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Govorčin, Slavko; Sinković, Tomislav

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UDK 630*811+812 (Quercus robur L.)

INFLUENCE OF DOUBLE SAPWOOD ON THE QUALITY OF SLAVONIAN OAK

SLAVKO GOVORČIN, TOMISLAV SINKOVIĆ

Faculty of Forestry, University of Zagreb,
Svetošimunska 25, HR - 10000 Zagreb

The phenomenon which can be viewed macroscopically on the cross section of a tree trunk in the form of two rings lighter in colour than the darker heart in heartwood species is called double sapwood. The outer, larger ring which is located peripherally is the outer or true sapwood, while the smaller ring located in the heart itself constitutes double sapwood.
The practical implications of double sapwood result in properties that are as poor as those in true sapwood. This defect is especially significant because of its occurrence in oak trees. This significantly reduces the value of wood, primarily its aesthetic value, and bears heavy consequences in the exploitation of the most valuable assortments because of the development of rot which in turn reduces quality during processing.
In order to assess the influrnce of double sapwood, i.e. the changes in the properties of wood in these areas, a sample was taken from 10 trees of Slavonian Oak (*Quercus robur* L.) in which double sapwood was discovered immediately upon felling.
By monitoring the position of certain physical and mechanical properties of Slavonian Oak wood in a transversal direction, the achieved results enable us to establish the influence of double sapwood on the quality and use values of wood.

Key words: Slavonian Oak, double sapwood, physical properties, mechanical properties, quality

INTRODUCTION

In defect qualifications, double sapwood is sometimes qualified as a defect in colour (Ugrenović, A., 1932), sometimes as a natural defect (Brown, H.P., Panshin, A.J. and Forsaith, C.C., 1949) and sometimes as a wood defect and anomaly, i.e. it is placed in the category of natural defects and defects that appear in the production process (Côté, W.A. 1968), and sometimes it is categorised as a colour change defect (Horvat I., 1973).

Double sapwood is a defect which is visible in the cross section of heartwood species and is manifested in two sapwood rings which differ in colour from the darker heartwood. The outer sapwood ring is larger in diameter and represents common sapwood, while the inner ring (integrated sapwood) is of a lesser diameter and is situated in the heart itself. A ring of heartwood is located in between these two sapwood rings. Double sapwood can be found only in heartwood species and even here it is very rare. Double sapwood is especially present in oaks, but can also be found in larch and arborvitae. The border line of double sapwood is more or less pronounced and overlaps almost exactly with the border lines of growth rings. Buffon and Duhamel du Monceau (1737) established the occurrence of double sapwood in oaks in trees which grew on thin and dry soil and associated this with very low temperatures. Later research confirmed this theory and established that double sapwood appears as a result of the lack of the normal process of duramination due to low temperatures during the time when the inner sapwood ring forms the outerlayer of the tree (Mer E., 1896, Henry E. 1896). Because of the low temperatures, the starch cannot be transformed into duramination substances and because of this the normal duramination process does not occur. Temporary insufficient nutrition due to unfavorable weather conditions can also be a cause of double sapwood (several years of drought).

Although double sapwood in Slavonian Oaks is primarily treated as a colour defect, i.e. of an aesthetic value, in practice the wood has properties that are as poor as wood with outer sapwood. This means that this ring of wood shows significantly reduced durability and, because of this property, the wood is treated as reject wood.

RESEARCH MATERIAL AND METHODS

The material necessary for researching the properties of double sapwood in Slavonian Oak was taken from test trunk samples of 10 trees in Eastern Slavonia. Of the 10 trees, 3 were from the Lipovac Forest Administration, forest area of Topolovac, department 6a, and 7 trees were from the Vrbanja Forest Administration, forest area of Boljkovo, department 130b. The trees were chosen so as to best represent the stand in age, size, habitus, dendrometric elements and outer trunk properties. The trees were healthy, normal, with regular crowns, straight stems, average flawlessness and fulness of bole as well as grain texture. The only defect was the macroscopically evident double sapwood rings whose width indicated the posibility of extracting test samples necessary for establishing the physical and mechanical properties of Slavonian Oak in exactly these areas (Fig.1). The test trunk samples used for establishing the physical and mechanical properties were taken from mid-way between the ground and the first live branch in all 10 trees.

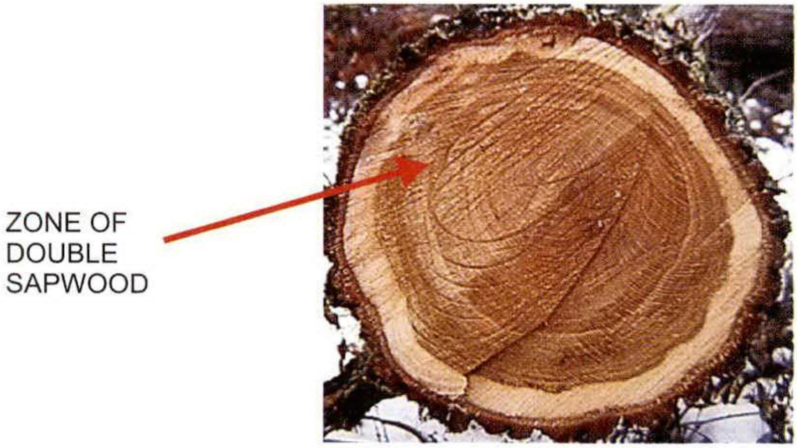

Figure 1. Cross section of oak with double sapwood zone

The trunk samples were taken immediately upon felling and were transported to the sawmill storage where, after approximately 30 days, they were made into heart boards oriented North-South and East-West. The heart boards were stacked and naturally dried until the water content was about 20%.

A maximum number of test samples was made from the heart boards, starting from the outer sapwood (last annual ring) towards the anatomical centre.

To test the physical properties, samples were made for testing the density in an absolutely dry condition, and samples were prepared for testing volumetric shrinkage in accordance with ISO 3131:1975 and ISO 4858:1982. To test the mechanical properties, we made samples for testing compression strength parallel to the grain and samples for testing bending strength in accoradnce with ISO 3787:1976 and ISO 3133:1975.

RESULTS

The results achieved through testing have been classified into areas (zones) which can be macroscopically seen on the cross section of the Slavionian Oaks with double sapwood. The first zone represents the area of true sapwood (outer sapwood), the second is the zone of heartwood and is located between the outer sapwood and double sapwood, the third is the zone of double sapwood and the fourth consitutes the zone of heartwood from the double sapwood to the anatomical centre of the stem.

The test results of the physical and mechanical propreties are given in Table 1 where they are classified according to the property for each individual tree with the respective values and statistical parameters, starting from the outer edge of the sapwood towards the anatomical centre, i.e. in a radial direction.

Table 1. Review of statistical data for density in absolutely dry condition, volumetric shrinkage, bending strength and compression strength parallel to the grain for trees and tree zones

PROPERTY		DENSITY IN ABSOLUTELY DRY CONDITION			VOLUMETRIC SHRINKAGE			BENDING STRENGTH			COMPRESSION STRENGTH PARALLEL TO THE GRAIN		
TREE	TREE ZONE	n	ave	var	n	ave	var	n	ave	var	n	ave	var
1	S	4	0.496	0.0004	4	11	1.65	4	75	33.69	4	44	0.46
	H	7	0.591	0.001	7	13.4	1.79	7	73	78.16	7	43	19.39
	DS	4	0.624	0.002	4	14	0.36	4	89	17.68	4	51	12.32
	H	10	0.647	0.0012	10	16.1	1.87	10	88	73.52	10	54	27.26
2	S	4	0.526	0.0004	4	11	1.12	4	77	40.87	4	44	7.52
	H	10	0.613	0.0003	10	13.8	0.32	10	81	61.27	10	47	10.32
	DS	4	0.568	0.001	4	13.79	0.58	4	86	143	4	47	36.45
	H	8	0.677	0.0014	8	15.8	0.16	8	104	57.92	8	58	7.31
3	S	4	0.489	0.001	4	10.6	3.54	4	72	52.42	4	42	4.5
	H	10	0.650	0.0021	10	14.3	0.72	10	92	208.38	10	50	29.93
	DS	4	0.651	0.0066	4	14.6	2.22	4	97	147.66	4	55	51.75
	H	18	0.725	0.0013	18	16.8	1.6	18	104	107.21	18	57	15.44
4	S	4	0.517	0.0003	4	10.7	0.26	4	91	5.77	4	47	4.54
	H	19	0.589	0.0011	19	13.1	1.57	19	95	56.24	19	53	22.65
	DS	4	0.552	0.0009	4	13.5	1.33	4	75	7.07	4	46	12.73
	H	7	0.622	0.0005	7	14.9	0.64	7	83	46.38	7	55	9.79
5	S	4	0.585	0.0023	4	12.5	0.57	4	111	146.82	4	56	29.83
	H	5	0.594	0.0022	5	13.3	2	5	103	206.25	5	53	20.62
	DS	4	0.657	0.0024	4	14.6	2.25	4	109	145.19	4	63	41.35
	H	17	0.633	0.0016	17	15.2	0.85	17	103	377.42	17	59	18.55
6	S	4	0.564	0.002	4	11.8	0.78	4	92	385.02	4	52	24.48
	H	0	0	0	0	0	0	0	0	0	0	0	0
	DS	4	0.580	0.0023	4	12.6	1.08	4	83	266.68	4	51	43.22
	H	25	0.648	0.0019	25	14.8	1.63	25	99	148.53	25	57	29.94
7	S	4	0.504	0.0005	4	11.4	0.47	4	76	37.53	4	43	4.62
	H	19	0.557	0.0007	19	13.6	1.1	19	84	95.83	19	48	15.14
	DS	4	0.562	0.0012	4	15	0.03	4	87	181.82	4	49	23.27
	H	3	0.632	0.0019	3	15.6	0.33	3	94	47.13	3	50	67.92
8	S	4	0.325	0.0068	4	7.6	4.88	4	39	440.47	4	24	79.89
	H	8	0.545	0.0007	8	12.4	1.49	8	84	82.5	8	51	8.7
	DS	4	0.555	0.0005	4	12.8	0.53	4	85	2.86	4	51	19.46
	H	10	0.618	0.0022	10	14.5	1.05	10	92	118.46	10	56	44.7
9	S	4	0.515	0.0003	4	10.8	1.37	4	85	48.95	4	51	2.1
	H	11	0.562	0.0019	11	12.1	1.65	11	94	97.39	11	55	58.19
	DS	4	0.612	0.0005	4	14	0.93	4	84	143.09	4	62	11.75
	H	9	0.581	0.0011	9	12.9	0.57	9	87	135.62	9	57	25.8
10	S	4	0.547	0.0001	4	10.5	0.81	4	101	18.8	4	57	2.06
	H	9	0.625	0.0009	9	12.8	3.88	9	111	94.6	9	65	13.59
	DS	4	0.635	0.0001	4	11.4	0.6	4	122	21.79	4	70	1.57
	H	15	0.668	0.0011	15	14.1	1.02	15	120	151.6	15	70	27.83

Legend: S-sapwood, H- heartwood, DS- double sapwood, n- number of samples, ave-average value, var- variance (N-1).

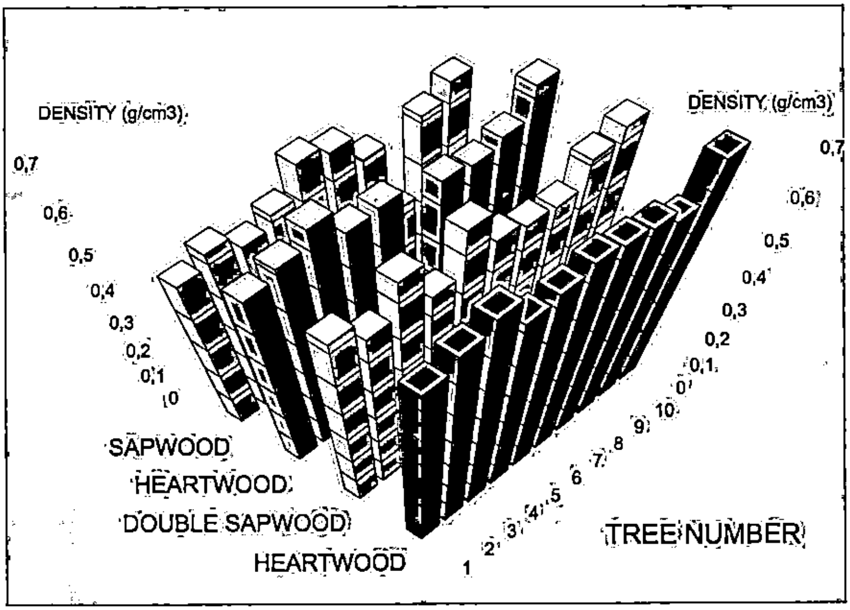

Figure 2. Distribution of density in absolutely dry condition through tree zones (sapwood, heartwood,double sapwood and heartwood) for 10 trees

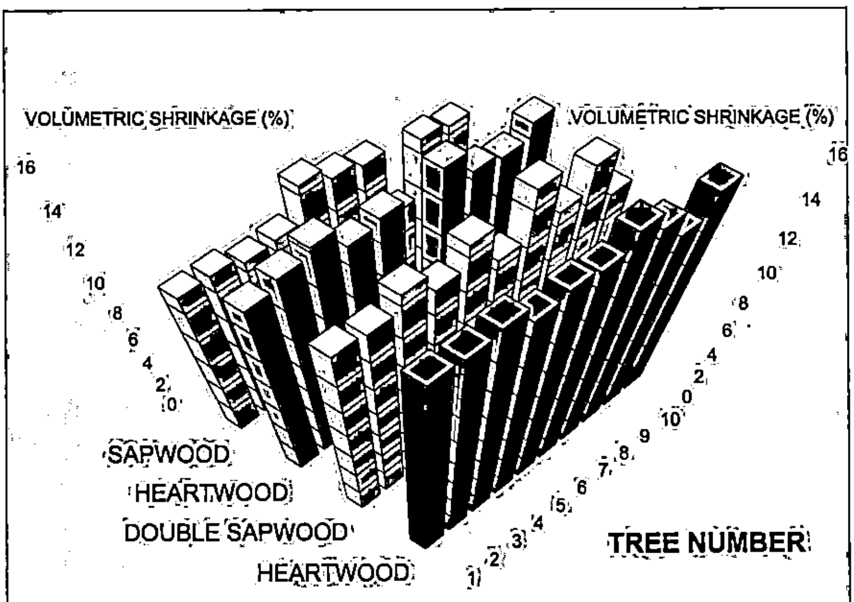

Figure 3. Distribution of volumetric shrinkage through tree zones (sapwood, heartwood, double sapwood and heartwood) for 10 trees

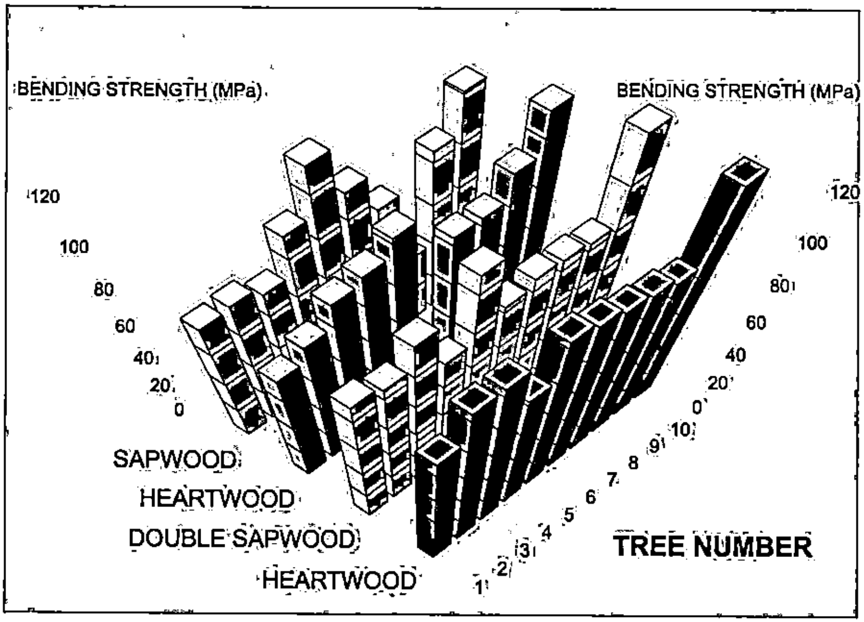

Figure 4. Distribution of bending strength through tree zones (sapwood, heartwood, double sapwood and heartwood) for 10 trees

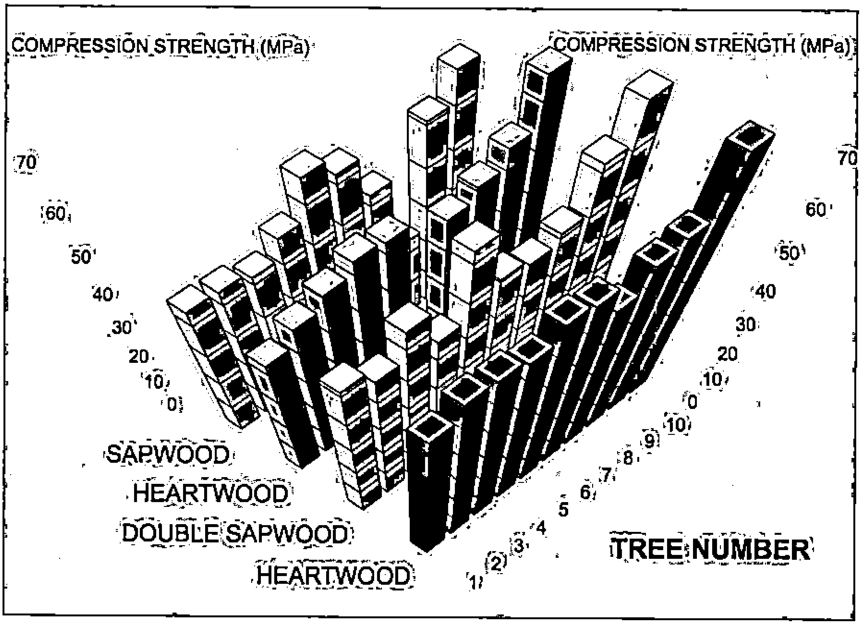

Figure 5. Distribution of compression strength parallel to the grain through tree zones (sapwood, heartwood, double sapwood and heartwood) for 10 trees.

Figure 2 gives a graphical illustration of the density in an absolutely dry condition through all 4 zones for each of the 10 trees.

Results for the density from the bark towards the heart show a trend of growth. The only exception being tree no.2 where the value of ρ_0 =0.5677 g/cm^3 for the double sapwood zone is lower than the value in the zone between the sapwood and the double sapwood which equals ρ_0 =0.6132 g/cm^3.

In tree no.4, the density value for the double sapwood zone of ρ_0 =0.5524 g/cm^3 is lower than the value for the heartwood zone between the sapwood and double sapwood which equals ρ_0 =0.5892 g/cm^3.

Figure 3 gives a graphical illustration of the volumetric shrinkage through all 4 zones for each of the 10 trees.

Results for the volumetric shrinkage from the bark towards the heart show a trend of growth. The only exception being tree no.10 where the value of βv =11.45% for the double sapwood zone is lower than the value in the zone between the sapwood and the double sapwood which equals β_0 =12.78%.

Figure 4 gives a graphical illustration of the bending strength through all 4 zones for each of the 10 trees.

Results for the bending strength through all 4 zones also show a trend of growth. The only exceptions being tree no.4 where the value of σs =75.14 MPa for the double sapwood zone is lower than the value in the zone between the sapwood and the double sapwood which equals σ_0 =94.75 MPa, and tree no. 9 where the value of σs =83.70 MPa for the double sapwood zone is lower than the value in the zone between the sapwood and the double sapwood which equals σ_0 =94.30 MPa. The results for tree no.5 have to be highlighted since they show an opposite trend for the values of bending strength where the highest value of σ_0 =111 MPa applies to the outer sapwood zone and the value for the heartwood equals σ_0 = 103 MPa.

Figure 5 gives a graphical illustration of the compression strength parallel to the grain through all 4 zones for each of the 10 trees.

Results for the compression strength parallel to the grain through all 4 zones also show a trend of growth. Tree no. 4 has the value of σ_t =45.56 MPa for the double sapwood zone which is lower than the value in the zone between the sapwood and the double sapwood which equals σ_t =53.45 MPa. In tree no. 1, the value for the zone between the sapwood and the double sapwood of σ_t =42.87 MPa is lower than the value for the double sapwood zone which equals σ_t =44.07 Mpa. The results for tree no. 5 show a lower value for the zone between the sapwood and double sapwood of σ_t =52.72 MPa in comparison to the value for the outer sapwood zone of σ_t =56.22 MPa.

Table 2 gives a review of mean values for the tested physical and mechanical properties through all 4 zones of the 10 Slavonian Oak trees.

Figure 6 illustrates the mean values of density in an absolutely dry condition through all 4 zones for all 10 trees. The values have an increasing trend from ρ_0 =

Table 2. Review of statistical data for density in absolutely dry condition, volumetric shrinkage, bending strength and compression strength parallel to the grain for all trees together and tree zones

PROPERTY		DENSITY IN ABSOLUTELY DRY CONDITION			VOLUMETRIC SHRINKAGE			BENDING STRENGTH			COMPRESSION STRENGTH PARALLEL TO THE GRAIN		
TREE	TREE ZONE	n	ave	var	n	ave	var	n	ave	var	n	ave	var
	S	40	0.507	0.0057	40	10.8	2.69	40	82	444.3	40	46	96.4
A	H	98	0.589	0.002	98	13.2	1.79	98	90	184.6	98	52	50.2
L	DS	40	0.600	0.0029	40	13.6	1.89	40	92	264	40	54	76.6
AL	H	122	0.652	0.0028	122	15.1	2.15	122	100	243	122	58	46.1

Legend: S-sapwood, H- heartwood, DS- double sapwood, n- number of samples, ave- average value, var- variance (N-1).

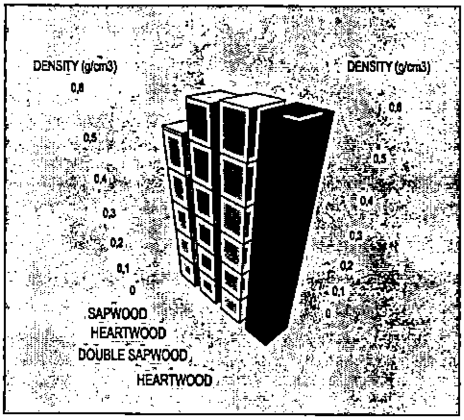

Figure 6. Distribution of density in absolutely dry condition through zones for all trees.

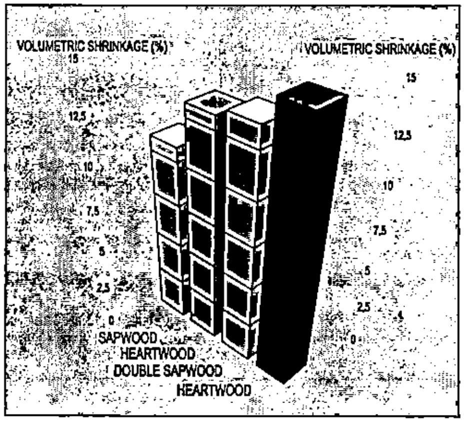

Figure 7. Distribution of volumetric shrinkage through zones for all trees.

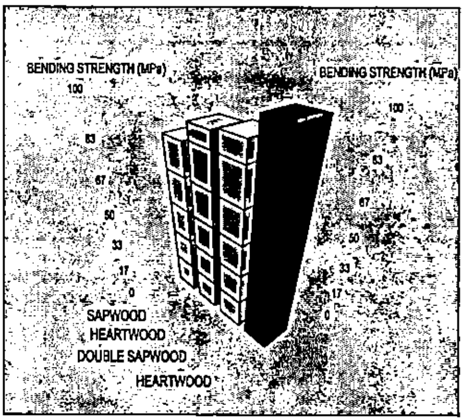

Figure 8. Distribution of bending strength through zones for all trees.

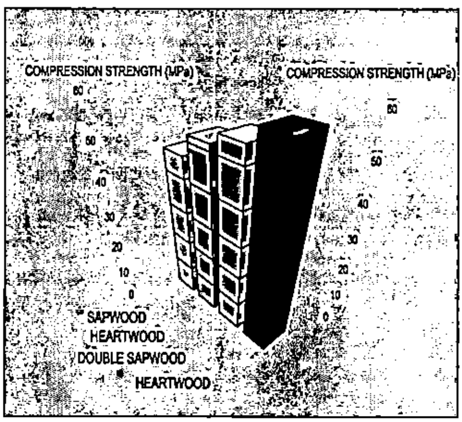

Figure 9. Distribution of compression strength parallel to the grain through zones for all trees.

0.507 g/cm^3 in the outer sapwood zone to ρ_0 = 0.652 g/cm ^{3} in the heartwood zone.

Figure 7 gives the mean values of volumetric shrinkage through all 4 zones for all 10 trees. The values have an increasing trend from β_v = 10.8% in the outer sapwood zone to β_v = 15.1% in the heartwood zone.

Figure 8 gives the mean values of bending strength through all 4 zones for all 10 trees. The values have an increasing trend from σ_s = 82 MPa in the outer sapwood zone to σ_s = 100 MPa in the heartwood zone.

Figure 9 gives the mean values of compression strength parallel to the grain through all 4 zones for all 10 trees. The values have an increasing trend from σ_t = 46 MPa in the outer sapwood zone to σ_t = 58 MPa in the heartwood zone.

DISCUSSION AND CONCLUSION

The test samples for this research were taken from trees in which double sapwood was noticed after felling. Immediately upon felling samples were taken from the trunks, leaving no time for the development of rot in the areas of the outer and double sapwood since the test material, properly stacked, was dried naturally until the water content was adequate for testing.

The test samples in all trees except for tree no. 8 were healthy with no signs of rot. Tree no. 8 had traces of peripheral decay in the outer sapwood area caused by drying ("dead standing" oak) which is evidenced by the research results and the values for all properties.

The distribution of wood density in an absolutely dry condition in each tree through all 4 zones shows an increase in density from bark to core. Values for tree nos. 2 and 4 show lower density values in the double sapwood zones in comparison to the values for the heartwood zones between the sapwood and double sapwood. However, only for tree no. 2 are the density values in the double sapwood zone significantly lower than the density values for the heartwood between the sapwood and double sapwood.

The distribution of wood density in an absolutely dry condition in each tree through all 4 zones shows a constant increase in density from bark to core. With regard to the research on the radial variation of wood density and especially research on the radial variation of oak wood density – oak being in the fourth group of tree species whose density is reduced from heart to bark (Panshin, A. and De Zeeuw, C. 1970), we can generally conclude that the results for density distribution through the 4 zones is normal. This means that in the double sapwood zone there has been no reduction of density values in an absolutely dry condition.

The volumetric shrinkage distribution viewed by tree through all 4 zones shows an increase in the value of volumetric shrinkage from bark to core. In tree no. 9 the results point to a lower value of volumetric shrinkage in the double sapwood zone in comparison to the volumetric shrinkage in the heartwood zone between the sapwood and double sapwood. However, the difference is insignificant.

The volumetric shrinkage distribution viewed by tree through all 4 zones shows an increase in the value of volumetric shrinkage from bark to core. Therefore, there is no reason to believe that double sapwood influenced the values for volumetric shrinkage.

The distribution of compression strength parallel to the grain by tree through all 4 zones shows a general increase in value from bark to core. The only exception is tree no. 4 where the compression strength value for the double sapwood zone is significantly lower than the value in the zone between the sapwood and the double sapwood.

Tree nos. 1 and 5 also deviate from the rule since the values for the heartwood zone between the sapwood and double sapwood are lower. However, in neither case is the difference in the value of compression strength significant.

The distribution of compression strength parallel to the grain by tree through all 4 zones shows a constant increase in value from bark to core. We can conclude that the achieved values are in accordance with the values for density which signifies that in general there has been no change in compression strength values in the double sapwood zone.

The bending strength distribution for each of the 10 trees through all 4 zones shows a general increase in the value of bending strength from bark to core. Tree no. 4 is an exception since the bending strength value for the double sapwood zone is significantly lower than the value in the zone between the sapwood and the double sapwood.

The decrease in bending strength value for tree no. 5 in the heartwood between the sapwood and double sapwood in comparison with the value for the outer sapwood is not significant.

The bending strength distribution for each of the 10 trees through all 4 zones shows a constant increase in value of bending strength from bark to core. This distribution of values is in accord with the values of density, volumetric shrinkage and compression strength, therefore we can conclude that double sapwood did not influence the bending strength properties.

The results of the research of these properties give reason to conclude that Slavonian Oak with double sapwood does not undergo physical or mechanical changes that would negatively affect its quality and user value. In this case, the double sapwood remains only an aesthetic defect.

The results of this research indicate that timely and adequate log processing of double sapwood Slavonian oak can help to avoid enormous damage incurred through slow transport from the stands and the lack of necessary primary processing of this valuable roundwood.

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UTJECAJ DVOSTRUKE BJELJIKE NA KAKVOĆU SLAVONSKOGA HRASTA

Pojava koja se može makroskopski vidjeti na presjeku stabla u obliku dvaju godova čija je boja svjetlija od tamnije srži u osrženim vrstama naziva se dvostruka bjeljika. Vanjski, svjetliji god koji je smješten periferno jest vanjska ili prava bjeljika, dok je manji god smješten u samoj srži i tvori dvostruku bjeljiku.

Praktične implikacije dvostruke bjeljike jednako su nepovoljne kao i implikacije prave bjeljike. Ta je mana osobito važna jer se pojavljuje u hrastovim stablima. Time se vrijednost drva, ponajprije njegova estetska vrijednost, znatno smanjuje, a u eksploataciji najvrednijih sortimenata nastaju teške posljedice zbog stvaranja truleži koja smanjuje kakvoću drva pri obradi.

Za procjenu utjecaja dvostruke bjeljike, to jest promjena u svojstvima stabala u ovim područjima, uzet je uzorak od 10 stabala slavonskoga hrasta (*Quercus robur* L.) u kojima je otkrivena dvostruka bjeljika odmah nakon sječe.

Praćenjem položaja određenih fizičkih i mehaničkih svojstava slavonskoga hrasta u transverzalnom smjeru dobiveni rezultati omogućuju da se ustanovi utjecaj dvostruke bjeljike na kakvoću i uporabnu vrijednost drva.

Ključne riječi: slavonski hrast, dvostruka bjeljika, fizička svojstva, mehanička svojstva, kakvoća