WOOD RESEARCH
60 (5): 2015
833-844

THE EFFECTS OF NATURAL WEATHERING ON HARDNESS AND GLOSS OF IMPREGNATED AND VARNISHED SCOTS PINE AND ORIENTAL BEECH WOOD

Turkay Turkoglu
Mugla Sitki Kocman University, Koycegiz Vocational School
Department of Forestry
Mugla, Turkey

Ergun Baysal
Mugla Sitki Kocman University, Faculty of Technology
Wood Science and Technology
Mugla, Turkey

Ihsan Kureli
Gazi University, Faculty of Technology Wood Science and Technology
Ankara, Turkey

Hilmi Toker, Mehmet Emin Ergun
Mugla Sitki Kocman University, Faculty of Technology
Wood Science and Technology
Mugla, Turkey

(Received February 2015)

ABSTRACT

The purpose of this study was to investigate the changes caused by natural weathering on surface hardness and gloss of Scots pine (*Pinus sylvestris* L.) and Oriental beech (*Fagus orientalis* L.) wood specimens impregnated with three different chemicals and coated with two types varnish. In this study, tanalith-E (TN-E), adolit-KD 5 (AD-KD 5), and chromated copper arsenate (CCA) were used as wood preservatives and then polyurethane (PV) and synthetic (SV) varnishes were applied to the wood surface. The surface hardness and gloss of wood specimens were determined after 3 and 6 months of natural weathering. After 3 months of natural weathering, results showed that while surface hardness values of solely varnish coated, and both impregnated and varnish coated wood specimens increased, surface hardness of untreated (control) specimens decreased. However, surface hardness values of untreated (control), and impregnated and coated wood specimens decreased considerably after 6 months of natural weathering. The gloss values of impregnated and coated, and untreated (control) wood specimens after 3 months of natural weathering were slightly low, and after 6 months of natural weathering, the decrease reached to the considerable level. After six months of natural weathering, the surface hardness and gloss loss of Scots pine and Oriental beech was the lowest in the TN-E impregnated and PV coated wood specimens.

KEYWORDS: Natural weathering, surface hardness, gloss, Scots pine, Oriental beech, impregnation, varnish.

INTRODUCTION

Wood is a sustainable and environmentally friendly natural material widely used as a construction material (Trisna and Hiziroglu 2013; Tomak et al. 2012). However, wood is much more easily degraded by environmental agents, including fire, biological organisms, water, and light, than many man-made materials (Kiguchi et al. 1998). Especially, outdoor conditions can cause rapid degradation of wood surface primarily due to the effect of the ultraviolet light component of sunlight and water (Yalinkilic et al. 1999). The main factor that causes the greatest changes in the surface properties of wood during outdoor exposure is sunlight (Tolvaj et al. 2011). Because lignin is the main chemical component of wood, the aromatic polymer, strongly absorbs sunlight (Jebrane et al. 2009), which causes depolymerization of lignin. As a result of this a reduction in molecular weight of lignin component leads to shorter polymer chains and degradation of mechanical properties (Bhat et al. 2010). Depending on the considered field of application, wood properties like surface hardness, gloss and deformability as well as abrasion and scratch resistance are of prime importance for wood (Veigel et al. 2014). In recent years, much effort has been put into the development of protective systems for wood to prevent photodegradation during outdoor weathering. Weathering is a complex process that modifies and degrades the overall molecular structure of wood (Ozgenc and Yildiz 2014). Weathering reduces the service life of wood and increases maintenance cost. Therefore, there is increasing interest in the solutions that reduce weathering of wood (Lesar et al. 2011). One of the most important and effective methods suggested to reduce or limit wood weathering is the treatment of wood with chemicals (Temiz et al. 2005). Thus, wood treatments such as impregnation with preservatives and modification techniques can improve the durability of wood outdoors depending on the intended applications (Kamdem and Pizzi 2002). Coatings are widely used for protecting wood surfaces against corrosion and environmental degradation as well as biodegradation (Akbarian et al. 2012; Williams et al. 1996) and they can provide wood with desirable aesthetical properties (De Meijer 2001). Impregnation of wood with a compatible preservative chemical and applying a vanish prior to outdoor use has been undertaken to make wood more stable against photochemical degradation, dimensional changes, and biological decomposition (Yalinkilic et al. 1999). Moreover, the surface properties of wood materials can be enhanced easily by impregnating and finishing with various preservatives to provide different performance characteristics for individual applications, such as high hardness, impact resistance, suitable gloss, and chemical resistance (Chang and Lu 2012). Treatment with wood preservatives especially formulated with chromium and/or copper compounds improves the durability of wood surfaces against UV irradiation and weathering factors (Temiz et al. 2005). Yalinkilic et al. (1999) investigated the outdoor performance of Scots pine and chestnut wood treated with chromium-copper-boron (CCB) and applied with polyurethane (PV) or alkyd-based synthetic varnish (SV) (Yalinkilic et al. 1999).

They reported that CCB impregnation before a surface coating system protected wood in long term outdoor conditions. It was claimed that the impregnated and coated wood surface became harder than untreated wood surfaces. They also found that polyurethane varnish yielded a harder surface than synthetic varnish (Yalinkilic et al. 1999). Another piece of research about outdoor weathering durability of obeche, red beech, spruce, and fir wood treated with CCB was carried out by Sell and Feist. They found that CCB-coated wood has high resistance and a protective effect against weathering (Sell and Feist 1985). The effect of accelerated weathering on surface properties of Scots pine impregnated with wolmanit-CB, tanalith-E (TN-E) and Adolit-KD5 (AD-KD5) and coated with SV and PV was investigated (Baysal et al. 2014). According to the findings of their study, while weathering caused an increase in the hardness of impregnated and varnished specimens, gloss of specimens decreased after weathering. In this regard, the weathering aspects of treated wood with new copper based wood preservatives have been become of more importance (Temiz et al. 2005). In last decade, several new chemical formulations such as TN-E and AD-KD5 have been developed and currently used for building construction, but there is not enough information about the effects of these new chemicals on the some properties of wood (Yildiz et al. 2004). The comparison of new copper based wood preservatives with chromated copper arsenate (CCA) and its performance testing is important in determining consumer expectation of these new products (Turkoglu et al. 2015).

This study was carried out on Scots pine and Oriental beech wood specimens impregnated with a 4 percent aqueous solutions of copper based commercial impregnation chemicals such as AD-KD 5 and TN-E. In addition, CCA was used to compare with AD-KD 5 and TN-E. After impregnation, SV and PV coatings were applied to the wood surface. Then, the wood specimens were exposed to natural weathering for two periods, 3 months and 6 months. Therefore, the objective of this study was to investigate surface hardness and gloss changes caused by natural weathering on the treated wood with copper-based impregnation chemicals before varnish coatings.

MATERIAL AND METHODS

Preparation of test specimens and chemicals

Wood specimens were prepared from air-dried sapwood samples of Scots pine and Oriental beech for impregnation treatment, with dimensions of 10 (radial) x 100 (tangential) x 150 (longitudinal) mm. They were dried at 50 ± 5°C until unchangeable weight was reached. Wood specimens were impregnated with three preservatives such as CCA, AD-KD 5, and TN-E. Impregnation chemicals were dissolved in distilled water to a concentration of 4 percent. The pH level of the impregnation solutions were 7.76 for CCA, 8.39 for AD-KD 5, and 8.25 for TN-E. An alkyd-based synthetic varnish and a solvent-based two-component polyurethane varnish were applied after the impregnation process in this study.

Impregnation process

The wood specimens were impregnated with 4 percent aqueous solution of CCA, AD-KD 5, and TN-E according to the ASTM D1413-07e1 - 2007. A vacuum desiccator used for the impregnation process was connected to a vacuum pump through a vacuum trap. Vacuum was applied for 30 min at 760 mm Hg before supplying the solution into the chamber and this was followed by another 30 min at 760 mm Hg diffusion period under vacuum. All specimens were conditioned at 20°C and 65 % relative humidity for three weeks before tests. Ten replications were made for each group. Calculating the amount of preservative impregnation chemicals absorbed by the wood specimens, as kilograms per cubic meter of wood was done using the following Eq.

$$\text{Retention} = \frac{G \times C}{V} \times 10 \qquad (kg.m^{-3})$$

where: $G = (T_2 - T_1)$ - grams of treatment solution absorbed by the wood specimens,
T_1 - the weight of the wood specimens before impregnation,
T_2 - the weight of the wood specimens after impregnation,
C - concentration as percentage,
V - volume of the wood specimen (cm^3).

Coating of the wood specimens

Synthetic and polyurethane varnishes were supplied by merchants and used according to the manufacturers' instructions. The viscosity of the varnishes was determined according to the manufacturer's directions and was found to be 18 s (DIN 4 cup) at 20 ± 2°C for both varnishes. Hardener and thinner mixture ratios were determined according to the manufacturer's suggestions. The varnish was applied to all surfaces and sides of the wood specimens with a spray gun according to the ASTM D3023-98 - 2013 standard. Filler was not used on the wood surfaces in order to avoid potential interference with the surface characteristics of the wood. Instead of using filler, varnish was applied twice for PV and 4 times for SV. The first coating applied to the wood surface was for filling the voids, and the second and upper coatings were applied for top coating. Sufficient time for layer settling was allowed between successive applications until the target retention of 100 $g.m^{-2}$ for the primer and 100 $g.m^{-2}$ for the top coating was reached, controlled by consecutive weighting. Specimens were left in ambient conditions for 24 h according to the manufacturer's recommendations after the first coating, and then surfaces were gently sanded using a fine-grit sandpaper (220 grit) to obtain a smooth surface before applying the top coating. After the application of the top coating of varnishes to the surfaces, specimens were conditioned for 3 weeks (Baysal et al. 2014).

Weathering exposure

Wood specimens were prepared for weathering exposure according to ASTM D7787 - 2013. They were exposed to weathering conditions during spring and summer (from March to August) in 2011. The site is situated at Mugla Sitki Kocman University (37° 09′ N and 28° 22′ E, 670 m above sea level) in Mugla, Southern Aegean Region of Turkey. Weather conditions of Mugla during weathering were given Tab. 1 (Meteorological data 2011).

Tab. 1: Weather conditions of Mugla from March to August in 2011.

Months	Mar	Apr	May	Jun	Jul	Aug
Average temperature (°C)	8.6	11.7	16.4	22.8	27.9	27.5
The highest temperature (°C)	19.9	21.7	29.1	35.9	38.4	38.1
The lowest temperature (°C)	-4.9	1.4	6.8	13	12.1	13.5
Sunbathing time (hour)	5.4	5.5	6.8	10	11.2	10.4
The number of the rainy day	11	17	9	6	0	0
Rainfall per month ($kg.m^{-2}$)	29.8	80.4	59.4	17.4	0	0
Humidity (%)	74.6	75.2	67.8	53.6	38.8	39.2

The exposure rack was positioned so that the exposed specimens were at an angle of 45° facing south. Wood specimens were set outside for weathering exposure according to ASTM

G7/G7M-13 - 2013. Exposure covered a period of 6 months. The wood specimens were removed at 3-month intervals for performance evaluation. Surface hardness and gloss measurements were made on the exposed surfaces of the wood specimens. The surface hardness and gloss were measured at the same points on the tangential face of the samples before and after natural weathering.

Surface hardness

The surface hardness of wood specimens was measured as the König hardness according to ASTM D 4366–14 - 2013. Wood specimens were placed on a panel table, and a pendulum was placed on the panel surface. Then, the pendulum was deflected through 6° and released, at the same time, a stopwatch was started. The time for the amplitude to decrease from 6° to 3° was measured as König hardness.

Gloss test

The gloss test of wood specimens was determined using a glossmeter (BYK Gardner, Micro-TRI-Gloss) according to ASTM D523-14 - 2013. The chosen geometry was an incidence angle of 60°. Results were based on a specular gloss value of 100, which relates to the perfect condition under identical illuminating and viewing conditions of a highly polished, plane, black glass surface.

RESULTS AND DISCUSSION

In this study, synthetic or polyurethane varnish was applied to Scots pine and Oriental beech wood specimens after being impregnated with three different chemicals except for the control specimens. The wood specimens were exposed to natural weathering for two periods, 3 months and 6 months. The effects of the preservatives and varnishes on surface hardness and gloss values before and after weathering are presented in this section. Retention amount of different impregnation solutions on Scots pine and Oriental beech wood are given in Tab. 2. Retention amount of wood specimens were calculated as 30.7 to 35.5 $kg.m^{-3}$ in Scots pine, and 23.1 to 28.8 $kg.m^{-3}$ in Oriental beech. The highest retention amounts determined in Scots pine and Oriental beech impregnated with TN-E were 35.5 and 28.8 $kg.m^{-3}$, respectively. The lowest retention amounts determined in Scots pine and Oriental beech impregnated with AD-KD 5 were 30.7 and 23.1 $kg.m^{-3}$, respectively.

Tab. 2: Retention amount of wood specimens.

Impregnation Solution	Concentration (%)	Retention ($kg.m^{-3}$)	
		Scots pine	Oriental beech
CCA	4	32.7	27.6
AD-KD 5	4	30.7	23.1
TN-E	4	35.5	28.8

Surface hardness

The surface hardness values of Scots pine and Oriental beech specimens before and after natural weathering are given in Tab. 3 and Tab. 4.

Tab. 3: Surface hardness of Scots pine specimens before and after natural weathering.

Treatment	Retention (%)	Before natural weathering		After 3 months natural weathering			After 6 months natural weathering		
		Mean	SD	Mean	SD	Change (%)	Mean	SD	Change (%)
Control	-	15.2	3.4	13.5	2.1	-11.18	3.9	0.7	-74.34
PV	-	23.4	3.9	47.6	9.8	103.42	11.8	2.2	-49.57
SV	-	13.0	3.7	30.2	7.9	132.31	6.1	2.1	-53.08
CCA + PV	32.7	15.2	5.2	42.8	7.9	181.58	14.2	4.1	-6.58
CCA + SV		7.6	2.4	26.4	7.2	247.37	5.3	1.7	-30.26
AD-KD 5 + PV	30.7	17.8	3.9	44.2	6.1	148.31	14.5	2.6	-18.54
AD-KD 5+ SV		8.8	2.5	23.8	4.6	170.45	4.5	1.4	-48.86
TN-E + PV	35.5	19.0	5.2	52.4	10.5	175.79	18.4	6.2	-3.16
TN-E + SV		12.6	2.7	31.2	4.4	147.62	7.2	1.2	-42.86

Note: Ten replicates were made for each treatment group. SD: Standard deviation.

Tab. 4: Surface hardness of Oriental beech specimens before and after natural weathering.

Treatment	Retention (%)	Before natural weathering		After 3 months natural weathering			After 6 months natural weathering		
		Mean	SD	Mean	SD	Change (%)	Mean	SD	Change (%)
Control		22.0	3.4	17.3	4.3	-21.36	3.2	0.4	-85.45
PV	-	27.3	4.3	43.8	8.6	60.44	5.7	0.6	-79.12
SV	-	23.0	2.5	41.8	9.5	81.74	5.3	1.2	-76.96
CCA + PV	27.6	22.2	3.7	46.8	5.6	110.81	5.6	1.4	-74.77
CCA + SV		15.8	2.5	45.0	9.4	184.81	4.5	0.5	-71.52
AD-KD 5 + PV	23.1	28.5	3.0	53.3	4.7	87.02	6.0	0.7	-78.95
AD-KD 5 + SV		15.5	2.3	43.0	9.1	177.42	4.5	0.9	-70.97
TN-E + PV	28.8	23.0	3.5	44.0	5.2	91.30	10.8	1.9	-53.04
TN-E + SV		19.8	3.0	43.0	10.1	117.17	7.4	1.6	-62.63

Note: Ten replicates were made for each treatment group. SD: Standard deviation.

The surface hardness of untreated (control) Scots pine and Oriental beech wood specimens were found to be 15.2 and 22.0, respectively before natural weathering. While surface hardness of Scots pine wood specimens applied with PV and SV were observed to be 23.4 and 13.0, respectively, for Oriental beech wood specimens surface hardness was found to be 27.3 and 23.0, respectively. While surface hardness of untreated (control) Scots pine and Oriental beech wood specimens decreased 11.18 and 21.36 % after three months of natural weathering, surface hardness of all other impregnated and varnished Scots pine and Oriental beech specimens increased to a considerable level after 3 months of natural weathering. Baysal (2008) found that SV and PV coating together with CCB impregnation hardened the wood surfaces after 3 months of outdoor weathering (Baysal 2008). This was because the impregnation materials increased hardness and wood samples had a harder varnish layer (Keskin et al. 2011). Surface hardness values of Oriental beech wood specimens were between 17.3 and 53.3 after the three months period. In the same period, the surface hardness of Scots pine was between 13.5 and 52.4. Yalinkilic et al. (1999) reported that impregnated and varnished wood surface, upon weathering, hardened markedly up to a point and then underwent a stable phase or gradual softening. After six months of natural weathering, surface hardness of all untreated (control), and impregnated and coated wood specimens dramatically decreased. The decline was 74.34 % for untreated (control) Scots pine and 85.45 % for untreated (control) Oriental beech. This is because weathering softens wood materials (Yalinkilic et al. 1999). The surface hardness values of impregnated and varnished wood specimens decreased 3.16 to 48.86 % for Scots pine and 53.04 to 78.95 % for Oriental beech after the six month weathering period owing to the fact that the film toughness of wood surface was degraded by environmental conditions (Yalinkilic et al. 1999). The least decrease in hardness values was 53.04 %, observed for Oriental beech impregnated with TN-E before polyurethane varnish coating after six months of weathering. The least decrease in surface hardness values was obtained from the Scots pine impregnated with CCA or TN-E before polyurethane varnish coating after six months of weathering. In similar research carried out by Peker (1997), Scots pine and Chestnut were impregnated and varnished and then exposed to natural weathering. He reported changes in the surface hardness after weathering and for Scots pine, the greatest surface hardness was obtained with tanalith-CBC and a polyurethane varnish (Peker 1997). In our study, the surface hardness of Scots pine and Oriental beech specimens increased after three months natural weathering because of being treated with wood preservatives. After six months, the surface hardness decreased dramatically in all specimens due to natural weathering. Similar surface hardness of Calabrian pine wood treated with boron and varnished with SV or PV was also observed (Toker et al. 2009). Our results showed that the minimum decline in surface hardness was for the Scots pine and Oriental beech impregnated with TN-E and polyurethane varnish coating after six months of natural weathering. The importance of varnish type on surface hardness was proved (Uysal et al. 2009). Atar et al. (2011) reported that PV coating increased the surface hardness of wood specimens more than SV coating (Atar et al. 2011). In another study, Baysal (2008) achieved the same results. Polyurethanes are a unique class of polymers that have a wide range of applications because their properties can be tailored by variation of their components (Lai and Baccei 1991; Chang and Chou 2000).

Gloss

Gloss is a measure of the coated surface to reflect light and it is an important property of the coating when the purpose is to provide an aesthetic or decorative look to the surface (Kumar et al. 2006; Cakicier et al. 2011). Gloss of wood specimens was measured at a 60° angle of incidence using a gloss meter. The results of gloss for Scots pine and Oriental beech specimens before and after natural weathering are given in Tabs. 5 and 6.

Before natural weathering, the gloss values of untreated (control) wood specimens were much lower than impregnated and varnished wood specimens. While the lowest gloss value was 7.4 for untreated (control) Scots pine, the gloss values of all other impregnated and varnished Scots pine were found to be between 51 and 89.3 before natural weathering. The same results were obtained for Oriental beech. While the gloss value of untreated (control) Oriental beech was 6.9, the gloss values of all other impregnated and varnished Oriental beech specimens were found to be 55.5 to 90.7. The gloss values of solely PV coated Scots pine and Oriental beech specimens before natural weathering were 89.3 and 90.7, respectively. They were the highest gloss values for Scots pine and Oriental beech before natural weathering. The film layer of varnishes is highly glossy before weathering and reflects well the natural appearance of wood surfaces (Yalinkilic et al. 1999). The second highest gloss values, 86.3 for Scots Pine and 75.7 for Oriental Beech, were found in specimens which were CCA impregnated and then PV coated before being naturally weathered. The gloss values of impregnated and varnished wood specimens are slightly lower than varnished

Tab. 5: Gloss values of Scots pine specimens before and after natural weathering.

Treatment	Retention (%)	Before natural weathering		After 3 months natural weathering			After 6 months natural weathering		
		Mean	SD	Mean	SD	Change (%)	Mean	SD	Change (%)
Control	-	7.4	1.7	3.1	1.4	-58.11	1.2	0.7	-85.14
PV	-	89.3	12.9	64.2	9.9	-28.11	35.8	7.4	-59.91
SV	-	77.4	17.1	35.3	10.7	-54.39	23.3	5.2	-69.90
CCA + PV	32.7	86.3	10.4	62.3	10.1	-27.81	42.2	7.5	-51.10
CCA + SV		62.8	15.1	28.1	5.4	-55.25	20.4	4.4	-67.52
AD-KD 5 + PV	30.7	84.5	12	56.9	9.7	-32.66	40.1	9	-52.54
AD-KD 5 + SV		51	8.5	26	4	-49.02	17.5	4.6	-65.69
TN-E + PV	35.5	83	15.5	57.5	12.4	-30.72	40.8	8	-50.84
TN-E + SV		73.4	14.4	37.1	8.4	-49.46	26.1	6.4	-64.44

Note: Ten replicates were made for each treatment group. SD: Standard deviation.

Tab. 6: Gloss values of Oriental beech specimens before and after natural weathering.

Treatment	Retention (%)	Before natural weathering		After 3 months natural weathering			After 6 months natural weathering		
		Mean	SD	Mean	SD	Change (%)	Mean	SD	Change (%)
Control	-	6.9	1.5	3.2	0.7	-53.62	1.2	0.4	-82.61
PV	-	90.7	5.9	54.2	9.2	-40.24	20.9	5.2	-76.96
SV	-	78.2	9	32.4	5.8	-58.57	15.7	4.4	-79.92
CCA + PV	27.6	75.7	14.1	45.4	8	-40.03	19.7	5.2	-73.98
CCA + SV		62.1	11.9	26.8	6.8	-56.84	14.2	3.9	-77.13
AD-KD 5 + PV	23.1	74.3	8.7	44.5	9.7	-40.11	18.3	5.3	-75.37
AD-KD 5 + SV		70.5	13.3	32.9	6.6	-53.33	15.2	3.7	-78.44
TN-E + PV	28.8	74.1	7.5	41.6	8.2	-43.86	25.5	6.9	-65.59
TN-E + SV		55.5	12.5	25.2	6.6	-54.59	14.3	4.1	-74.23

Note: Ten replicates were made for each treatment group. SD: Standard deviation.

wood specimens before natural weathering. It can be explained that impregnation caused a small decrease in gloss values of wood specimens. After three months of natural weathering, while the gloss loss of untreated (control) Scots pine and Oriental beech was 58.11 and 53.62 % respectively, all impregnated and varnished wood specimens were observed to have drastic gloss loss of between 27.81 and 55.25 % for Scots pine, 40.03 and 58.57 % for Oriental beech. After six months of natural weathering, the gloss values of all wood specimens decreased by a remarkable level. The highest gloss losses were observed to be 85.14 and 82.61 % in Scots pine and Oriental beech control specimens, respectively. Wood materials are susceptible to environmental factors. Application of a clear coating is the easiest and most common method for protection wood against environmental degradation and enhancing its distinctive appearance (Chang and Chou 2000). However, it can be also degraded easily under the weathering conditions in the short term (Hu et al. 2009). Because the surfaces are generally rough (microscopically) after coating with brushing or spraying, abrasion on the wood surfaces, along with erosion, causes gloss degradation (Yalinkilic et al. 1999). Erosion on the wood surfaces and degradation in the varnish layers after weathering might cause these changes on varnished surfaces (Baysal et al. 2014). Our result showed that the lowest gloss loss was observed to be 50.84 and 65.59 % in Scots pine and Oriental beech impregnated with TN-E before PV coating, respectively, after six months of natural weathering. Baysal et al. (2014) reported that the impregnation with copper-based preservatives before PV coating protected the wood surface against gloss loss. They also found that the lowest gloss loss observed was in TN-E pretreatment before PV coating (Baysal et al. 2014). Before and after natural weathering, our result showed that the gloss values of PV coating wood specimens were higher than wood specimens coated with SV. The similar result was obtained from Calabrian pine wood treated with boron and varnished with SV or PV (Toker et al. 2009).

CONCLUSIONS

In this study, Scots pine and Oriental beech wood specimens were impregnated with a 4 percent aqueous solution of TN-E, AD-KD 5, and CCA. Then, synthetic or polyurethane varnish coatings were applied to wood specimens. The effects of 3 and 6 months of natural weathering on surface hardness and gloss of wood specimens were determined. It was observed that the retention amount of Scots pine was higher than the retention amount of Oriental beech. It was found that while surface hardness of untreated (control) Scots pine and Oriental beech wood specimens decreased after three months of natural weathering, surface hardness of all other impregnated and varnished wood specimens increased. After six months of natural weathering, surface hardness of all untreated (control) and impregnated and coated wood specimens dramatically decreased. The surface hardness of impregnated wood specimens which had PV applied before natural weathering was much higher than when SV was applied. Before natural weathering had occurred, it was observed that the gloss values of untreated (control) wood specimens were much lower than impregnated and coated wood specimens. The gloss values of impregnated and coated, and untreated (control) wood specimens after 3 months of natural weathering were dramatically lower, and after 6 months, gloss values of all wood specimens had decreased considerably. The gloss values of PV coated wood specimens were higher than wood specimens coated with SV.

At the end of six months natural weathering, the minimum decrease of surface hardness and gloss values for Scots pine and Oriental beech wood was obtained from TN-E impregnated and polyurethane varnish coated wood specimens. According to this study, new generation copper based wood preservatives such as TN-E and AD-KD 5 can use be used instead of CCA for protection of wood against natural weathering.

REFERENCES

1. Akbarian, M., Olya, M.E., Ataeefard, M., Mahdavian, M., 2012: The influence of nanosilver on thermal and antibacterial properties of a 2K waterborne polyurethane coating. Progress in Organic Coatings 75(4): 344-348.
2. ASTM D1413-07e1, 2007: Standard test method for wood preservatives by laboratory soil-block cultures.
3. ASTM D3023-98, 2013: Standard practice for determination of resistance of factory-applied coatings on wood products to stains and reagents.
4. ASTM D4366-14, 2013: Standard test methods for hardness of organic coatings by pendulum damping tests.

5. ASTM D523-14, 2013: Standard test method for specular gloss.
6. ASTM D7787/D7787M-13, 2013: Standard practice for selecting wood substrates for weathering evaluations of architectural coatings.
7. ASTM G7/G7M-13, 2013: Standard practice for atmospheric environmental exposure testing of nonmetallic materials.
8. Atar, M., Keskin, H., Korkut, S., Sevim Korkut, D., 2011: How impregnation with boron compounds affects the surface hardness of some varnishes. Pigment and Resin Technology 40(4): 229-234.
9. Baysal, E., 2008: Some physical properties of varnish coated wood preimpregnated with copper chromated boron (CCB) after 3 months of weathering exposure in Southern Eagen Sea Region. Wood Research 53(1): 43-54.
10. Baysal, E., Dizman Tomak, E., Ozbey, M., Altin, E., 2014: Surface properties of impregnated and varnished Scots pine wood after accelerated weathering. Coloration Technology 130(2): 140-146.
11. Bhat, I.U.H., Abdul Khalil, H.P.S., Awang, K.B., Bakare, I.O., Issam, A.M., 2010: Effect of weathering on physical, mechanical and morphological properties of chemically modified wood materials. Materials and Design 31(9): 4363-4368.
12. Cakicier, N., Korkut, S., Korkut, D.S., Kurtoglu, A., Sonmez, A., 2011: Effects of QUV accelerated aging on surface hardness, surface roughness, glossiness and color difference for some wood species. International Journal of Physical Sciences 6(8): 1929-1939.
13. Chang S.T., Chou, P.L., 2000: Photodiscoloration inhibition of wood coated with UV-curable acrylic clear coatings and its elucidation. Polymer Degradation and Stability 69(3): 355-360.
14. Chang, C.W., Lu, K.T., 2012: Natural castor oil based 2-package waterborne polyurethane wood coatings. Progress in Organic Coatings 75(4): 435-443.
15. De Meijer, M., 2001: Review on the durability of exterior wood coatings with reduced VOC-content. Progress in Organic Coatings 43(4): 217-225.
16. Hu, J., Li, X., Gao, J., Zhao, Q., 2009: Ageing behavior of acrylic polyurethane varnish coating in artificial weathering environments. Progress in Organic Coatings 65(4): 504-509.
17. Jebrane, M., Sèbe, G., Cullis, I., Evans, P.D., 2009: Photostabilisation of wood using aromatic vinyl esters. Polymer Degradation and Stability 94(2): 151-157.
18. Kamdem, D.P., Pizzi, A., Jermannaud, A., 2002: Durability of heat-treated wood. Holz als Roh-und Werkstoff 60(1): 1-6.
19. Keskin, H., Atar, M., Sevim Korkut, D., Korkut, S., 2011: Impact of impregnation with Imersol Aqua on the surface adhesion strength of synthetic, acrylic, polyurethane, and water-based varnishes. Pigment and Resin Technology 40(3): 154-160.
20. Kiguchi, M., Evans, P.D., 1998: Photostabilisation of wood surface using a grafted benzophenone UV absorber. Polymer Degradation and Stability 61(1): 33-45.
21. Kumar, V., Bhardwaj, Y.K., Sabharwal, S., 2006: Coating characteristics of electron beam cured bisphenol A diglycidyl ether diacrylate resin containing 1, 6-hexanediol diacrylate on wood surface. Progress in Organic Coatings 55(4): 316-323.
22. Lai, Y.C., Baccei, L.J., 1991: Synthesis and structure–property relationships of UV-curable urethane prepolymers with hard–soft–hard blocks. Journal of Applied Polymer Science 42(7): 2039-2044.
23. Lesar, B., Pavlič, M., Petrič, M., Škapin, A.S., Humar, M., 2011: Wax treatment of wood slows photodegradation. Polymer Degradation and Stability 96(7): 1271-1278.
24. Ozgenc, O., Yildiz, U.C., 2014: Surface characteristics of wood treated with new generation preservatives after artificial weathering. Wood Research 59(4): 605-616.

25. Peker, H., 1997: Efficiency of treatment chemicals materials to varnishes used on surfaces of furniture. PhD Thesis, Karadeniz Technical University, Trabzon, Turkey.
26. Sell, J., Feist, W.C., 1985: Weathering behavior of chromium-copper-boron treated wood. Holz als Roh- und Wekstoff 43(12): 518-523.
27. Temiz, A., Yildiz, U.C., Aydin, I., Eikenes, M., Alfredsen, G., Colakoglu, G., 2005: Surface roughness and colour characteristics of wood treated with preservatives after accelerated weathering test. Applied Surface Science 250(1-4): 35-42.
28. Toker, H., Baysal, E., Kesik, H.I., 2009: Surface characteristics of wood pre-impregnated with borates before varnish coating. Forest Products Journal 59(7-8): 43-46.
29. Tolvaj, L., Persze, L., Albert, L., 2011: Thermal degradation of wood during photodegradation. Journal of Photochemistry and Photobiology B: Biology 105(1): 90-93.
30. Tomak, E.D., Baysal, E., Peker, H., 2012: The effect of some wood preservatives on the thermal degradation of Scots pine. Thermochimica Acta 547: 76-82.
31. Trisna, P., Hiziroglu, S., 2013: Characterization of heat treated wood species. Materials and Design 49(7): 575-582.
32. Turkish State Meteorological Service Database, 2011: Meteorological data.
33. Turkoglu, T., Baysal, E., Toker, H., 2015: The effects of natural weathering on color stability of impregnated and varnished wood materials. Advances in Materials Science and Engineering Volume 2015, Article ID 526570: 1-9.
34. Uysal, B., Kurt, S., Ozcan, C., 2009: Thermal conductivity of laminated veneer lumbers bonded with various adhesives and impregnated with various chemicals. BioResources 4(2): 756-770.
35. Veigel, S., Grüll, G., Pinkl, S., Obersriebnig, M., Müller, U., Gindl-Altmutter, W., 2014: Improving the mechanical resistance of waterborne wood coatings by adding cellulose nanofibres. Reactive and Functional Polymers 85: 214-220.
36. Williams, R.S., Knaebe, M.T., Feist, W.C., 1996: Finishes for exterior wood: Selection, application, and maintenance. Publication No: 7291 Forest Products Society, Wisconsin, USA.
37. Yalinkilic, M.K., Ilhan, R., Imamura, Y., Takahashi, M., Demirci, Z., Yalinkilic, A.C., Peker, H., 1999: Weathering durability of CCB-impregnated wood for clear varnish coatings. Journal of Wood Science 45: 502-514.
38. Yildiz, U.C., Temiz, A., Gezer, E.D., Yildiz, S., 2004: Effects of the wood preservatives on mechanical properties of yellow pine (*Pinus sylvestris* L.) wood. Building and Environment 39(9): 1071-1075.

Turkay Turkoglu
Mugla Sitki Kocman University
Koycegiz Vocational School
Department of Forestry
48800, Mugla
Turkey

Ergun Baysal*
Mugla Sitki Kocman University, Faculty of Technology
Wood Science and Technology
Mugla, Turkey
Phone: +90-0-252-2111708
Corresponding author: ergun69@yahoo.com

Ihsan Kureli
Gazi University, Faculty of Technology Wood Science and Technology
Ankara, Turkey

Hilmi Toker, Mehmet Emin Ergun
Mugla Sitki Kocman University, Faculty of Technology
Wood Science and Technology
Mugla, Turkey