Mr. sc. Slavko Govorčin, Mr. sc. Tomislav Sinković
Šumarski fakultet Zagreb

Some physical and mechanical properties of the Bednja abonos*

Neka fizička i mehanička svojstva abonosa (crnog hrasta zakopanog u zemlji) iz Bednje

Izvorni znanstveni rad
*Prispjelo: 16. 03. '95. • Prihvaćeno: 30. 03. '95. • UDK: 630*0.812*

SUMMARY • *Oakwood buried in the ground, or abonos, is subfossil wood which has been exposed for a very long time to the process of humidification under the influence oof running fresh water. It is black in colour due to a chemical reaction between the tanstuff in the wood and the contents of iron in the water. Besides this change in colour, there are some other significant alterations of the physical and mechanical properties of oakwood. Although some of its properties have changed for the worse compared to the recent oakwood, there is a great demand for the oak abonos, especially when used as veneer, for interior furnishing and manufacture of precious furniture, parts of musical instruments and decorative woodwork.*
Key words: oak abonos (oakwood buried in the ground), wood colour, physical and mechanical properties of abonos.

SAŽETAK • *Abonos ili eban (crni hrast) drvo je odležalo u zemlji koje je dugo godina bilo izloženo procesu humifikacije pod utjecajem vode tekućice. Drvo abonosa hrasta crne je boje, što je posljedica međusobne kemijske reakcije trijeslovine u drvu i željeza u vodi. Osim promjene prirodnog tona boje, nastaju i znatne promjene fizičkih i mehaničkih svojstava hrastovine. Unatoč nekim lošijim svojstvima drva, ali i izrazito velikoj trajnosti u odnosu prema normalnoj hrastovini, drvo abonosa hrasta je vrlo traženo i cijenjeno, posebno kad se upotrebljava kao furnir, za unutrašnje uređenje i izradu skupocjenog pokućstva, izradu dijelova glazbala i za rezbarske radove.*
Ispitivanjem dobiveni rezultati nekih svojstava abonosa hrasta (Quercus sp.), procijenjenoga na oko 4 000 godina starosti, upozoravaju da je kemijski sastav gotovo jednak kemijskom sastavu recentnog hrastova drva, ali sa znatnim povećanjem udjela ekstraktivnih tvari i pepela. Gustoća abonosa hrasta podjednaka je ili malo veća od gustoće recentnog hrastova drva.

---

* Rad je prezentiran na međunarodnom simpoziju "Wood structure and properties '94" u Zvolenu, Slovačka. Zbog ograničene dostupnosti zbornika radova simpozija članak prenosimo u "Drvnoj industriji" uz odobrenje izdavača.

Utezanja abonosa hrasta su u odnosu prema recentnom hrastovu drvu dvostruko veća. Ispitana mehanička svojstva abonosa hrasta znatno su smanjena, s tim da je to očitije kad je riječ o čvrstoći na savijanje.

Iz dobivenih odnosa širine goda i gustoće, odnosa širine goda i utezanja, odnosa gustoće i utezanja, te odnosa gustoće i mehaničkih svojstava abonosa hrasta vidljivo je da oni pokazuju karakteristike recentnog hrastova drva odnosno karakteristike prstenasto-poroznih listača.

Ključne riječi: abonos, eban (crni hrast zakupan u zemlji), boja drva, fizička i mehanička svojstva drva abonosa.

INTRODUCTION

Exposed to natural humidification and other underground processes for hundreds and thousands of years, parts of whole logs of certain tree species have turned into wood highly esteemed for its colour and special properties.

This subfossil wood, which has been lying at the bottom of swamps or lakes under layers of mud and water, is known in the Croatian language as abonos or nabonos. Particularly valued is subfossil oakwood with its unusual, refined green-greyish or entirely black colour, which is the result of chemical raction between the tanstuff in the wood and the contents of iron in the surrounding water.

The water prevented the contact with air by maintaining a relatively low and uneven temperature, thus preventing the fungi from entering and developing in the wood. The deep fresh water assisted the secretion of wood matter subject to decay and the settling of lime and flint upon the wood surface, thus supplying it with an impenetrable coat. Regardless of the distinct longitudinal and transversal fissures, the wood, especially oakwood aged in this way, is extremely durable.

In comparison with properties of recent wood, significant physical and mechanical changes are evident; the density is more or less the same or slightly increased, the shrinkage has increased considerably, and other mechanical properties have generally become poorer.

And yet, oakwood abonos is highly valued not only for its colour and durability, but also for its acoustic properties. It is demanded as veneer, solid wood for interior decorations, manufacture of expensive furniture and parts of musical instruments, as well as for decorative woodwork and wood sculpture.

RESERACH MATERIAL AND METHODS

The available material for the research was taken from the Rinkovac site near a village called Bednja, about 50 km north of Zagreb. It was incindentally discovered during ameliorative operations in the bed of the Bednja river, wich had frequently flooded the land along its banks.

According to the pedological map, this site lies upon hydromorphous soil: glei - amfiglei with characteristics of loamy clay, silt and clay, and carbonate soils. Pedologically, both underground and surface waters exert various kinds of impact upon the soil consisting of loam and clay (personal communication; Andrija Vranković, Faculty of Forestry, University of Zagreb).

The obtained material consisted of several pieces of oak logs *(Quercus sp.)*, whose age has been estimated at 4,000 years by the radioactive carbon C-14 method.

From the available material test samples were made for chemical analysis and various properties established, such as average growth ring width, moisture content, density, linear and volume shrinkage, compression strength parallel to the grain, and static bending strength. On the basis of the obtained values it was possible to determine the relations between the growth ring width and the tested physical properties, as well as those of density and shrinkage on the one hand, and the tested mechanical properties on the other.

Chemical analysis

The chemical analysis was conducted on fractions of wood matter with dimensions between 0,25 and 0,40 mm in absolutely dry state. Standard analytical methods were applied to determine the extractives by using a mixture of methanol and benzene in the Soxhlet apparatus; cellulose was tested by the Kurschner-Hoffer method; lignin by the

Hagglund method; pentosans by the Kull-gren-Tydeen method; hexosans by the 100% difference, and ash by burning in the stove at 700° C.

Annual ring width

Using the measuring loupe with the 0.1 mm resolution the annual ring width was established on the end grain surfaces of the 2 x 3 x 3 cm (in longitudinal (L), radial (R) and tangential (T) directions respectively) samples, which had already been used for the determination of density and shrinkage.

Moisture content

Immediately after the compression and bending strength had beeen measured, the moisture content was determined on the same samples. The gravimetric (oven-drying) method was applied with drying the samples at t = 103 ± 2 °C until constant weight was reached, and the values were expressed as percentage of moisture volume in the wood compared to the volume of the oven dry wood.

Density of air dry wood

The density of air dry wood was determined on the 2x3x3 (LxRxT) cm samples on which shrinkage had been measured, and aslo on the 30x2x2 (LxRxT) cm samples already used for determining the compression and bending strength. The density of air dry wood was eastablished out of the proportion of sample weight and volume as to the moisture content at the moment of testing, expressed in g/cm^3.

Shrinkage

Shrinkage was determined on 2 x 3 x 3 cm (LxRxT) samples cut so that the ring border lines on the end grain sections were parallel to one of the front surface sides. Linear shrinkage was determined from the relation of the size difference of a particular sample size in green and oven dry state and the size of the green sample expressed as percentage.

Volumetric shrinkage was determined from the relation of the sample volume difference in green and oven dry state, and the volume of the green sample expressed as percentage.

Compression strength

Compression strength was determined on 4x2x2 cm (LxRxT) samples exposed to the impact of exterior mechanical force acting in longitudinal direction upon the sample placed between two surfaces at a speed of 6 mm/min. At the moment of the samples rapid strength loss the currently acting force value was recorded and divided with the sample's end grain surface area, and the compression strength parallel to the grain as expressed in MPa was determined.

Bending strength

Bending strength was determined on 30x2x2 cm (LxRxT) samples placed upon two supports at a distance of 28 cm, exposed to a force acting centrally and tengentially upon the rings at a speed of 6 mm/min until the sample broke. The value of the force at the moment of failure was used in the Navier equation to determine the bendning strength expressed in MPa.

RESULTS

Chemical analysis

Standard analytical methods were applied (thanks to Professor Vladimir Sertić, Faculty of Forestry, University of Zagreb) to obtain the following chemical composition of the black oak found in the ground:

extractives	4.53 %
cellulose	41.16 %
lignin	27.42 %
pentosans	23.41 %
hexosans	2.29 %
ash	1.19 %

Annual ring width

The ring width was determined on 50 samples, i.e. 730 annual rings, and the following values were obtained: $\overline{X}$ = 2.15 mm; min = 1.14 mm; max = 3.32 mm; standard deviation (S) = 0.81 mm; coefficient of variation (V) = 37.4%.

Moisture content

At the moment when mechanical properties of the oak abonos were established, moisture content was checked in 85 samples, and the following values were acquired: $\overline{X}$ = 10.94%; min = 9.93%; max = 12.29%; S = 0.51%; V = 4.66%.

Density of air dry wood

The density of air dry wood determined in 50 samples (2x3x3 cm) with moisture content Vs = 11.56% was $\overline{X}$ = 0.7354 g/cm^3, min = 0.6204 g/cm^3, max = 0.9792 g/cm^3, S = 0.0985 g/cm^3, V = 13.26%. The density of air dry wood established in 68 samples (4x2x2 cm) with moisture content Vs = 10.94% was $\overline{X}$ = 0.7224 g/cm^3, min = 0.5959 g/cm^3, max = 0.6961 g/cm^3, S = 0.0302 g/cm^3, V = 4.55%.

Shrinkage

Linear and volumetric shrinkages were determined in 50 samples, and the following values of longitudinal shrinkage were obtained: $\overline{X}$ = 1.09%, min = 0.48%, max = 2.44%, S = 0.44%, V = 40.17%. The values of radial shrinkage were as follows: $\overline{X}$ = 9.37%, min = 7.12%, max = 14.28%, S = 1.80%, V = 19.03%; tangential shrinkage: $\overline{X}$ = 17.22%, min = 14.70%, max = 20.84%, S = 1.68%, V = 9.67%; volumetric shrinkage: $\overline{X}$ = 25.79%, min = 22.41%, max = 31.03%, S = 2.39%, V = 9.18%.

Compression strength parallel to the grain

Determined in 68 samples with moisture content Vs = 10.94%, the following values of the compression strength were obtained: $\overline{X}$ = 46.24 MPa, min = 32.92 MPa, max = 81.08 MPa, S = 10.27 MPa, V = 22.08%.

Bending strength

Determined in 17 samples with moisture content Vs = 10.94%, the following bending strength values were achieved: $\overline{X}$ = 66.16 MPa, min = 46.69 MPa, max = 88.28 MPa, S = 12.75 MPa, V = 18.70%.

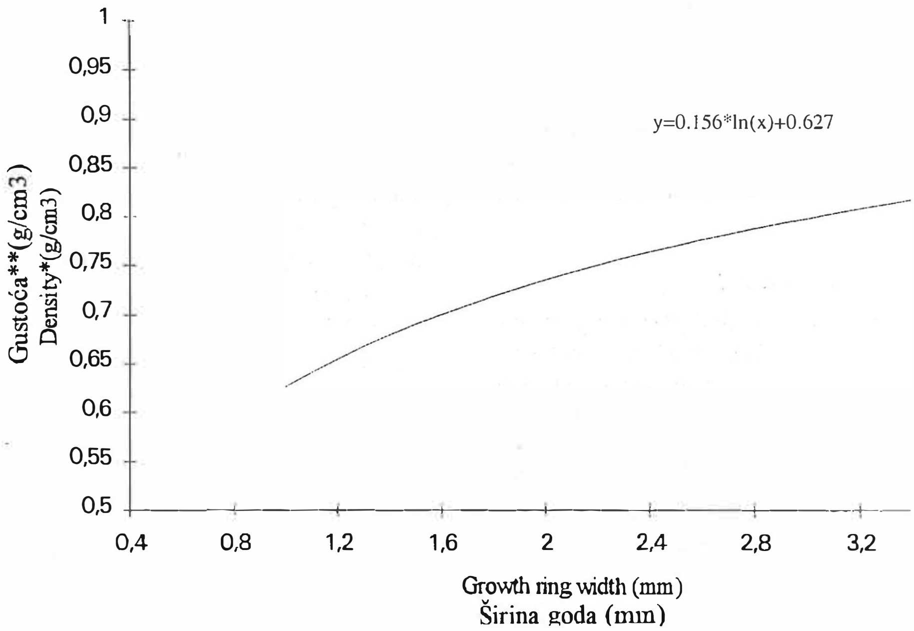

Figure 1.
The realationship between growth ring width and density • Odnos između širine goda i gustoće**

*Density of air dry wood at the moisture content of 11.56%. •
* Gustoća drva u prosušenom stanju kod sadržaja vode od 11.56%

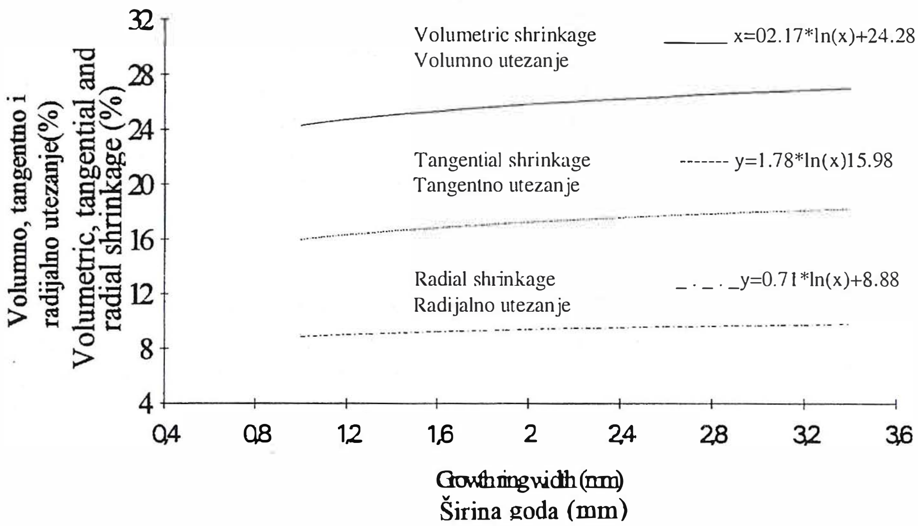

Figure 2.
The realtionship between growth ring width and volumetric, tangential and radial shrinkage • Odnos između širine goda i volumnog, tangentnog i radijalnog utezanja

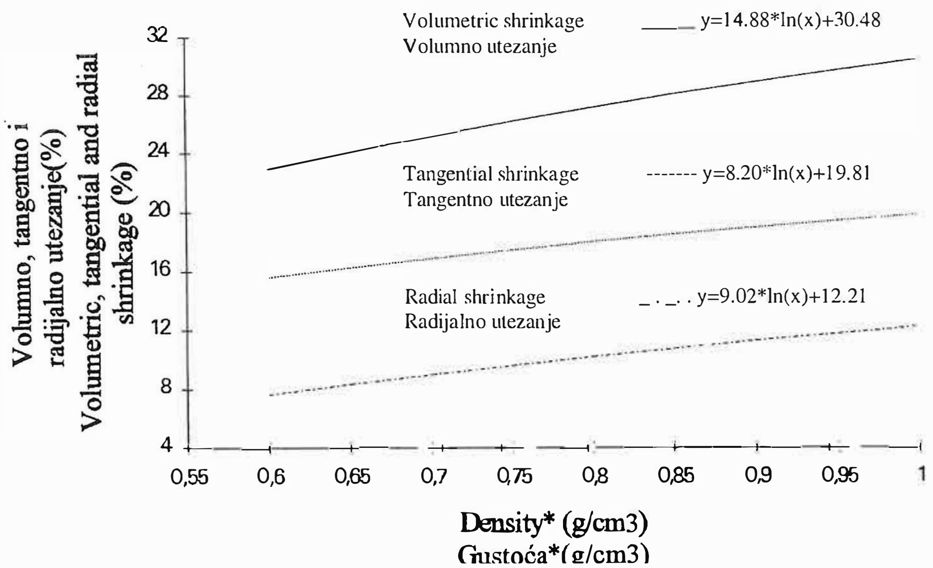

Figure 3.
The relationship between density and volumetric, tangential and radial shrinkage. • Odnos između gustoće* i volumnog, tangentnog i radijalnog utezanja*

*Density of air dry wood at moisture content of 11.56 %. • *Gustoće drva u prosušenom stanju kod sadržaja vode od 11,56 %

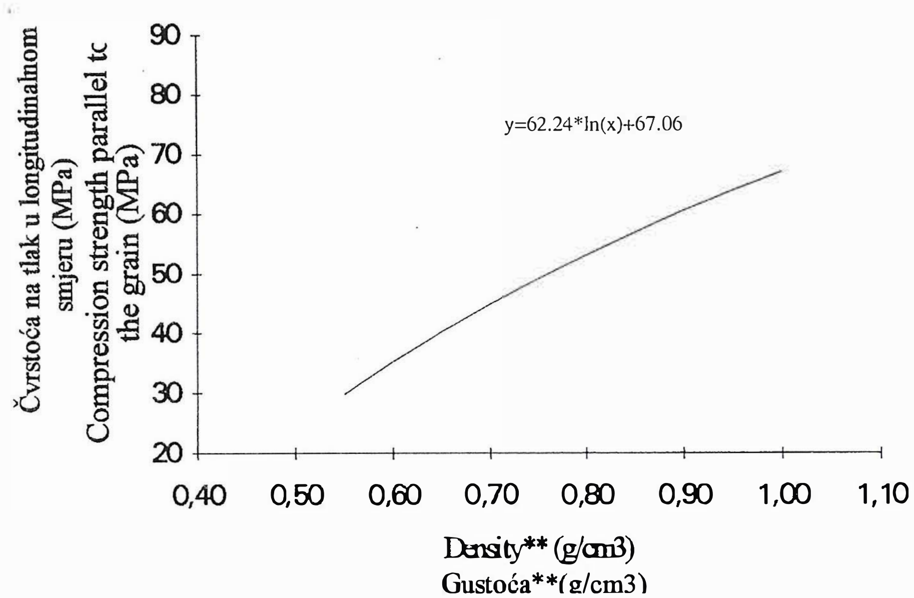

Figure 4.
*The relationship between density** and compression strength parallel to the grain. • Odnos između gustoće** i čvrstoće na tlak u longitudinalnom smjeru*

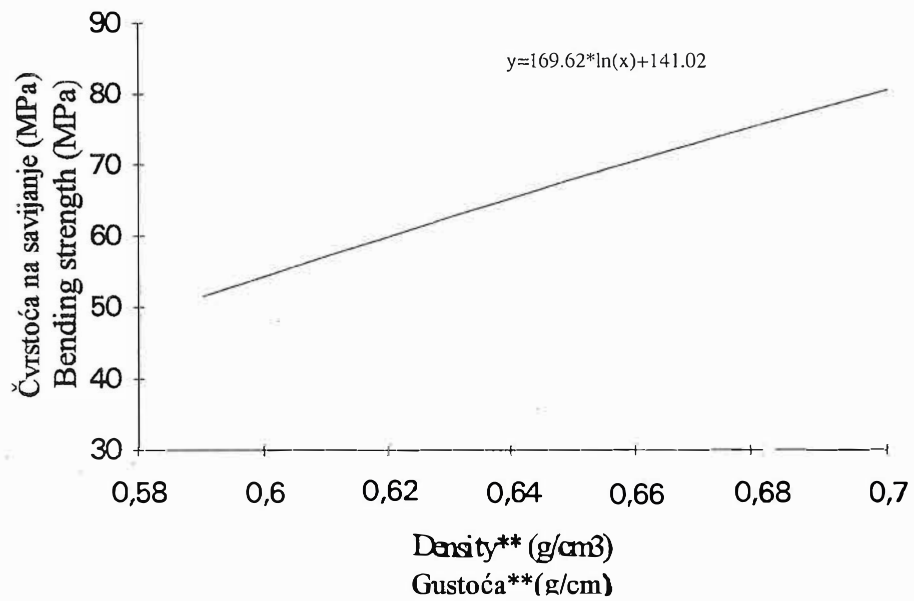

Figure 5.
*The relationship between density** and bending strength. • Odnos između gustoće** i čvrstoće na savijanje*

** Density of air dry wood at moisture content of 10.94 %. • **Gustoća drva u prosušenom stanju kod sadržaja vode od 10,94 %

CONCLUSION

The research on the properties of oak abonos (Quercus sp.), whose age was estimated at 4,000 years, has established that its chemical composition is almost the same as that of recent oakwood, though with significantly increased content of extractives and ash. The densities are similar or slightly higher with the abonos, whose linear and volumetric shrinkage is twice as great. As to the mechanical properties, those of oak abonos are singificantly reduced, which is particularly expressed in bending strength.

The relations of ring width and density, ring width and shrinkage, density and shrinkage, and density and mechanical properties have all shown similarities with recent oakwood, i.e. characteristic values of the ring-porous brodleaves.

LITERATURE

1. Borgin, K., Tsoumis, G. and Passialis, C., 1979.: Density and Shrinkage of Old Wood. Wood Science and Technology, 13, 49-57.
2. Dzbenshni, W., 1970.: Techniczne Wlasnosci drewna dedu wykopaliskowego. Sylwan, 114, 5, 1-27.
3. Horvat, I., 1967.: Tehnologija drva. Drvnoindustrijski priručnik, Tehnička knjiga, Zagreb, 379-566.
4. Horvat, I., 1983.: Abonos. Šumarska enciklopedija, Jugoslavenski leksikografski zavod, Zagreb, 1,2.
5. Schniewind, A.P., 1990.: Physical and Mechanical Properties of Archeological Wood. American Chemical Society, 87-109.
6. Ugrenović, A.,1959.: Tehnologija drveta. Nakladni zavod Hrvatske, Zagreb, 2, 1-502.
7. Voulgariclis, E. And Passialis, C., 1990.: Chrinkage and Colour Restoration of Oakwood Buried in the Ground. Holzforschung und Holzverwertung, 42, 4, 74-75.