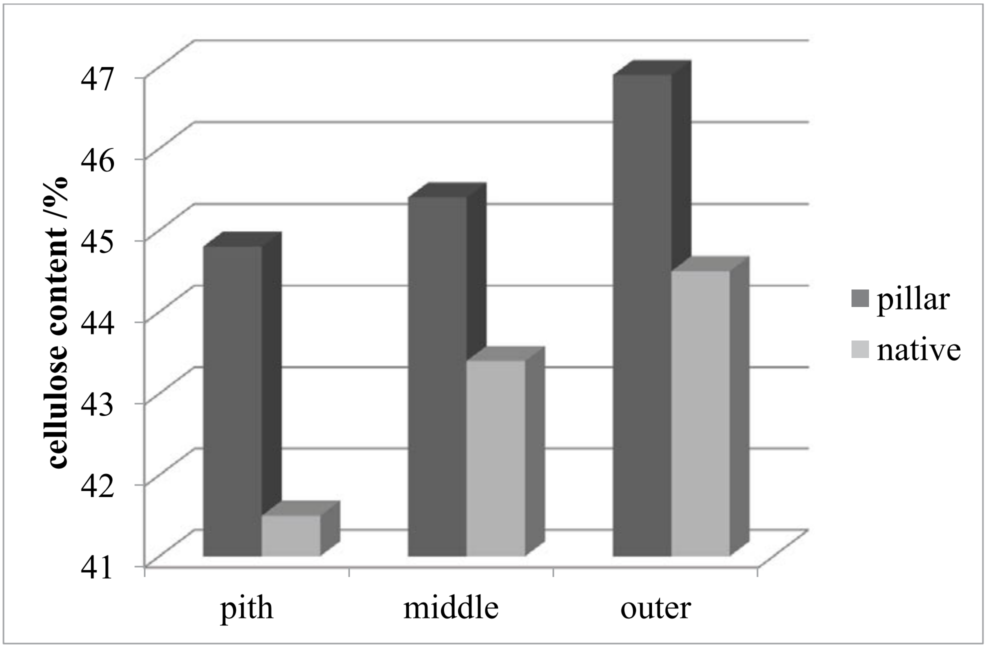


Fig. 2 Cellulose content on the cross-section of analyzed beam and native wood

Cellulose content in outer wood is cca. 4.5 % higher in comparison to pith adjacent wood and cca. 3 % higher in relation to middle wood (fig. 2). Also according to Krutul and Kozakiewicz (1997), cellulose content in oak heartwood gained from vertical building element is 8.0 and 8.4 % higher in outer wood in relation to pith adjacent and middle wood.Cellulose content in native oak heartwood is higher in outer heartwood – cca. 7 % in comparison to pith adjacent wood and 2 % in relation to middle heartwood. It means that obtained results of cellulose content in wood after prolonged impact of weather conditions are similar to results obtained for native wood (fig. 2).

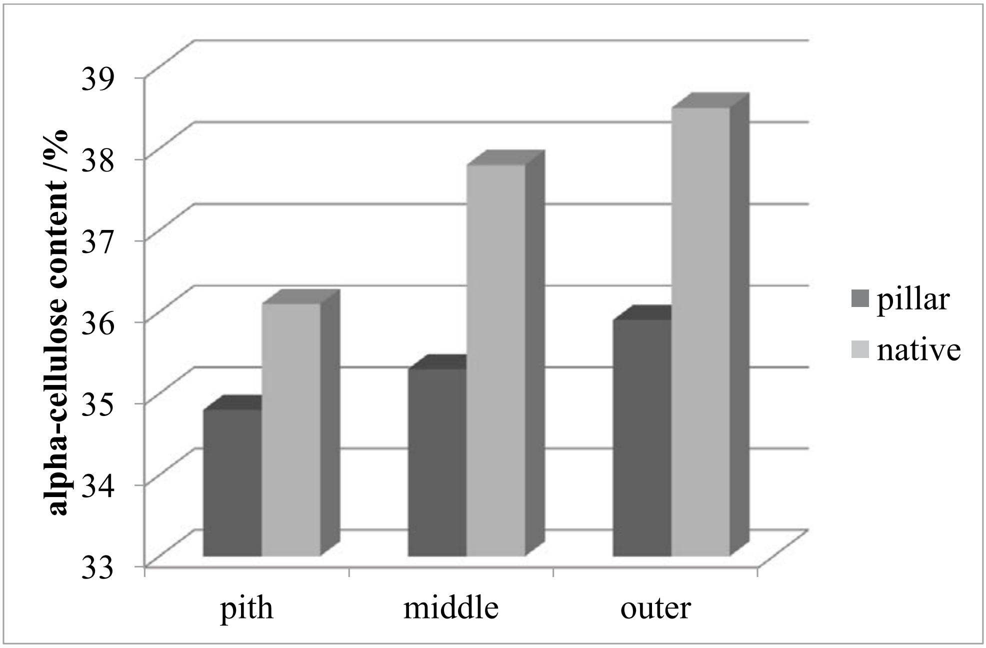


Fig. 3 Alpha-cellulose content on the cross-section of analyzed beam and native wood

Alpha-cellulose content is one of important cellulose properties. Insolubility of alpha-cellulose in 17.5 % NaOH is an important cellulose property in its chemical processing. Alpha-cellulose polymerization degree is higher in relation to beta- and gamma- cellulose. So called pulp is the sum of all cellulose types. The examination of alpha cellulose content in the pulp may be one of the indicators of destructive changes caused by prolonged action of atmospheric factors on wood.

On the basis of data presented in the fig. 3, it may be stated that polymerization degree of the cellulose from outer wood is the highest.  It is 6.5 % higher in relation to pith adjacent wood and cca. 2 % higher in relation to middle wood.

According to Krutul and Kozakiewicz (1997), alpha-cellulose content in all of analyzed zones of oak heartwood is similar. Only in samples from the surface of analyzed element, which was directly submitted to sunshine, temperature changes and atmospheric falls, alpha-cellulose content is cca. 10.5% lower in comparison with other wood zones.

Data presented in the fig. 3 shows that native oak outer heartwood contains cca. 6 % more of alpha cellulose than pith adjacent wood and 4.5 % more than middle wood. This content in particular native wood zones is about 6.5 % higher in comparison to particular wood zones of oak heartwood submitted for the action of atmospheric conditions.

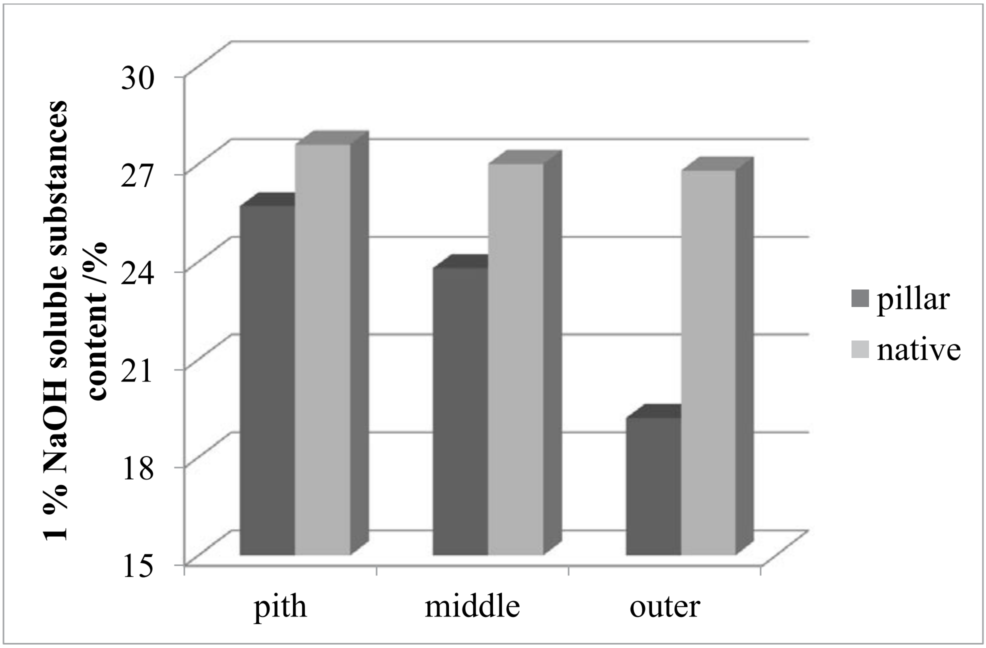


Fig. 4 1% NaOH soluble substances content on the cross-section of analyzed beam and native wood

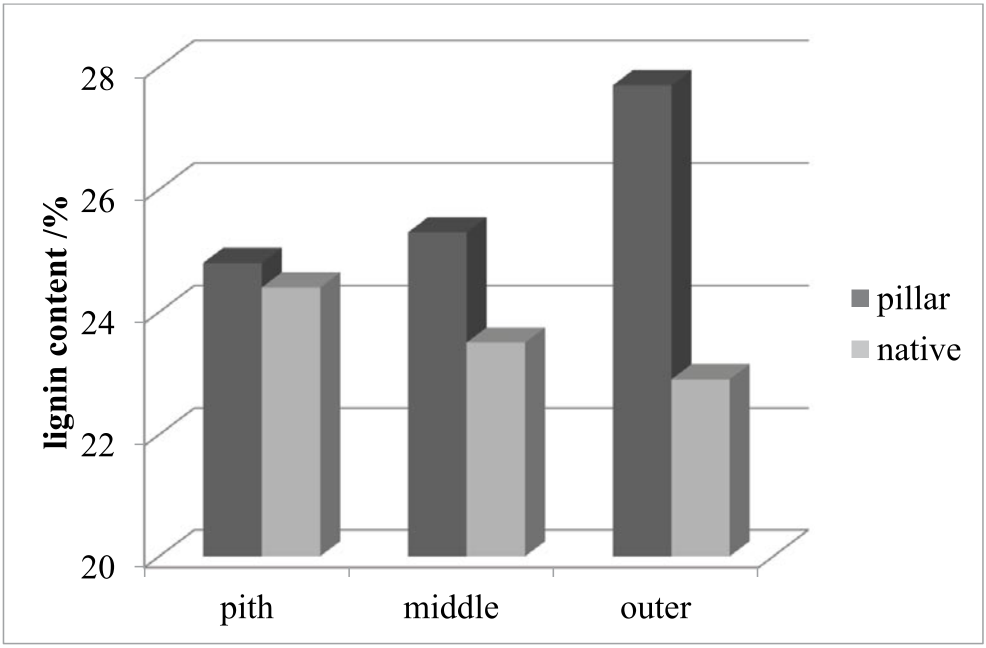


Fig. 5 Lignin content on the cross-section of analyzed beam and native wood

There are other substances in wood which are of polysaccharide character and are soluble in 1 % NaOH at the temperature of 100°C. Their degradation under the influence of acids is faster. According to data presented in the fig. 4, pith adjacent wood from examined pillar contains 7.5 % more of 1% NaOH soluble substances in relation to middle wood and 25 % more of these substances in comparison to outer wood. Also in the native oak wood similar dependence may be observed, but differences are significantly lower – these values are, correspondingly, 2 and 3 %.

Krutul and Makowski (2003) stated that pith adjacent heartwood from examined vertical building element contains cca. 4 % more of 1 % NaOH soluble substances than middle wood and about 15 % more than outer wood. These substances content in outer wood of the pillar analyzed in present paper is cca. 20 % higher in comparison to outer wood from building element examined by mentioned authors. It leads to the conclusion that action of atmospheric condition causes faster polysaccharides degradation in outer wood and increase of 1 % NaOH soluble substances.

Results of lignin content determination are presented in the fig. 5. Lignin content in pith adjacent wood from examined pillar is 2.5 % lower in relation to middle wood and cca. 15 % lower in relation to outer wood. Lignin content in the native pith adjacent wood is 3.5 % higher in comparison to middle wood and cca. 6 % higher in comparison to the outer heartwood (fig. 5).

According to Krutul and Makowski (2003), pith adjacent wood from the examined building element contains 6 % less of lignin than middle wood and cca. 8 % less than outer wood.

Summarizing, there are visible changes in the distribution of extractives, 1 % NaOH soluble substances and lignin on the cross-section of oak wood submitted for prolonged action of atmospheric conditions in relation to the native heartwood. Changes in cellulose distribution were not stated.

## CONCLUSION

After prolonged action of atmospheric conditions changes in distribution of extractives, 1 % NaOH soluble substances and lignin followed in oak heartwood, while distribution of cellulose did not change. Extractives and lignin content in outer wood is higher in relation to pith adjacent wood, while this dependence is opposite in native oak wood.

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Streszczenie: *Skład chemiczny drewna dębowego po długotrwałym działaniu warunków atmosferycznych.* Próbki do badań pozyskano z drewna twardzieli dębowej poddanego długotrwałemu działaniu warunków atmosferycznych. Na przekroju poprzecznym w krążku pozyskanym z podpory żurawia wyróżniono drewno strefy przyobwodowej, środkowej i przyrdzeniowej. Uzyskane wyniki badań odniesiono do danych drewna twardzieli dębowej natywnego.
Zostało stwierdzone, że w drewnie twardzieli dębowej po długotrwałym działaniu warunków atmosferycznych na przekroju poprzecznym w stosunku do drewna natywnego twardzieli dębowej, występują zmiany w rozmieszczeniu substancji ekstrakcyjnych, rozpuszczalnych w 1 % NaOH i ligniny, natomiast nie występują zmiany w rozmieszczeniu celulozy. Zawartość substancji ekstrakcyjnych i ligniny w drewnie strefy przyobwodowej jest większa w stosunku do drewna strefy przyrdzeniowej a w drewnie natywnym jest odwrotnie.
Zawartość substancji rozpuszczalnych w roztworze 1% NaOH jest większa w drewnie strefy przyrdzeniowej w odniesieniu do drewna strefy przyobwodowej, podobnie jak w drewnie natywnym. Jednakże w drewnie po długotrawałym działaniu warunków atmosferycznych zawartość tych substancji w drewnie strefy przyrdzeniowej jest o ok. 25 % większa w stosunku do drewna strefy przyobwodowej, a w drewnie natywnym o ok. 3 %. Rozmieszczenie celulozy jest jednakowe zarówno po długotrwałym oddziaływaniu warunków atmosferycznych jak i w drewnie natywnym.

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