Holz als Roh- und Werkstoff 54 (1996) 407–410 © Springer-Verlag 1996

Treatability of several Greek wood species with the water soluble preservative CCB

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Roudwood from 7 softwood and 17 hardwood Greek species (length 1,20 m, diameter 14–20 cm) or/and sawn timber (length 1,25 m, cross section 5 cm × 7 cm) were impregnated with 2% CCB in the full cell process. Based on the dry salt retention, on the impregnated cross cut area, on the lateral and axial penetration and on the distribution of the preservative on cross sections, the wood species were classified according to their treatability into six classes: Very Permeable, Permeable, Moderately Permeable, Resistant, Very Resistant and Impermeable.

Tränkbarkeit verschiedener griechischer Holzarten mit wasserlöslichen CCB

Rundholz (Länge 1, 20 m, Durchmesser 14–20 cm) und Schnittholz (Länge 1, 25 m, Querschnitt 5 cm × 7 cm) aus griechischen Holzarten (7 Nadelhölzer und 17 Laubhölzer) wurden mit 2% CCB bei Anwendung des Volltränkverfahrens imprägniert. Auf der Basis der trockenen Einbringmenge des Tränksalzes, seiner Ausbreitungsfläche und Verteilung im Holzquerschnitt und seiner seitlichen und axialen Eindringtiefe wurden die Holzarten hinsichtlich ihrer Tränkbarkeit in den folgenden sechs Klassen eingestuft: leicht tränkbar, tränkbar, mässig tränkbar, schwer tränkbar, sehr schwer tränkbar, nicht tränkbar.

1 Introduction

Wood production in Greece is far below consumption needs (Philippou 1990) and thus expanding the life service of wood in its end uses as well as enhancing the production and proper utilization of wood of all forest species growing in Greece is becoming an increasing necessity. Particularly, the demand for wood treated with preservatives against biological deterioration and fire is increasing rapidly in past years due to expanding demands for wood for electricity and telecommunication poles, construction of wooden houses and other buildings, green houses, fish-cultivation platforms, fences, railroad sleepers, etc. Impregnation of wood, particularly in small dimensions, with water soluble salt preservatives is thus becoming very important.

For effective wood preservation it is important to know the treatability behavior of the wood species to impregnation with preservatives. For most of the known European forest species liquid penetration is known and these species are classified on permeability or treatability scales (Perttungen 1966, Bergman 1973, B. R. E. 1979, Reimao and Cockcroft 1985, Voulgaridis 1986). However, this is a lack of information on the behavior to liquid impregnation treatments of most species growing in Greece.

The objective of this work was to investigate and assess the treatability behavior (resistance to impregnation) with C.C.B. water soluble preservative of 24 wood species growing in Greece, using a full cell impregnation process and to then classify the species according to their resistance to impregnation.

2 Materials and methods

2.1 Preparation of wood specimens

Wood from 24 Greek species was used in round wood and sawn timber form as shown in Table 1. The selected wood species represent the most important ones in Greece from production and utilization points of view.

The specimen dimensions were: for sawn timber 1200 mm in length, 80–150 mm in width, 50–60 mm in thickness and for logs 1200 mm in length and 120–250 mm in diameter. The number of specimens for each species used is shown in Table 1. A total of 545 specimens was used.

The most common timber sections contained heartwood and sapwood in the same piece, or only sapwood or heartwood, aimed for the treatability investigations separately for heartwood and sapwood, or both together. Timber specimens were air dried to 15–18% moisture content and roundwood to 25–28%. The wood was free from serious defects such as high knot area ratio and insect or fungi attack.

2.2 Impregnation of wood

Impregnation of wood in both forms was carried out with the water soluble preservative CCB (Copper/Chromium/Boron) in concentration 2% (BS 4072: 1974). The full cell method of impregnation (BS 5589: 1978) was applied in the impregnation unit of the State Wood Industry at Kalambaka. The impregnation schedule is shown in Fig. 1.

After impregnation the dry salt retention and the percentage of impregnated cross cut area were calculated. The calculation of retention for each piece of wood was based on the formula:

$$R = \frac{(A-B)\,C}{V}$$

where, R = retention of dry salt (Kg/ m^3), A, B = weight of wood after impregnation (A) and before impregnation (B) (Kg), V = wood volume (m^3), C = concentration of the preservative solution (2%).

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This study is based on part of results of the Ph. D. dissertation "Preservation of Greek wood species with water soluble preservatives" by J. A. Kakaras (in Greek).

Table 1. Wood species and number of specimens used in the experiment

a/a	Wood species	Number of specimens: Roundwood	Timber
	Softwood		
1	*Abies cephalonica (grecian fir)*	12	23
2	*Picea abies (spruce)*	12	23
3	*Pinus nigra (black pine)*	12	23
	> > sapwood	-	23
	> > heartwood	-	23
4	*Pinus brutia (hard pine)*	-	23
5	*Pinus leucodermis sapwood (whitebark pine)*	-	12
	> > heardwood	-	12
6	*Pinus halepensis (aleppo pine)*	12	-
7	*Cupressus sempevirens (medit. cypress)*	-	12
	Hardwoods		
8	*Fagus sylvatica (beech)*	12	23
9	*Quercus pubescens (pubescent oak)*	12	23
10	*Castanea sativa (chestnut)*	12	-
11	*Populus euroamericana (poplar clone I-214)*	12	23
12	*Platanus orientalis (oriental plane)*	12	23
13	*Ostrya carpinifolia (hophornbeam)*	12	23
14	*Acer pseudoplatanus (great maple)*	12	23
15	*Juglans regia (walnut)*	-	23
16	*Salix alba (white willow)*	-	23
17	*Salix carpea (willow)*	-	3
18	*Fraxinus oxycarpa (ash)*	-	14
19	*Alnus glutinosa (black alder)*	-	23
20	*Tilia vulgaris (common limetree)*	-	16
21	*Tilia cordata (small-leaved limetree)*	-	11
22	*Ulmus montana (mountain elm)*	-	-
23	*Ulmus campestris (english elm)*	-	4
24	*Aesculus hippocastanum (horse-chestnut)*	-	2
	Total	132	413

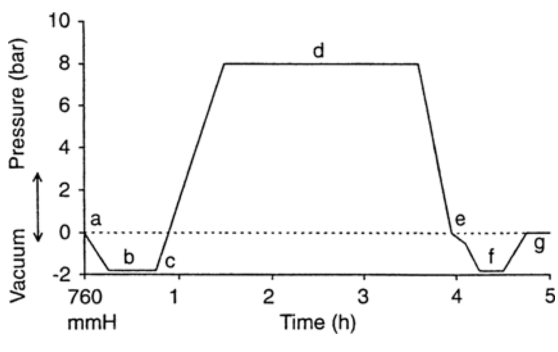

Fig. 1. Impregnation schedule applied to experimental logs and beams of fir wood (*a–b* Initial vacuum, *c* Flooding with preservative, *d* Pressure period, *e* Release of Pressure-Draining, *f* Final vacuum, *g* Vacuum drawn)

Bild. 1. Tränkungsprogramm, das für das Rundholz und Schnittholz der Tanne angewandt wurde (*a–b* Anfangsvakuum, *c* Einfüllen mit Tränkmittel, *d* Druckperiode, *e* Druck beenden-Tränkmittel ablassen, *f* Endvakuum, *g* Vakuum beenden)

The percentage of impregnated cross cut area was estimated after cross cutting of each piece of wood in the middle and measuring the impregnated area by the method of point sampling. Other information such as lateral and axial penetration were also measured in section and longitudinal (radial) surfaces, respectively.

3 Results and discussion

3.1 Dry preservative retention and impregnated cross cut-area

Dry CCB salt retention and percentage of impregnated cross-cut area in the middle of roundwood and timber specimens of the 24 Greek wood species under study are given in Table 2.

Wood treatability with CCB varied widely among the species. Dry salt retention varied in roundwood from 2.4 kg/ m^3 (chestnut) to 11,2 kg/m^3 (poplar) and in timber from 3.9 kg/m^3 (oak) to 12-2 kg/m^3 (lime). The impregnated cross-cut area varied in roundwood from 14,7% (oak) to 100% (beech, ash, lime, horse-chestnut).

Variability in treatability appeared also within species (between specimens) particularly in the % of impregnated area. Standard deviation of salt retention ranged from low $\pm$ 0,2 to $\pm$ 2,4 and of % impregnated area from 0 to $\pm$ 30,1. In general the species (or specimens) more difficult to treat showed a higher standard deviation. This variability in treatability within the same species (between trees and specimens) has also been noticed by other scientists and it is attributed mainly to the structural variability of wood, to the percentage of sapwood-heartwood and to changes associated with wood seasoning (Cote 1963, Nikolas 1973, B.R.E. 1979, Voulgaridis 1986).

3.2 Treatability classification

Regarding treatability, the Greek wood species were classified into six general classes as shown below and in Table 3.

CLASS 1. Very permeable (V.P.): Retention (R): > 8 kg/m^3 and impregnated cross-cut area (I. C. C. A.): 95–100%.
CLASS 2. Permeable (P): R = 6–8 kg/m^3 and I. C. C. A. = 85–95%.
CLASS 3. Moderately Permeable (M.P.): R = 5–6 kg/m^3 and I. C. C. A. = 70–85%.
CLASS 4. Resistant (R):R = 4–5% kg/m^3 and I. C. C. A. = 40–70%.
CLASS 5. Very Resistant (V. R.): R = 0,5–4 kg/m^3 and I. C. C. A. = < 40%.
CLASS 6. Impermeable (IMP): <0,5 kg/m^3 and penetration less than 0,5 mm.

This classification was based on the criteria of preservative retention and impregnated cross-cut area of timbers that are used in European and American Standards (ASTM, AWPA, B.S., B.R.E., Maclean 1960, Redding 1971). Other supplement criteria (particularly for the classification of sapwood and heartwood) such as preservative penetration (axial and lateral) and uniformity of penetration in transverse sections of round wood and timber were used. Whenever the treatment data and the above classification criteria, did not agree completely classification was made to the nearest class.

In Table 3 classification is given separately for sapwood and heartwood. The sapwood of many species was readily treatable even in species where heartwood was impermeable as in *Pinus leucondermis, Ostrya carpiniflora* and *Juglans regia* or very resistant as in *Pinus brutia, Platanus orientalis, Salix spp.* and *Ulmus spp.* Only the sapwood of *Castanea sativa* and *Picea abies* was very resistant and the sapwood of *Quercus pubescens* and *Abies chephallonica* was resistant to penetration of CCB.

In all pine species sapwood was permeable to very permeable. The permeability of pine sapwood is mainly due to the fact that besides axial penetration through tracheids, extensive lateral, mainly radial, penetration takes place through the system of resin canals, radial tracheids and parenchyma (Bergnan 1973,

Table 2. Dry CCB salt retention and percentage of impregnated crosscut area after full cell process Impregnation of Greek wood species

a/a	Wood species	Retention Kg/ m^3*		% impregnated cross-cut area	
		Roundwood	Timber	Roundwood	Timber
	Softwoods				
1	*Abies cephallonica*	5.9(1.5)	5.2(1.6)	47.0(19.2)	51.9(20.2)
2	*Picea abies*	4.3(1.0)	5.5(2.4)	38.9(25.8)	50.8(18.9)
3	*Pinus nigra*	8.4(1.1)			
	> > sapwood	-	10.4(1.1)	100.0(0.0)	100.0(0.0)
	> > heartwood		4.4(1.4)		31.1(12.7)
4	*Pinus brutia*		9.7(1.1)		-
5	*Pinus leucodermis sapwood*		8.9(1.1)		89.5(6.0)
	> > heartwood		0.0		0.0
6	*Pinus halepensis*	8.5(0.9)		-	
	> > sapwood	-		100.0(0.0)	
7	*Cupressus semprevires*		9.1(1.1)		91.4(11.8)
	Hardwoods				
8	*Fagus sylvatica*	10.3(1.0)	10.8(1.1)	97.4(5.9)	100.0(0.0)
9	*Quercus pubescens*	2.9(0.7)	3.9(1.2)	14.7(3.6)	30.7(10.5)
	> > sapwood	-	-	37.1(10.4)	78.8(19.7)
	> > heartwood	-	-	0.0	0.0
10	*Castanea sativa*	2.4(0.5)		17.3(0.3)	
11	*Populus euroamericana*	11.2(1.2)	9.5(0.6)	99.0(1.2)	93.3(0.9)
12	*Platanus orientalis*	9.1(0.6)		92.5(10.0)	
	> > sapwood		8.5(1.1)		93.1(5.8)
	> > heartwood	-	-	0.0	0.0
13	*Ostrya carpinifolia*	7.5(1.7)	7.6(1.9)	78.6(10.3)	69.8(16.1)
	> > heartwood	-	-	0.0	0.0
14	*Acer pseudoplatanus*	7.2(1.3)	8.1(1.4)	77.0(21.5)	75.6(17.4)
15	*Juglans regia*		7.8(1.0)		75.4(15.8)
	> > sapwood		-		95.9(2.9)
	> > heartwood		-		0.0
16	*Salix alba*		8.2(1.5)		80.9(13.6)
	> > heartwood		-		51.5(30.1)
17	*Salix carpea*		10.1(0.2)		83.3(5.0)
18	*Fraxinus oxycarpa*		7.6(1.0)		100.0
	> > sapwood		-		100.0
	> > heartwood		-		100.0
19	*Alnus glutinosa*		11.5(1.8)		95.5(3.7)
20	*Tilia vulgaris*		12.2(1.5)		96.5(3.9)
21	*Tilia cordata*		12.1(1.7)		99.8(0.6)
22	*Ulmus montana sapwood*		9.9(1.8)		94.2(6.0)
23	*Ulmus caprestris*		6.4(1.5)		65.1(16.0)
	> > heartwood		-		0.0
24	*Aesculus hippocastanum sapwood*		9.9(0.4)		100.0

* Mean values. Numbers in brackets give the standard deviation

Nickolas 1973). On the other hand, the heartwood of pines was very difficult to impregnate with CCB. The heartwood of *Pinus leucodermis* was impermeable, heartwood of *Pinus halepensis* and *Pinus brutia* very resistant and that of *Pinus nigra* resistant. The very low permeability of pine heartwood is attributed mainly to resin deposits around the tracheids and radial cells, and the aspiration of resin canal by tylosoids which takes place during transformation from sapwood to heartwood (Cote 1963, Bergman 1973, Tsoumis 1983).

From the softwood species studied only in *Cupressus semprevirens* were both sapwood and heartwood easy to treat. In *Abies chephallonica* and *Picea abies* both sapwood and heartwood showed resistance to impregnation with CCB. The resistance to impregnation of *Abies spp.* and *Picea spp.* has been well recognised and studied by many researchers (Bergman 1973, Blew et al. 1967, Bolton and Petty 1975, Johansson and Nordman 1987, Kummar and Morrell 1988). The aspiration of bordered pits which takes place during wood seasoning is almost permanent and significantly decreases the permeability of the refractory softwoods. It was noticed in this study that penetration of CCB in the sapwood of fir and spruce was mainly lateral (in tangential direction) and took place mainly in the latewood zones. This was attributed to the fact that latewood has smaller and denser pits (Tsoumis 1983, Voulgaridis 1986) and is thus more resistant to aspiration. *Abies chephallonica* is one of the most important species with many end uses in Greece and a further study was undertaken to investigate possibilities of increasing its treatability with CCB by steaming, ponding and drill perforation. The results of the study showed a significant increase of the dry salt retention and the impregnated area in logs and sapwood timber, particularly when drill perforation was used (Kakaras and Voulgaridis 1992).

Most of the broadleaved species studied showed a good treatability for both sapwood and heartwood. Only *Quercus* and *Castanea spp* sapwood and heartwood were very difficult to impregnate (heartwood was impermeable). *Ostrya*, *Acer*, *Juglans*, Salix and *Ulmus spp* had permeable to very permeable sapwood and very resistant or impermeable heartwood. The resistance to penetration of CCB of the heartwood of the above species could be attributed to tylosis and extractives accumulation in the

Table 3. Classification of 24 Greek wood species according to their resistance to Impregnation with CCB

a/a	Wood species	Permeability Scale*	
		Sapwood	Heartwood
	Softwood		
1	*Abies cephallnica*	R.	R.
2	*Picea abies*	R.	V.R.
3	*Pinus nigra*	P.	R.
4	*Pinus brutia*	P.	V.R.
5	*Pinus leucodermis*	P.	I.MP.
6	*Pinus halepensis*	V.P.	V.R.
7	*Cupressus sempervirens*	P.	M.P.
	Hardwood		
8	*Fagus sylvatica*	V.P.	V.P.
9	*Quercus pubescens*	R.	I.MP.
10	*Castanea sativa*	V.R.	I.MP.
11	*Populus euroamerica I-214*	V.P.	P.
12	*Platanus orientalis*	V.P.	R.
13	*Ostrya carpinifolia*	P.	I.MP.
14	*Acer pseudoplatanus*	M.P.	M.P.
15	*Juglans regia*	P.	I.MP.
16	*Salix alba*	V.P.	R.
17	*Salix carpea*	V.P.	V.P.
18	*Fraxinus oxycarpa*	V.P.	V.P.
19	*Alnus glutinosa*	V.P.	V.P.
20	*Tilia vulgaris*	V.P.	V.P.
21	*Tilia cordata*	V.P.	V.P.
22	*Ulmus montana*	V.P.	-
23	*Ulmus campestris*	M.P.	V.R.
24	*Aesculus hippocastanum*	V.P.	V.R.

* V.R.: Very Permeable, P: Permeable, M.P.: Moderately Permeable, R.: Resistant, V.R.: Very Resistant, IMP.: Impermeable

pits or to other changes that take place during transformation from sapwood to heartwood (Cote 1963, Bergman 1973, Tsoumis 1983). The resistance to impregnation of *Quercus pubescens* and *Castanea sativa* sapwood cannot be easily explained. Reimao and Cockcroft (1985) found that sapwood in both these species was permeable. It will be interesting to study further the reasons for the resistance to impregnation of *Quercus* and *Castanea* sapwood noticed in this study.

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