Impact of Impregnation with Boron Compounds on the Surface Hardness and Abrasion Resistance of Some Varnished Woods

Musa Atar,[1] Burhanettin Uysal,[2] Mutlu Sarííca[1]

[1]*Department of Furniture and Decoration, Gazi University, Besevler, Ankara, Turkey*
[2]*Department of Furniture and Decoration, Karabük University, Karabük, Turkey*

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ABSTRACT: This study was performed to determine the impact of impregnation with boron compounds on the surface hardness and abrasion resistance of some varnished woods. For this purpose, test specimens prepared from Oriental beech, White oak, Scotch pine, and Uludag fir, which met the requirements of ASTM D 358, were impregnated according to ASTM D 1413-99 with boric acid (Ba), borax (Bx), and boric acid + borax (Ba+Bx) by the vacuum technique. After impregnation, the surfaces are coated with synthetic (Sn), water-borne (Wb) and acid hardening (Ah) varnishes in accordance with ASTM D 3023. the surface hardness of specimens after the varnishing process was determined in accordance with ASTM D 4366. The abrasion resistance of specimens after the varnishing process was determined in accordance with TS 4755. According to the wood type, impregnation material and varnish type, the surface hardness was the highest for Oriental beech impregnated with borax + boric acid and acid hardening varnish and the lowest for Uludag fir impregnated with borax + boric acid and synthetic varnish. According to the wood type, impregnation material and varnish type, the abrasion resistance was the highest for Oriental beech impregnated with borax + boric acid and acid hardening varnish and the lowest for Scotch pine impregnated with borax + boric acid and synthetic varnish. Those results should be taken into account for applications like parquet, flooring etc., where the surface hardness and abrasion resistance values are very important. J Appl Polym Sci 114: 204–211, 2009

Key words: coatings; surfaces hardness; abrasion resistance; boron Compounds; wood

INTRODUCTION

The compounds of wood material are degraded by environmental conditions due to chemical or biological factors. Furthermore, wood materials are exposed to mechanical impacts such as abrasion, scratch, crushing as well as physical impacts at many applications such as parquet, flooring, wall covering, furniture, and woodwork. The protection and lifetime extension of the wood material against these negative factors have an importance with regards to economy and techniques.[1] In order to increase the usages and resistance of the wood material, it is dried, impregnated, and coated with protective materials. Without impregnation and surface process, it was notified that the lignin in the wood, which was exposed to external environment for 20 years, was degraded.[2] In order to make wooden furniture and decoration elements resistant to the physical, chemical, and mechanical impacts, weather conditions, and negative impacts of the biological agents, generally varnishes are used for coating the surfaces by forming layers.[3–5] It was notified that coating Oriental beech, oak, Scotch pine, spruce, and Uludag fir with various varnishes after impregnation with boron compounds increased their surface hardness value.[6] After the impregnation and varnishing process, Scotch pine and chestnuts left at external conditions, surface hardness value (swing) was achieved the highest in Scotch pine + Tanalith–BC + polyurethane varnish (80.83), and the lowest in Scotch pine + water repellent synthetic varnish (28.40), and it was notified that Tanalith–CBC and impregnation process increased (7 %) the surface hardness value.[7] Surface hardness values (swing) was obtained the highest in oak + borax + acrylic varnish (131.4), and the lowest in oak + borax + synthetic varnish (37.6); so impregnation by boron compound increased (17%) the hardness value.[8]

Surface hardness values (swing) was obtained the highest in Oriental spruce + boric acid + polyurethane (135.4), and the lowest in Scotch pine + boric acid + synthetic varnish (41.0); so impregnation with boron compounds increased (3% and 10 %, respectively) the surface hardness value.[9] This case may depend on to increase in density of wood material because of the impregnation material. Depending on the bleaching treatment types, the average

Correspondence to: M. Atar (musaatar@gazi.edu.tr).

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highest varnish layer hardness (swing) was measured in Tanalith-CBC + $NaSiO_3$-H_2O_2 + water-borne treated samples (62.67) whereas the lowest in Imersol-WR 2000 + KMnO4-NaHSO3- H_2O_2 + water-borne treated samples (43.50) in Oriental beech wood.[10] Depending on the bleaching treatment types, the average highest varnish layer hardness (swing) was measured in Tanalith-CBC + NaOH + $Ca(OH)_2$ + H_2O_2 + water-borne treated samples (56.50) whereas the lowest in Imersol-WR 2000 + $NaHSO_3$ + $H_2C_2O_4$ $2H_2$ + water borne treated samples (40.83) in oak.[11]

The surface hardness with water-borne varnish on the Scotch pine, Oriental beech, and White oak was less than solvent-based varnishes (VOC); the highest surface hardness value was obtained in the Oriental beech and acrylic varnish.[12]

Abrasion resistance were measured by scratch, Brinell, and pendulum hardness tests on the Oriental beech, MDF, Werzalit, and laminates coated with polyurethane varnish and without any varnish. The highest abrasion resistance was found on the varnished Oriental beech (240 rpm).[13]

In a study, the highest abrasion resistance was measured as in Scotch pine + polyurethane varnish (131.35 μm) and the lowest Oriental spruce and parquet varnish (71.50 μm). The varnishes are important in abrasion resistance. The average amount of abrasion in varnished samples was 73.7 μm but in unvarnished samples, it was 171 μm.[14]

The abrasion resistance of particleboard surfaces coated with melamine-impregnated papers was higher than the surfaces coated with wood veneer or dyed with lacquer. This may be due to the high resistance of melamine and urea formaldehyde resin impregnated coating papers.[15]

In a study comparing the abrasion resistance of massif parquet and laminate parquet, it was the highest in UV dried polyurethane varnish coated (5 plies) laminate parquet (84 rpm) and the lowest in Oriental beech + polyurethane varnished parquet (74 rpm).[16]

The aim of this study was to determine the impact of impregnation material with boric acid (Ba), borax (Bx), and boric acid+ borax (Ba+Bx) on the surface hardness and abrasion resistance of varnished Oriental beech, oak, Scotch pine, and Uludag fir.

MATERIAL AND METHODS

Materials

Wood materials

Oriental beech (*Fagus orientalis* Lipsky), White oak (*Quercus petreae* Liebl.), Scotch pine (*Pinus sylvestris* Lipsky.), and Uludag fir (*Abies Bornmülleriana* Lipsky) were chosen randomly from timber merchants of Ankara, Turkey. Special emphasis was given for the selection of the wood material. Accordingly non-deficient, proper, knotless, normally grown (without zone line, without reaction wood and without decay, insect mushroom damages) wood materials were selected according to the TS 2470 standard.[17]

Varnishes

Synthetic, water-borne and acid hardening varnishes were used according to the producer's definition. Amount of varnish was determined according to the amount of solid material according to the producer's definition.

Impregnation materials

Boron compounds are obtained from Etibank Bandírma Borax and Boric Acid Factory, Turkey. The properties of boric acid ($H_3\,B\,O_3$) is 56.30% ½ $B_2\,O_3$, 43.70% H_2O with a molecular weight 61.84, density 1.435 g.cm^{-3} and melting point 171°C. Borax ($Na_2\,B_4\,O_7.\,5H_2\,O$) content is 21.28% Na_2O, 47.80% B_2O_3, 30.92% H_2O with a molecular weight 291.3, density 1.815 g cm^{-3} and melting point 741°C.

Methods

Preparation of test specimens

The rough drafts for the preparation of test and control specimens were cut from the sapwood parts of massif woods with a dimension of 190 × 140 × 15 mm and conditioned at a temperature of 20 ± 2°C and 65 ± 3% relative humidity condition until reaching to 12% humidity distribution in accordance with ASTM D 358.[18] The specimens with a dimension of 100 × 100 × 10 mm were cut from the drafts and drilled a hole with diameter of 6.5 mm at the middle for abrasion resistance test. The specimens, with a dimension of 150 × 100 × 10 mm were cut from the drafts for surface hardness test. The test specimens were impregnated with 5% boric acid, borax, and boric acid + borax according to ASTM D 1413.[19] Accordingly, the samples were exposed to a 760 mm/Hg^{-1} pre vacuum for 60 min and then were held in a solution under normal atmospheric pressure for 60 min for the diffusion of the impregnation material. The processes were carried out at 20 ± 2 °C. The retention of impregnation material (R) was calculated with the following formula;

$$R = \frac{G.C}{V} 10^3\ kg.m^{-3}\ (G = T_2 - T_1) \qquad (1)$$

Where, G is the amount of impregnation solution absorbed by the specimen, T_2 is the specimen weight after the impregnation, T_1 is the specimen weight

TABLE I
Retention Amounts of Impregnation Materials (Kg.m^{-3})

	Oriental Beech	White Oak	Scotch Pine	Uludağ Fir
Impregnation materials	x	x	x	x
Boric acid (Ba)	20.87	3.4	14.37	11.45
Borax (Bx)	29.65	4.14	14.99	11.64
Boric acid + Borax (Ba + Bx)	21.35	3.5	11.7	12.46

x: Average values, Ba: Boric acid, Bx: Borax.

before the impregnation, C is the concentration (%) of the impregnation solution, and V is the volume of the samples. Impregnated test samples were kept under a temperature of 20 ± 2°C and 65 ± 3% relative humidity until they reach to a stable weight.

Varnishing

Test specimens were varnished according to ASTM D 3023.[20] The surfaces of impregnated specimens were sanded with abrasive papers to remove the fiber swellings and dusts were cleaned before varnishing. The producer's definition was taken into account for the composition of the solvent and hardener ratio. One or two finishing layers were applied after the filling layer. The spray nozzle distance and pressure were adjusted according to the producer's definition and moved in parallel to the specimen surface at a distance of 20 cm. Varnishing was performed at 20 ± 2°C temperature and 65 ± 3% humidity.

Hardness measurements

The hardness measurements were performed after the varnish coating; the test samples were conditioned at 23 ± 2°C and 50 ± 5% relative humidity for 16 h. The hardness measurements of varnished surfaces were taken according to ASTM D 4366 with a pendulum-damping test.[21] The test device determined the layer hardness by means of the swing of a pendulum. The pendulum had marbles 5 ± 0.0005 mm in diameter with a Rockwell conventional hardness value 63 ± 3.3. The amount of the swing was directly proportional to the surface hardness.

Abrasion resistance

The abrasion resistance was performed after the varnish coating; the test samples were conditioned at 23 ± 2°C and 50 ± 5% relative humidity for 16 h. Abrasion resistance tests of varnished surfaces were taken according to TS 4755 with Taber test equipment.[22] The test samples were connecting to the disc rotating in an axis parallel to horizontal plain with an rpm of 58–62 cycle/minute. In abrading the sample surfaces according to TS 1324,[23] it is coated with rubber and abrasive wheels with 12.7 mm width and 50 mm diameter that are 50–55 mm far away from each other. The top surfaces were abraded by controlling the samples every 25 revolutions and if 50% of the wood bottom was appeared, the test was finalized and rated amounts were determined.

Data analysis

For hardness test, four wood types, three impregnation materials + 1 without impregnation specimen, 3 varnish type + 1 without varnishing specimen, five units for each test, 320 units in total (4 × 4 × 4 × 5) were prepared. For abrasion test, 4 wood types, 3 impregnation materials+1 without impregnation, 3 varnish types + 1 without varnishing specimen, 5 units for each test, 240 units in total (4 × 3 × 4 × 5) were prepared. Total number of samples was 560 (320 + 240). In order to determine the impact of the impregnation materials of the samples to surface hardness and abrasion resistance values, multiple variance analysis was realized Duncan Test was used to determine the significant difference between the groups.

RESULTS

Retention amounts

The averages of retention amounts of impregnation materials are given in Table I.

Retention amount of the impregnation materials according to types of wood and impregnation material is the highest in beech and borax (29.65 kg.m^{-3}) and the lowest in oak and boric acid (3.4 kg.m^{-3}). Accordingly, types of wood and impregnation materials are important for retention.

Hardness

The average surface hardness values determined according to the interactions of types of wood type + impregnation materials, impregnation materials +

TABLE II
Surface Hardness Average Values According to Wood Material Type, Impregnation Material and Varnish Type (Swing)

	Swing	
Types of material*	x	HG[a]
Impregnation + wood materials*		
I	48.70	cd
I+Ba+Bx	53.85	ab
I+Bx	54.85	a
I+Ba	48.95	cd
II	48.85	cd
II+Ba+Bx	44.50	ef
II+Bx	51.10	bc
II+Ba	46.40	de
III	36.35	g
III+Ba+Bx	42.80	f
III+Bx	41.65	f
III+Ba	43.30	ef
IV	34.80	gh
IV+Ba+Bx	33.75	ghi
IV+Bx	32.40	hi
IV+Ba	31.40	i
Impregnation + varnishes**		
Ah	40.25	d
Wb	75.15	a
Sn	34.20	e
(Ba+Bx)+Ah	19.10	h
(Ba+Bx)+ Wb	40.05	d
(Ba+Bx)+St	67.65	b
Bx+Ah	39.35	d
Bx+Wb	27.85	f
Bx+Sn	43.55	c
Ba+Ah	68.25	b
Ba+ Wb	39.00	d
Ba+Sn	29.20	f

[a] Different letters in a column refers to significant diferences among different interactions of wood material, varnish and impregnation materials at 0.05 confidence level (*LSD: 3.041, **LSD: 3.041), I: Oriental beech, II: White oak, III: Scotch pine, IV: Uludağ fir, Sn: Synthetic, Ah: Acid hardening, Wb: Water based varnishes, Ba: Boric acid, Bx: Borax, Ba+Bx: Boric acid + Borax, x: Average values, HG: Degree of Homogeny.

varnish type, and wood type + varnish type are given in Table II.

The surface hardness value is determined as the highest in beech + borax and the lowest in Uludag fir + boric acid for wood type and impregnation material interaction; the highest in borax +boric acid and acid hardening varnish the lowest in boric acid + synthetic varnish for impregnation material and varnish type interaction. Multiple variance analysis results about the impact of the wood type, varnish type, and impregnation material on surface hardness are given in Table III.

The impact of wood type, impregnation materials, and varnish type materials on the layer hardness is important for the effect of variance sources on the surface hardness ($\alpha = 0.05$). Duncan Test results are given in Table IV to indicate the importance of differences between the groups.

The hardness was the highest in Oriental beech and acid hardening varnishes and the lowest in the Scotch pine and synthetic varnish for the varnished wood materials without impregnation. For samples varnished after impregnation, hardness was the highest in the Oriental beech varnished with the acid hardening varnish after impregnation with boric acid + borax but the lowest in the Uludag fir varnished with the synthetic varnish after impregnation with boric acid.

Abrasion resistance

The average abrasion resistance values according to the types of wood and impregnation material, impregnation material, and varnish type interactions are given in Table V.

According to the wood materials, the abrasion resistance was the highest in beech and the lowest in the Scotch pine and Uludag fir. According to the varnishing materials, the abrasion resistance was the

TABLE III
Multiple Variance Analysis of Hardness Values for the Interaction of Wood Material Type, Varnish Type and Impregnation Material

Source	Degrees of freedom	Sum of squares	Mean square	F value	Probably % 5 (sig.)
Wood materials[a]	3	15808.984	5269.661	220.5312	0.0000
Impregnation[b]	3	395.609	131.870	5.5186	0.0011
AB	9	1467.053	163.006	6.8217	0.0000
Varnish[c]	3	83589.109	27863.036	1166.0461	0.0000
AC	9	3167.553	351.950	14.7288	0.0000
BC	9	2530.328	281.148	11.7658	0.0000
ABC	27	2069.259	76.639	3.2073	0.0000
Error	256	6117.200	23.895		
Total	319	115145.097			

[a] Factor A = I: Oriental beech, II: Oak, III: Scotch pine, IV: Uludağ fir.
[b] Factor B = Ba: Boric acid, Bx: Borax, Ba+Bx: Boric acid + Borax.
[c] Factor C = Sn: Synthetic, Ah: Acid hardening,Wb: Water-based varnishes.

TABLE IV
Duncan Test Results (Swing)

Type of process	Swing[a] X	Swing[a] HG	Type of process	Swing[a] x	Swing[a] HG	Type of process	Swing[a] x	Swing[a] HG
I+Ah	87.6	a	II+Ba	49.2	ghijk	III	31.6	uvwxyz
II+Ah	81.6	ab	I	48	hjkl	III+Wb	31.2	uvwxyza
I+(Ba+Bx)+Ah	81	b	I+(Ba+Bx)+Wb	47.2	hijklm	IV+Ba+Wb	31.2	uvwxyza
II+Bx+Ah	79.4	b	II+Ba+Wb	45.6	ijklmn	IV+Bx	29.2	vwxyzab
I+Bx+Ah	77.4	bc	III+Ba	45.4	ijklmn	IV+Wb	28.4	wxyzabc
I+Ba+Ah	71.8	cd	II+Bx	44.8	jklmn	III+(Ba+Bx)+Sn	27.8	wxyzabcd
II+Ba+Ah	70.2	de	II+Bx+Wb	44.4	jklmn	IV	27.4	xyzabcd
III+(Ba+Bx)+Ah	68.4	de	III+Bx	44	jklmno	II+(Ba+Bx)+Sn	27.2	xyzabcd
III+Ba+Ah	67.6	de	I+Ba+Wb	43	jklmnop	IV+(Ba+Bx)	26.6	yzabcd
II+(Ba+Bx)+Ah	67	de	II+(Ba+Bx)	42.4	klmnopq	III+Ba+Sn	26	zabcde
III+Ah	66.8	de	II+(Ba+Bx)+Wb	41.4	lmnopqr	IV+Bx+Wb	26	zabcde
III+Bx+Ah	66	de	I+Wb	40.2	mnopqrs	IV+Bx+Sn	24.2	abcde
IV+Ah	64.6	e	III+(Ba+Bx)	39	nopqrst	III+Bx+Sn	23.4	bcde
I+Ba	58.2	f	II+Wb	37	opqrstu	II+Sn	22.8	bcdef
I+Bx	56.2	fg	III+(Ba+Bx)+Wb	36 p	qrstuv	I+Ba+Sn	22.8	bcdef
IV+(Ba+Bx)+Ah	54.2	fgh	II+Bx+Sn	35.8	qrstuv	IV+Ba+Sn	21.6	cdef
II	54	fgh	I+(Ba+Bx)+Sn	35	rstuvw	IV+(Ba+Bx)+Sn	21.4	cdef
I+Bx+Wb	52.4	fghi	III+Ba+Wb	34.2	stuvwx	II+Ba+Sn	20.6	def
I+(Ba+Bx)	52.2	fghi	I+Bx+Sn	33.4	stuvwxy	IV+Ba	20.6	def
IV+Ba+Ah	52.2	fghi	III+Bx+Wb	33.2	stuvwxyz	I+Sn	19	ef
IV+Bx+Ah	50.2	ghij	IV+(Ba+Bx)+Wb	32.8	tuvwxyz	IV+Sn	18.8	ef

LSD = 6.083.

highest in acid hardening varnish and the lowest in the water-borne varnish. Abrasion resistance was decreased by impregnation process but impregnation after varnishing have no affect on abrasion resistance; so the main factor in rising the abrasion resistance is varnishing. Multiple variance analysis results related to the abrasion resistance values affect of the wood type, varnish type, and impregnation material are given in the Table VI.

The impact of wood, impregnation materials, and varnishing materials on the abrasion resistance is important for the effect of variance sources on the surface hardness ($P < 0.05$). Duncan Test results are given in Table VII to indicate the importance of differences between the groups.

The abrasion resistance is determined as the highest in beech + borax + boric acid + acid hardening varnish (167 rpm) and the lowest in Uludag fir + borax + boric acid + synthetic varnish (850 rpm).

DISCUSSION

Impregnation retention amounts are the highest in beech + borax, the lowest in oak + boric acid. Retention amount is the highest in beech, the lowest in other wood types. The tyloses formation in oak, the resin in Scotch pine, and pit aspiration in Uludag fir may have affected the results.

The layer thickness (swing) was 117.56 μm in the acid hardening varnish, 90.19 μm in water-borne varnish, 91.25 μm in the synthetic varnish. The differences between the varnish layers may have depended on the different solid materials.

The hardness value is determined as the highest in acid hardening varnish (75.15) and the lowest in synthetic varnish (19.1) in terms of varnish type. Hardness values were occurred from high to low as acid hardening, water-borne, and synthetic varnish. The low occurrence of hardness value of synthetic varnish may arise from the drying oils used in the production. Thus, it was notified that the drying oils have decreasing impact of hardness surface coated with synthetic varnishes.[24]

The surface hardness values was measured as different for different wood types and impregnation materials. This may be due to the structure of wood and different ways of impacts of boron compounds.

The surface hardness values were found as different for impregnation material and varnish type interaction. It increased surface hardness some amount in water-based and synthetic varnishes with boron compounds impregnation but decreased in acid hardening varnish. This may be due to the interaction of boron compounds having an acidic character with acid hardening varnish.

The surface hardness value is determined as the highest in beech + borax + boric acid + acid hardening varnish (81) and the lowest oak + boric acid + synthetic varnish (20.06) in terms of wood type, impregnation material, and varnish type interaction.

TABLE V
Abrasion Resistance Average Values According to Wood Material Type, Impregnation Material and Varnish Type (rpm)

Types of material	Abrasion[a] x	HG
Impregnation + wood materials*		
I	130	a
I+Ba+Bx	125.66	a
I+Bx	125	a
I+Ba	103.33	b
II	96.66	c
II+Ba+Bx	95	c
II+Bx	83.33	de
II+Ba	86.66	d
III	83.33	de
III+Ba+Bx	66.66	g
III+Bx	75	f
III+Ba	63.33	g
IV	83.33	de
IV+Ba+Bx	80	ef
IV+Bx	80	ef
IV+Ba	76.66	f
Impregnation + varnishes**		
Ah	141.25	a
Wb	62.5	f
Sn	91.25	d
(Ba+Bx)+Ah	129.25	b
(Ba+Bx)+Wb	61.25	f
(Ba+Bx)+Sn	85	e
Bx+Ah	128.75	b
Bx+Wb	62.5	f
Bx+Sn	81.25	e
Ba+Ah	115	c
Ba+Wb	51.25	g
Ba+Sn	81.25	e

[a] Different letters in a column refers to significant diferences among different interactions of wood material, varnish, and impregnation materials at 0.05 confidence level (*LSD: 4.987, **LSD: 4.319). I: Oriental beech, II: White oak, III: Scotch pine, IV: Uludağ fir, Sn: Synthetic, Ah: Acid hardening, Wb: Water based varnishes, Ba: Boric acid, Bx: Borax, Ba+Bx: Boric acid + Borax, x: Average values, HG: Degree of Homogeny.

The impact of wood type and impregnation on the surface hardness after varnishing was found unimportant. So, acid hardening varnishes may be used in the applications with high impact resistance.

The surface abrasion resistance is found the highest in the beech (130 rpm) and the lowest in the Scotch pine and Uludag fir (83.33 rpm). Its order from high to low is beech, oak, and Scotch pine and Uludag fir. This case may arise from the structural differences of the wood types. This, it was notified that diffuse vessel leaf wood is more resistant than the ones with porous against abrasion.[25]

The surface abrasion resistance is determined as the highest in acid hardening varnish (141.25 rpm) and the lowest in water-borne varnish (62.5 rpm) in terms of varnish type. The abrasion of acid hardening varnish less than the others may arise from its high cohesion power.

Impregnation materials have a decreasing impact on abrasion resistance. Boron compounds were having acidic characteristic may be decreasing the strength of wood fibers but impregnation with boron compounds after varnishing seems to be unimportant.

For the interaction of impregnation material and varnish type; the abrasion resistance is decreased some amount is synthetic and acid hardening varnishes but not changed in water-borne varnishes. Boron compounds may be decreased the adhesion in synthetic and acid hardening varnishes.

Surface abrasion resistance is determined as the highest in beech + borax + boric acid + acid hardening varnish (167.00 rpm) and the lowest in water-borne varnish sample of the scotch pine impregnated with boric acid (30.00 rpm) in terms of wood type, impregnation material, and varnish type interaction.

As a result, it may be accepted firstly the varnish type and secondly wood type have an impact on abrasion resistance but the impact of impregnation material is negligible.

TABLE VI
Multiple Variance Analysis of Abrasion Resistance for the Interaction of Wood Material Type, Varnish Type and Impregnation Material

Source	Degrees of freedom	Sum of squares	Mean square	F value	Probably % 5 (sig.)
Wood materials[a]	3	82747.083	27582.361	573.7609	0.0000
Impregnation[b]	3	7601.256	2533.750	52.7064	0.0000
AB	9	4674.583	519.398	10.8044	0.0000
Varnish[c]	2	196070.6	98035.313	2039.30	0.0000
AC	6	3653.542	608.924	12.6667	0.0000
BC	6	2424.375	404.063	8.4052	0.0000
ABC	18	6414.792	356.377	7.4133	0.0000
Error	192	9230.000	48.073		
Total	239				

[a] Factor A = I: Oriental beech, II: White Oak, III: Scotch pine, IV: Uludağ fir.
[b] Factor B = Ba: Boric acid, Bx: Borax, Ba+Bx: Boric acid + Borax.
[c] Factor C = Sn: Synthetic, Ah: Acid hardening, Wb: Water-based varnishes.

TABLE VII
Duncan Test Results (rpm)

Type of process	Abrasion[a] x	Abrasion[a] HG	Type of process	Abrasion[a] x	Abrasion[a] HG
I+(Ba+Bx)+Ah	167	a	II+Ba+Sn	90	f
I+Ah	165	a	I+(Ba+Bx)+Wb	85	f
I+Bx+Ah	150	b	I+Ba+Wb	75	g
II+Ah	150	b	II+Bx+Sn	75	g
I+Ba+Ah	135	c	III+Sn	75	g
I+Sn	125	d	IV+Ba+Sn	75	g
I+(Ba+Bx)+Sn	125	d	IV+Bx+Sn	75	g
I+Bx+Sn	125	d	IV+Sn	75	g
II+(Ba+Bx)+Ah	125	d	IV+(Ba+Bx)+Sn	65	h
II+Bx+Ah	125	d	II+(Ba+Bx)+Wb	60	h
IV+(Ba+Bx)+Ah	125	d	III+Ba+Sn	60	h
III+Ah	125	d	II+Wb	50	i
III+Bx+Ah	125	d	II+Bx+Wb	50	i
IV+Ah	125	d	II+Ba+Wb	50	i
II+Ba+Ah	120	d	III+Wb	50	i
IV+Bx+Ah	115	d	III+(Ba+Bx)+Wb	50	i
IV+Ba+Ah	105	e	III+Bx+Wb	50	i
I+K+Wb	100	e	IV+Ba+Wb	50	i
I+Bx+Wb	100	e	IV+Wb	50	i
I+Ba+Sn	100	e	IV+(Ba+Bx)+Wb	50	i
II+(Ba+Bx)+Sn	100	e	IV+Bx+Wb	50	i
III+(Ba+Bx)+Ah	100	e	III+Bx+Sn	50	i
III+Ba+Ah	100	e	III+(Ba+Bx)+Sn	50	i
II+Sn	90	f	III+Ba+Wb	30	j

[a] LSD: 8.638.

CONCLUSION

The impregnation of wood is important for conservation to the damages of external conditions and increase of lifetime. Boron compounds have no impact on the hardness of surface layer, but the varnish type has an important impact. The impregnation with boron compounds have no impact on the abrasion resistance of woods, but the type of woods and varnishing materials are important to increase the abrasion resistance. So, the parquets used in common use areas must be produced from Scotch pine and coated with synthetic and water-borne varnishes. The abrasion resistance and surface hardness of Oak and Oriental beech are the highest due the high density, so the parquets produced from those woods are the best suitable for the application in public use areas. For increasing the abrasion resistance, the acid hardening varnish is better than two others.

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