

Surface properties of wood material impregnated with copper-based chemical (Korasit KS) after natural weathering

Bakır esaslı kimyasal (Korasit KS) ile emprenye edilen ağaç malzemenin doğal yaşlandırma sonrası üst yüzey özellikleri

Çağlar ALTAY 

Aydın Adnan Menderes University, Aydın Vocational School, Department of Interior Design, Aydın, Turkey

Eser Bilgisi / Article Info

Araştırma makalesi / Research article

DOI: [10.17474/artvinofd.1174997](https://doi.org/10.17474/artvinofd.1174997)

Sorumlu yazar / Corresponding author

Çağlar ALTAY

caglar.altay@adu.edu.tr

Geliş tarihi / Received

14.09.2022

Düzeltilme tarihi / Received in revised form

26.10.2022

Kabul Tarihi / Accepted

26.10.2022

Elektronik erişim / Online available

28.10.2022

Anahtar kelimeler:

Oriental beech

Color

Gloss

Surface roughness

Korasit KS

Keywords:

Doğu kayını

Renk

Parlaklık

Yüzey pürüzlülüğü

Korasit KS

Abstract

In this work, the surface characteristics of Oriental beech (*Fagus orientalis* L.) wood impregnated with Korasit KS, a water-based and copper-containing impregnation substance, were examined after 3 months of natural weathering. The impregnation material was penetrated into the wood material at 3% and 6% concentration levels according to the ASTM D 1413-07 (ASTM 2007) standard. According to the results, the L* values of all samples decreased after 3 months natural weathering. Impregnated samples provided better color stability than control samples. Moreover, this stability increased as the concentration amount increased in the impregnation process. While the gloss of all samples decreased after natural weathering, this decrease was more in control samples. According to the surface roughness test results, all samples' Ra, Rz and Rq values increased after natural weathering. This increase was more in the impregnated samples.

Özet

Bu çalışmada, su bazlı ve bakır içerikli bir emprenye maddesi olan Korasit KS ile emprenye edilen Doğu kayını (*Fagus Orientalis* L.) odununun 3 aylık doğal yaşlandırma sonrası yüzey özellikleri incelenmiştir. Emprenye malzemesi ağaç malzemeye ASTM D 1413-07 (ASTM 2007) standardına göre %3 ve %6 konsantrasyon seviyelerinde nüfuz edilmiştir. Sonuçlara göre tüm numunelerin L* değerleri 3 aylık doğal yaşlandırmadan sonra azalmıştır. Emprenye edilen örnekler, kontrol numunelerinden daha iyi renk stabilitesi sağlamıştır. Ayrıca emprenye işleminde konsantrasyon miktarı arttıkça bu stabilitede artmıştır. Doğal yaşlandırma sonrası tüm numunelerin parlaklığı azalırken, bu azalma kontrol numunelerinde daha fazla gerçekleşmiştir. Yüzey pürüzlülüğü test sonuçlarına göre tüm numunelerin Ra, Rz ve Rq değerleri doğal yaşlandırma sonrası artmıştır. Bu artış emprenye edilen örneklerde daha fazla olmuştur.

INTRODUCTION

The need for wood material is increasing day by day due to its thermal properties, good paint and varnishability, sound absorption, easy processing, and more aesthetic than other materials (Percin et al. 2009). Furthermore, wood material has more than 5000 uses (Yazici 2005). Despite all these advantages and usage area, wood material also has some undesirable features such as burning, exposure to mechanical effects, deformation as a result of exposure to weathering (Okcu 2006, Ors et al. 2006). Furthermore, since wood is a renewable organic material, it can be easily damaged by fungi and insects under suitable conditions, it can be biodegraded and this leads to a shortening of the useful life of wood in end use (Sivrikaya et al. 2017). In order to eliminate these disadvantages and increase the durability of the wood

material, methods such as impregnation of the wood material with various chemical substances, chemical modification, and surface coating processes are required (Zelinka and Rammer 2005). Impregnation is the process of penetrating the wood material of various protective chemicals in order to prevent the wood material from rotting, burning and deformation (Ors and Keskin 2001, Kartal and Unamura 2004). However, these preservatives used can create a corrosive environment for metallic materials in contact with wood (Rammer et al. 2006, Lin et al. 2009, Zelinka and Stone 2011). Corrosion is the deterioration of alloys and metals as a result of electrochemical and chemical reactions with their surroundings. In addition, according to new findings, it is stated that non-metallic materials are also affected by environmental conditions (Can et al. 2020). Since CCA (Copper, Chrome, Arsenic), which is used as the most

effective impregnation agent in the wood protection industry, has been banned due to its harmful effects on the environment, new generation impregnation materials have started to be used (Gezer et al. 2004). Boric acid and CCB (Copper, Chrome, Boron) are some of the new generation impregnation materials used against this negativity in the wood industry (Sivrikaya and Saraçbaşı 2004, Kartal et al. 2006).

Most of the wood preservative chemicals used against fungi interact either by inhibiting the formation of acetyl coenzyme (COA) or by inhibiting respiratory chain formulations (Zhang et al. 2009). It is thought that copper-containing impregnations provide metal-enzyme interaction with DNA modification and formation of high-activity free radicals produced by copper ions. The interaction between copper-containing preservatives and wood is very important in terms of both the performance of the preservative and its environmental effects (Zhang et al. 2009). Structural differences are observed between wood species because wood consists of complex structures such as cellulose, hemicellulose and lignin and contains different reactive groups (carbonyl, ether, acid, hydroxyl). These differences affect the fixation of chemical substances in wood (Vasisht 1996). In the literature, it was reported that wood impregnated with CCA and ACQ had lower light degradation in the accelerated weathering than that of non-impregnated wood (Jin et al. 1991). Grelier et al. (2000) investigated the photodegradation properties of woods impregnated with copper-amine. Their results showed that the samples impregnated with ACQ and CCA had better photo-oxidation (lignin) protection by accelerated weathering than the control samples. It has been determined that UV rays provide a good surface protection against UV rays for 1600 hours and especially on wood samples treated with ACQ (Grelier et al. 2000). Commercially, wood is treated with waterborne preservatives such as chromated copper arsenic (CCA), copper-azole, ammoniacal copper arsenate (ACZA), and amine/ammoniacal copper quat at a certain retention and penetration to increase the service life of wood (Feist and Hon 1984).

It was aimed to determine the changes in color, gloss, and surface roughness properties of wood material after 3 months of natural weathering by applying Korasit KS impregnation material to samples prepared from Oriental beech (*Fagus Orientalis* L.) in this study. The copper-based Korasit KS material used in the study was preferred because it is water-based, environmentally friendly, and

harmless to human health.

MATERIALS AND METHODS

Preparation of Wood Material

The Oriental beech (*Fagus orientalis* L.) wood was prepared in 10 x 100 x 150 mm (radial, tangential, and longitudinal) dimensions for the natural weathering (color, gloss, and surface roughness) test by TSE 2470 (1976) standard.

Impregnation Procedure

According to ASTM D 1413-07, Oriental beech (*Fagus orientalis* L.) was impregnated with Korasit KS (ASTM 2007). The impregnation material used in this study was obtained from the Varkim company in the Izmir province of Turkey (Varkim 2022). After a pre-vacuum for 30 minutes of 760 mm Hg was used throughout the impregnation procedure for 30 minutes, air-dry test samples were allowed to diffuse in the solution at room temperature for the same amount of time. In order to measure the adhesion rate of the impregnation material and avoid being influenced by the moisture of the wood, samples were prepared to be dry both before and after impregnation. At concentrations of 3% and 6%, the impregnation material was applied to the wood material. The following equation was used to calculate the Korasit KS retention:

$$\text{Retention} = \frac{G, C}{V} \times 100 \text{ (gr/cm}^3\text{)} \quad (1)$$

Where;

G = T₂ - T₁

T₁ = Sample weight before impregnation (gr)

T₂ = Sample weight after impregnation (gr)

V = Sample volume (cm)

C = Concentration amount (%)

Natural Weathering Test

Wood panels are designed to expose samples to outdoor weather conditions according to ASTM D 358–55 (1970). The samples were placed on panels approximately 50 cm above the soil, facing south and at an angle of 45° (Figure 1). Then, the samples placed on the panels were exposed to weathering conditions for 3 months during summer (from June to August 2022) in the Mugla/TURKEY region (Baysal 2008, Kart et al. 2018). A total of 30 wood samples were prepared, 10 of which were wood samples for each

sample type. Weathering conditions of Mugla during June-August 2022 were given in Table 1 (Turkish State Meteorological Service Database 2022).

Table 1. Weathering conditions of Mugla from June to August in 2022

Months	June	July	August
Average temperature (°C)	23.1	28.0	26.1
The highest temperature (°C)	33.3	39.5	37.6
The lowest temperature (°C)	13.6	17.2	15.2
The number of the rainy days	11	0	5
Humidity (%)	55.5	33.8	53.3



Figure 1. An image of the experimental setup

Color Changes Test

The L^* , a^* , and b^* color parameters of the samples were calculated using the CIEL*a*b* method for the color test. Here, the a^* and b^* axes stand in for the chromaticity coordinates and the L^* axis represents lightness. Additionally, the $+a^*$ and $-a^*$ parameters denote red and green colors, respectively. In addition, the $+b^*$ and $-b^*$ parameters stand for yellow and blue, respectively. L^* value ranges from zero (black) to one hundred (white) (Zhang 2003). In this test, the color difference (ΔE^*) was calculated using Equations 2 to 5 according to the ASTM D1536-58T (ASTM 1964) standard.

$$\Delta a^* = a_f^* - a_i^* \quad (2)$$

$$\Delta b^* = b_f^* - b_i^* \quad (3)$$

$$\Delta L^* = L_f^* - L_i^* \quad (4)$$

$$(\Delta E^*) = [(\Delta a^*)^2 + (\Delta b^*)^2 + (\Delta L^*)^2]^{1/2} \quad (5)$$

Where;

10 replicates were performed for each sample group. Also, Δa^* , Δb^* , and ΔL^* represent the changes between the first and last interval values.

Gloss Test

The gloss values of the test samples were calculated according to the ASTM D 523-14 (ASTM 2018) standard and with the (Micro-TRI-Gloss) device. The geometry chosen here represents an angle of incidence of 85. In addition, 10 repetitions were applied for each sample group in this test.

Surface Roughness Test

With a Mitutoyo Surftest SJ-301 instrument, roughness measurements were taken under DIN 4768 (1990) standard. In this work, the average peak-valley height (R_z), a measure of surface roughness, was measured. The stylus with a diamond tip had a 5 m radius and a 90° conical angle, and it was used to examine the surface roughness profile. The stylus was fed at a rate of 0.5 mm/s over an 8 mm sampling length (Zhong et al. 2013). Every treatment group received 10 replications. Parallel to the fibers, measurements of surface roughness was taken. A total of 3 measurements were taken from each sample.

Statistical Analysis

The data obtained from the experiments were transferred to the SPSS 16.0 statistical program, and the Duncan test applied at 95% confidence level was calculated. In this program, in order to determine homogeneity groups (HG), alphabetic letters are used to indicate whether there is statistical significance between sample types.

RESULTS AND DISCUSSION

Retention Amounts

Retention amounts of Oriental beech wood samples impregnated with Korasit KS are given in Table 2.

Table 2. Retention amounts of Oriental beech wood samples impregnated with Korasit KS

Chemicals	Retention (gr/cm ³)
Control	-
Korasit KS (%3)	18.91
Korasit KS (%)	22.30

In this study, the retention amount was found to be 18.91 gr/cm³ in samples impregnated with Korasit KS at the rate of 3%, while the retention amount was found as 22.30 gr/cm³ in 6% samples.

Color Changes Test

Color changes test values of Oriental beech wood samples impregnated with Korasit KS are given in Table 3.

After natural weathering, the L^* values of all samples decreased. The reduction in the control samples was greater than in the impregnated samples. Furthermore, all samples showed a tendency to be reddish and yellowish, giving positive a^* and positive b^* values, respectively. According to the results of the total color change values (ΔE^*), the color stability of the impregnated samples was more preserved than the control samples. In addition, better color stability was achieved as the amount of concentration increased in the impregnation process. The highest color change was detected in the control samples. In addition, the lowest total color change (ΔE^*) was determined in the samples impregnated at 6% concentration. After natural weathering, the samples that were impregnated at 6% concentration were the ones that preserved the color stability the most and showed the most positive properties. According to Zhang et al. (2009), copper-amine complexes preserve the color of treated wood and increase the UV resistance of the surface by forming a complex with constituents of wood. As a result, copper-treated wood had enhanced color performance. It is supported by the information in the literature that the impregnation process provides color stability in wood material. Özgenç and Yıldız (2014) impregnated wood with micronized copper quat (MCQ), ammonia copper quat (Celcure AC 500), copper (II) sulfate pentahydrate ($\text{Cu(II)SO}_4 \cdot 5\text{H}_2\text{O}$), and Didecyldimethylammonium chloride (DDAC). They then determined the color changes of these samples after accelerated weathering. According to their results, impregnation materials with Celcure AC 500 and MCQ provided less color change than DDAC and $\text{Cu(II)SO}_4 \cdot 5\text{H}_2\text{O}$ materials. In addition, Celcure AC 500 provided the lowest color change in the applied samples. Temiz et al. (2007) reported that complexing between chromium and guaiacyl units of lignin delayed the total color change in wood treated with CCA (chromated copper arsenate) and linseed oil. The application of chrome-copper-boron (CCB) treatment to wood material was advised by Yalinkilic et al. (1999) to stabilize the surface color of varnish-coated wood panels. According to Humar et al. (2011), copper-ethanolamine-based wood preservatives affect some properties of water-borne acrylic coatings used on wooden substrates. In our study, copper-containing impregnation material gave positive

values after natural weathering conditions. Therefore, our study was compatible with the literature. The graphical representation of the color changes test values after weathering is shown in Figure 2.

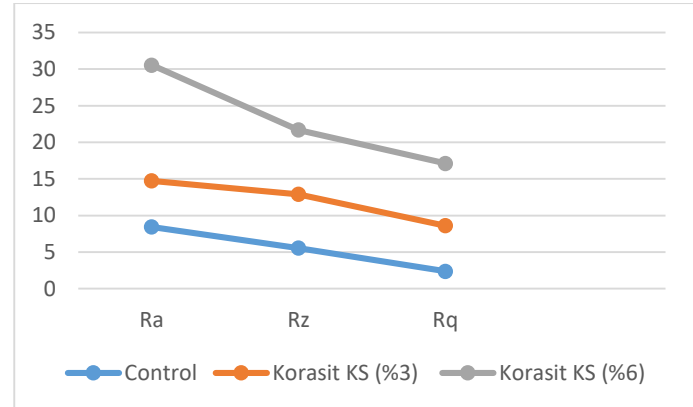


Figure 2. Color changes test values after weathering

Gloss test

Gloss test values of Oriental beech wood samples impregnated with Korasit KS are given in Table 4.

Before weathering, it was determined that the impregnated samples showed lower gloss values compared to the control samples. Accordingly, before weathering, the impregnation treatment had a negative effect on the gloss values of the wood samples.

After natural weathering, the gloss of all samples decreased. While less decrease was observed in the samples impregnated compared to the control samples, a statistical difference was detected between the control and impregnated samples. Chromophoric structures in lignin, which are released as a result of the photodegradation of wood, absorb light. During the gloss measurement, the light coming to the sample surface is absorbed by the lignin, causing the value measured by the device to be low (Can 2018). Baysal et al. (2014) determined that Scotch pine wood treated with copper-based impregnation materials decreased in brightness after 500 hours of accelerated weathering. Baysal et al. (2016) investigated the gloss values of bamboo (*Phyllostachys basmasoides*) wood impregnated with Tanalith-E, ACQ and Wolmanite-CB after accelerated weathering. Results showed that following an accelerated weathering period, the gloss of bamboo samples that had been impregnated diminished. Turkoglu et al. (2015) studied at the gloss values of Scots pine wood that had been pre-impregnated with a few copper-based

Table 3. Color changes test values of Oriental beech wood samples impregnated with Korasit KS

Chemicals	Concentration (%)	Color values after natural weathering						Total Color Changes	
		ΔL^*	Std. dev.	Δa^*	Std. dev.	Δb^*	Std. dev.	ΔE^*	Homogeneity group
Control	-	-7.51	1.12	3.15	0.47	2.58	0.38	8.54	A
Korasit KS	3	-6.90	1.03	1.69	0.25	1.04	0.15	7.17	A
Korasit KS	6	-3.05	0.45	0.11	0.02	1.62	0.24	3.45	B

Note: Std. dev.: Standard deviation.

Table 4. Gloss test values of Oriental beech wood samples impregnated with Korasit KS

Chemicals	Concentration (%)	Gloss values before natural weathering		Gloss values after natural weathering		Gloss changes values after natural weathering (%)	
		85° Mean		85° Mean		85°	Homogeneity group
Control	-	2.70 (0.45)		1.30 (0.38)		-51.85	A
Korasit KS	3	1.73 (0.13)		0.95 (0.21)		-45.08	AB
Korasit KS	6	1.88 (0.78)		1.21 (0.14)		-35.63	B

Note: Values in parentheses represent the standard deviation.

compounds. They discovered that pre-impregnation with chemicals resulted in a loss of gloss in samples of Scots pine wood. Ozdemir et al. (2015) found that water-based wood preservatives decreased the gloss values of the wood and increased the porosity of the surface. Our study's findings in this area were consistent with those found in the literature. The graphical representation of the gloss test values after weathering is shown in Figure 3.

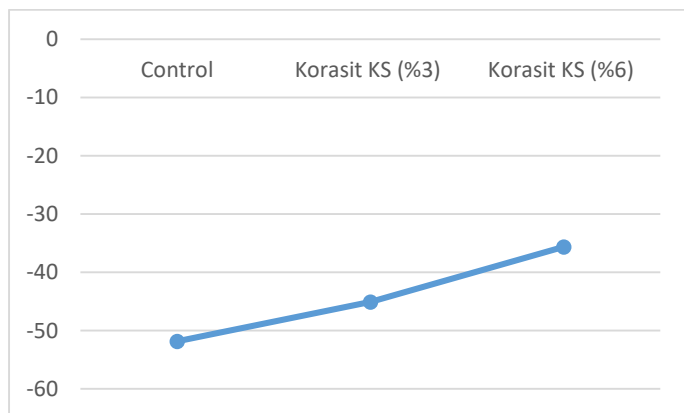


Figure 3. Gloss test values after weathering (%)

Surface Roughness Test

Surface roughness values of Oriental beech wood samples impregnated with Korasit KS are given in Table 5.

After natural weathering, an increase in Ra , Rz , and Rq values of all samples were detected. This increase in the impregnated samples was higher than in the control

samples. In addition, as the concentration amount increased in the impregnation process, the surface roughness value of the samples increased. In this study, the impregnation process caused the wood material to have a rougher surface. A statistical difference was found in the control and impregnated samples. According to investigations on surface roughness, lignin loss, color measurements, and microscopic examinations, copper azole demonstrated resistance to weathering effect and reduced the degradation caused by stain-fungi (Temiz et al. 2005). Due to the heterogeneity and anisotropy of wood, surface roughness is a complicated phenomenon. The evaluation of the surface roughness of wood should take into account several factors, including anatomical variations, growing traits, machining properties, pre-treatments (such as steaming, drying, etc.) applied to the wood before machining, and copper-wood interactions after impregnation (Aydin and Colakoglu 2003). Copper is still the primary biocide component used today in the protection of wood in ground contact or exposed to weather, although copper-based preservatives have been widely utilized for more than a century (Lebow et al. 2004). Numerous researchers have observed that wood treated with alkylammonium compounds (AACs), copper ethanolamine (Cu-EA), ammoniacal copper quat, copper-azole, tanalith-E 3491, and wolmanit CX-8 is more resistant to weathering effects (Jin et al. 1991, Cornfield et al. 1994, Temiz et al. 2005, Nejad and Cooper 2011). In plywood treated with various fire retardants, rougher surfaces developed as the concentration increased, according to Ayrimis et al. (2006). Baysal et al. (2021)

Table 5. Surface roughness values of Oriental beech wood samples impregnated with Korasit KS

Chemicals	Concentration (%)	Surface roughness values after natural weathering (%)					
		R_a	H.G	R_z	H.G	R_q	H.G
Control	-	8.43 (1.26)	A	5.55 (0.83)	A	2.39 (0.35)	A
Korasit KS	3	14.73 (2.20)	B	12.91 (1.93)	B	8.62 (1.29)	B
Korasit KS	6	30.54 (4.58)	C	21.70 (3.25)	C	17.12 (2.56)	C

Note: Values in parentheses represent the standard deviation. H.G.: Homogeneity group.

impregnated Calabrian pine (*Pinus brutia*) wood with Celcure C4, Korasit KS, and Tanalith E 8000. Then they investigated the roughness properties of wood after weather conditions. According to the results, higher surface roughness values were determined in the impregnated wood samples. Results from our study by Ayırlımsı et al. (2006) and Baysal et al. (2021) is consistent with the results. The graphical representation of the surface roughness test values after weathering is shown in Figure 4.

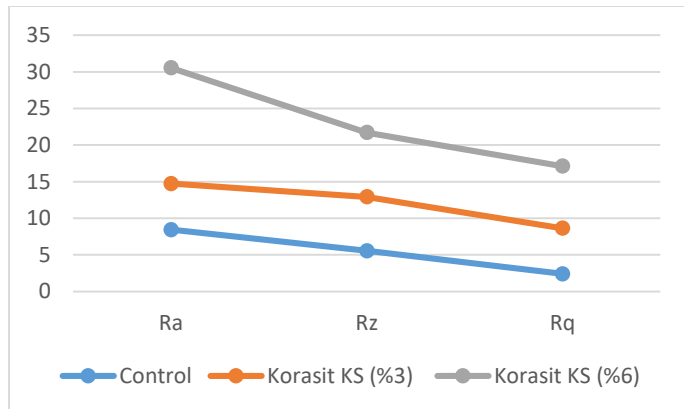


Figure 4. Surface roughness test values after weathering (%)

CONCLUSIONS

The results showed that ΔL^* values of control and impregnated wood samples decreased and this decrease was more in control samples. It also showed that the control and impregnated samples tended to be reddish and yellowish, respectively, giving positive a^* and b^* values after natural weathering. The total color changes showed that the impregnated samples gave lower values and protected the color stability better than the control sample. The gloss of control and impregnated samples increased before weathering while it decreased after weathering. The least decrease was observed in the samples impregnated at 6% concentration after weathering. The surface roughness of all samples

increased after weathering. This increase after weathering was less in the control sample compared to the impregnated samples.

REFERENCES

- ASTM D1536-58 (1964) Tentative method of test color difference using the color master differential colorimeter. ASTM, ABD
- ASTM D358-55 (1970) Standard specification for wood to be used panels in weathering tests of paints and varnishes. ASTM, ABD
- ASTM D523-14 (2018) Standard test method for specular gloss. ASTM, ABD
- ASTM-D 1413-07 (2007) Standard test method for wood preservatives by laboratory soil-block cultures. ASTM, ABD
- Aydın I, Colakoglu G (2003) Roughness on Wood Surfaces and Roughness Measurement Methods. *Artvin Orman Fakültesi Dergisi* 4 (1-2): 92-102
- Ayrlımsı N, Korkut S, Tanrıtanır E, Winandy JE, Hiziroglu S (2006) Effect of various fire retardants on surface roughness of plywood. *Building and Environment* 41(7):887-892
- 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
- Baysal E, Toker H, Turkoglu T, Gunduz A, Altay C, Kucuktuvek M, Peker H (2021) Weathering characteristics of impregnated and coated Calabrian pine wood. *Maderas. Ciencia y tecnología* 23(31): 1-10
- Baysal E, Tomak ED, Ozbey M, Altin E (2014) Surface Properties of Impregnated and Varnished Scots Pine Wood After Accelerated Weathering. *Coloration Technology* 130(2): 140-146
- Baysal E, Tomak ED, Topaloglu E, Pesman, E (2016) Surface Properties of Bamboo and Scots Pine Impregnated with Boron and Copper Based Wood Preservatives After Accelerated Weathering. *Maderas. Ciencia y tecnología* 18(2): 253-264
- Can A (2018) Su İtici Maddeler ile Kombine Edilmiş Bazı Emprenye Maddelerinin Performansinin incelenmesi. Phd. Thesis, Bartın University, Institute of Sciences, Department of Forest Industrial Engineering, Bartın, Turkey, 176 pages (In Turkish).
- Can A, Sivrikaya H, Tascioglu C (2020) Determination of Metal Corrosion in Wood Treated with new-generation water-borne preservatives. *Drewno* 63 (205): 59-68
- Cornfield JA, Hale M, Fettis G (1994) A comparison of analytical and visual techniques used for assessment of weathering properties of chromium and copper azole treated timber. In: International Research Group on Wood Preservation, Sweden, pp 1-15

- DIN 4768 (1990) Determination of values of surface roughness parameters Ra, Rz, Rmax using electrical contact (stylus) instruments, concepts and measuring conditions. Deutsches Institut für Normung E.V.
- Feist W, Hon DNS (1984) Chemistry of weathering and protection. in R. M. Rowell, ed. The chemistry of solid wood. Advances in Chemistry Series, American Chemical Society, Washington, DC. pp 401-451
- Gezer ED, Yuksek T, Yıldız UC (2004) CCA (Bakır, Krom, Arsenik) Elementlerinin Toprakta Hareketleri. Kafkas Üniversitesi Artvin Orman Fakültesi Dergisi 5(2): 102-112
- Grelier S, Castellan A, Kamdem DP (2000) Photoprotection of copper-amine-treated pine. Wood and Fiber Science 32 (2): 196-202
- Humar M, Pavlič M, Žlindra D, Tomažic M, Petrič M (2011) Performance of Waterborne Acrylic Surface Coatings on Wood Impregnated with Cu-Ethanolamine Preservatives. Bulletin of Material Science 34(1): 113-119
- Jin L, Archer K, Preston A. (1991) Surface characteristics of wood treated with various AAC, ACQ and CCA formulations after weathering. In: International Research Group on Wood Protection Documents, 22. Annual meeting, Kyoto-JAPAN, IRG/WP/2369
- Kart S, Baysal E, Turkoglu T, Kucuktuvek M, Peker H, Altay C, Toker H (2018) The effect of natural weathering on change in the color of heat treated and varnished scots pine and oriental beech woods. Wood Research 63(5): 771-782
- Kartal SN, Engur MO, Kose C (2006) Emprenye Maddeleri ve Emprenye Edilmiş Ağaç Malzeme ile ilgili Çevre Problemleri. Düzce Üniversitesi Orman Fakültesi Dergisi 56 (1): 17-23
- Kartal SN, Unamura Y (2004) Borlu bileşiklerin emprenye maddesi olarak ağaç malzeme ve kompozitlerde kullanılması. 3. Uluslararası Bor Sempozyumu, Eskişehir, pp 333-338
- Lebow S, Winandy J, Bender D (2004) Treated Wood in Transition: A Look at CCA and the Candidates to Replace it, Wood Design Focus 3-8
- Lin LD, Chen YF, Wang SY, Tsai MJ (2009) Leachability, Metal Corrosion, and Termite Resistance of Wood Treated with Copper-Based Preservative. International Biodeterioration & Biodegradation 63(4): 533-538.
- Nejad M, Cooper P (2011) Exterior Wood Coatings. Part 1: Performances of Semitransparent Stains on Preservative-Treated Wood. Journal of Coatings Technology and Research 8(4): 449-458
- Okcu O (2006) Emprenye edilmiş lamine ağaç malzemenin yapışma ve yanma özellikleri. Zonguldak Karaelmas Üniversitesi Fen Bilimleri Enstitüsü Yüksek Lisans Tezi, Zonguldak, 70 s
- Ors Y, Atar M, Keskin H, Yavuzcan HG (2006) Impacts of Impregnation with Imersol-Aqua on the Modulus of Elasticity in Bending. Journal of Applied Polymer Science 99(6): 3210-3217
- Ors Y, Keskin H (2001) Ağaç malzeme bilgisi, Nobel Akademik Yayıncılık, Ankara.
- Ozdemir T, Temiz A, Aydın I (2015) Effect of Wood Preservatives on Surface Properties of Coated Wood. Advances in Materials Science and Engineering 2015:1-6
- Ozgenç O, Yıldız UC (2014). Surface characteristics of wood treated with new generation preservatives after artificial weathering. Wood Research 59(4): 605-616
- Percin O, Ozbay G, Ordu M (2009) Farklı Tutkallarla Lamine Edilmiş Ahşap Malzemelerin Mekaniksel Özelliklerinin İncelenmesi. Dumlupınar Üniversitesi Fen Bilimleri Enstitüsü Dergisi 19: 109-120
- Rammer DR, Zelinka SL, Line P (2006) Fastener corrosion: testing, research and design considerations. In: 9th World Conference on timber engineering. Oregon State University, pp 1-8
- Sivrikaya H, Can A, Tumen I, Aydemir D (2017) Weathering Performance of Wood Treated With Copper Azole and Water Repellents. Wood Research 62(3): 437-450
- Sivrikaya H, Saracbası A (2004) Bor madeninin ahşap koruma endüstrisinde değerlendirilmesi. II, Uluslararası Bor Sempozyumu, Eskişehir, Türkiye, pp 365- 373
- Temiz A, Terziev N, Eikenes M, Hafren J (2007) Effect of Accelerated Weathering on Surface Chemistry of Modified Wood. Applied Surface Science 253(12): 5355-5362
- Temiz A, Yıldız UC, Aydın 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
- TS 2470 (1976) Odunda fiziksel ve mekaniksel deneyler için numune alma metodları ve genel özellikler. TSE Standard
- Turkish State Meteorological Service Database, Meteorological data, 2022, <http://www.mgm.gov.tr>
- Turkoğlu T, Baysal E, Kureli I, Toker H, Ergun, ME (2015) The Effects of Natural Weathering on Hardness and Gloss of Impregnated and Varnished Scots Pine and Oriental Beech Wood. Wood Research 60(5): 833-844
- Varkim (2022) https://www.varkim.com.tr/?page_id=1563 Accessed date: 20.10.2022
- Vasishth P (1996) Factors influencing the interactions and permanency of copper in wood. Mississippi State University, Phd. Thesis, USA, 139s
- Yalinkilic MK, İlhan R, Imamura Y, Takahashi M, Demirci Z, Yalinkilic AC, Peker H., 1999: Weathering Durability of CCB-Impregnated Wood for Clear Varnish Coatings. Journal of Wood Science 45(6): 502-514
- Yazıcı H (2005) Açık Hava Koşullarının Odun Dayanımına Etkisi. ZKÜ Bartın Orman Fakültesi Dergisi 7(8): 72-79
- Zelinka SL, Rammer DR (2005) The Use of Electrochemical Impedance Spectroscopy (EIS) to Measure the Corrosion of Metals in Contact with Wood. TMS Letters 2 (1):15-16
- Zelinka SL, Stone DN (2011) Corrosion of Metals in Wood: Comparing The Results of a Rapid Test Method with Long-Term Exposure Tests Across Six Wood Treatments. Corrosion Science 53(5): 1708-1714
- Zhang J, Kamdem DP, Temiz A (2009). Weathering of copper-amine treated wood. Applied Surface Science 256(3): 842-846
- Zhang X (2003) Photo-resistance of alkyl ammonium compound treated wood. The University of British Columbia, M.S.c. Thesis, Vancouver, Canada (in English)
- Zhong ZW, Hiziroglu S, Chan CTM (2013) Measurement of the Surface Roughness of Wood Based Materials Used in Furniture Manufacture. Measurement, 46(4): 1482-1487