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SOME SURFACE CHARACTERISTICS OF VARNISHED THERMOWOOD AFTER WEATHERING

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ABSTRACT

This study was designed to investigate some surface characteristics such as glossiness and surface roughness changes of varnished thermowood after six months of weathering. Thermal modification of Scots pine (*Pinus sylvestris* L.) and Oriental beech (*Fagus orientalis* L.) wood were carried out by hot air in an oven for 1, 2, and 3 hours at 205, 215, and 225°C. After the modification process, wood specimens were varnished using a polyurethane varnish (PV) and cellulosic varnish (CV). The natural weathering process caused an increase in the surface roughness of the test specimens according to the test results. The Scots pine and Oriental beech test specimens which were heat treated and varnished gave more favorable results compared to only varnish test specimens after natural weathering in terms of surface characteristics such as surface roughness and glossiness. Generally, as the heat treatment time and temperature increase, it is observed that the surface characteristics of the Scots pine and Oriental beech wood specimens improve positively. According to the results of the tests, the samples varnished with polyurethane varnish gave better results in terms of surface roughness at the end of the natural weathering process, whereas the samples varnished with cellulosic varnish gave better results in terms of glossiness values.

KEYWORDS: Scots pine, Oriental beech, thermal modification, varnish, glossiness, surface roughness, weathering.

INTRODUCTION

Wood has been preferred for construction and building for many years due to its excellent properties such as sustainability, natural beauty, high specific strength, ease processing, heat insulation and local availability in most areas. However, it is susceptible to environmental influences since wood is a biological material. For this reason, it is necessary to process the wood to ensure long service life and to improve specific surface properties to suit the intended use. Wooden materials expose to sunlight, moisture, wind, and dust when used especially outdoors.

Sunlight is the main factor that causes the greatest changes in the surface properties of wood during outdoor exposure (Tolvaj et al. 2011). Wooden surfaces exposed to the outside quickly disintegrate because the lignin strongly absorbs the UV light, which leads to radical-induced depolymerization of lignin and cellulose. Lignin is the major structural component of wood and the aromatic polymer and strongly absorbs sunlight (Evans et al. 2002, Jebrane et al. 2009).

The natural weathering process generally causes discoloration, physical deterioration on the wood surface and loss of paint retention properties. The visible change is the first noticeable sign of the chemical changes in the decomposition process. Wood also loses its lightness (Jirous-Rajkovic et al. 2004). The weathering causes color change and loss of glossiness at the beginning. Then when the surface is checked it is seen that the wood is rougher (Denes and Young 1999, Ozgenc et al. 2012). The most effective method of preventing the photodegradation of wood involves modified with dilute aqueous solutions of inorganic salts, particularly hexavalent chromium compounds. Application of chromium trioxide on wood surfaces prevents lignin degradation during natural weathering process (Evans et al. 1992, Kiguchi and Evans 1998). On the other hand, chemical treatment poses a serious threat to the environment. However, environmental concerns related to the use of conventional wood preservatives have led to an increased interest in thermal modification approaches (Hill 2006). Heat treatment is an alternative method to improve surface and physical properties of wood with no use of chemical additives (Johansson 2008). In a widely used heat treatment procedure, the material is exposed to temperatures between 120 and 250°C for 15 min to 24 hours in where the exposure time is depended upon species, process, moisture content, sample size, and the planned target usage (Korkut and Guller 2008, Kocaefe et al. 2010). Since heat treatment doesn't include the use of chemicals and is not toxic it is the most suitable method for wood. Utilization of heat treatment for wood modification has been increased in the last decade (Bachle et al. 2010, Khalid et al. 2010). During thermal treatment at high temperatures, the color of wood tends to darken due to the considerable changes in the chemical composition of wood, such as the degradation of the amorphous carbohydrates (Kamperidou et al. 2012). Hemicelluloses start to decompose first among the wood polymers, due to the low molecular weight that makes them more reactive (Hakkou et al. 2005, Kamperidou et al. 2012). Additionally, lignin softens; cellulose and hydrophilic groups modify (Bekhta and Niemz 2003, Kocaefe et al. 2007).Although heat treated wood shows the advantage in terms of aesthetic properties (uniform and effective change in color) and some technical guidelines (much reduced swelling and shrinkage and improved resistance to the fungus), it has some shortcomings when compared to normal wood. The mechanical properties are substantially reduced, so that the material generally used for fully supported the structure (Vukas et al. 2010).

Thermowood has a large application for indoor use for kitchen furniture, parquet, decorative panels, and mainly for the interior of saunas as well as outdoor use in the cladding, garden furniture, decks, and window frames (Esteves and Pereira 2009). Thermowood took its deserved place in the market for being more durable and healthy. Thermowood possesses new physical properties such as improved dimensional stability, reduced hygroscopicity, better resistance to degradation by micro-organisms and, insects and most importantly, attractive darker color. These new versatile and attractive properties help thermowood to become desirable for indoor and outdoor applications (Huang et al. 2012). Korkut et al. (2013) found that wood color changed significantly after thermal modification and thermally treated wood specimens had showed lower redness and lower yellowness. Gunduz and Aydemir (2009) reported that the heat treatment temperature had a much more significant effect on color changes than the duration of the treatment. Akgul and Korkut (2012) found that that darkening as a result of heat treatment was clearly visible and it increased with treatment duration and temperature. Aksoy et al. (2011) and Korkut et al. (2013) reported that gloss values of thermally treated wood decreased with increasing treatment temperature and duration. Toker et al. (2016) investigated heat-treated of Oriental beech (*Fagus orientalis* L.) and Scots pine (*Pinus sylvestris* L.) woods. They found that heat treatment caused decrease in gloss values of Oriental beech and Scots pine wood specimens. Moreover, higher treatment temperature and duration resulted in higher gloss loss of wood specimens after heat treatments.

It is known that various paints, varnishes, and other coatings are available to enhance or maintain against weathering too (Chang and Chou 2000, Kielmann et al. 2016, Kielmann and Mai 2016). The weathering of exterior wood veneers has been investigated by many researchers (Nejad and Cooper 2011, Gobakken and Westin 2008, Cristea and Riedl 2010). In the recent years, there has been a growing customer demand for the use of transparent or semi-transparent coatings that retain the natural appearance of wood, such as glossiness, roughness, and texture (Jirous-Rajkovic et al. 2004, George 2005, Scrinzi 2011). When compared to untreated wood, heat-treated wood shows greater resistance to weathering (Temiz et al. 2006, Nuopponen et al. 2004, Ayadi et al. 2003). The modified chromophoric lignin structure due to heat treatment may interfere with light absorption process, thereby inducing photo-stability (Srinivas and Pandey 2012). Kucuktuvek et al. (2017) investigated surface hardness and surface roughness changes of heat treated Scots pine wood after weathering. They found that generally surface hardness losses of heat treated Scots pine wood were lower than that of un-heated Scots pine wood after weathering. Heat treated Scots pine wood gave smooth surface after weathering. Ayadi et al. (2003) investigated color stability of thermally treated wood during artificial weathering. They found that heat treatment increased the color stability of wood. The best photostability of retified wood color could be partially explained by the increase of lignin stability by condensation and phenol content during the heat treatment. Turkoglu et al. (2017) investigated some surface characteristics such as surface roughness and gloss changes of heat treated Oriental beech wood. They found that heat treatment resulted in better surface roughness and glossiness compared to non- heated Oriental beech after natural weathering. Generally, higher temperature and duration of treatment resulted in better surface characteristics of Oriental beech after natural weathering. Yildiz et al. (2011) determined on color stability of heat treated alder wood after natural weathering. They reported that there was a tendency on color changes in thermally treated and weathered stakes compared to the weathered control stakes.

Investigations on surface characteristics of varnished thermowood after exposure to weathering are very limited and the effects of weathering on varnished thermowood species are not well known. The combined treatment of both heat treatment and varnish application can be expected to improve the weathering performance of the wood surface. Turkoglu et al. (2017) investigated some surface characteristics such as surface hardness, surface roughness, and color changes of heated and varnished Oriental beech (*Fagus orientalis* Lipsky) after accelerated weathering. They found that accelerated weathering generally caused increase of surface hardness of Oriental beech. Surface roughness and total color changes of heated and varnished Oriental beech were lower than only varnished (control) Oriental beech after accelerated weathering. Heated and varnished Oriental beech wood gave better surface characteristics than only varnished oriental beech after accelerated weathering. Therefore, in this study, it was aimed to investigate some surface characteristics such as glossiness and surface roughness changes of heated and polyurethane varnish (PV) and cellulosic varnish (CV) coated Scots pine and Oriental beech wood after six months of weathering process in Mugla which is in Southern Aegean Region of Turkey.

MATERIAL AND METHODS

Preparation of test specimens

10 x 100 x 150 mm (radial x tangential x longitudinal) specimens were machined from air-dried sapwood of Scots pine (*Pinus sylvestris* L.) and Oriental beech (*Fagus orientalis* L.) lumbers. All specimens were conditioned at 20°C and 65% relative moisture content for two weeks before tests.

Heat treatment

Heat treatment was performed using a temperature-controlled laboratory oven. Three different temperatures (205, 215, and 225°C) and three treatment durations (1, 2, and 3 hours) were applied to the wood specimens under atmospheric pressure and in the presence of air.

Varnish application

Cellulosic and polyurethane varnishes were used. PV and CV varnishes were applied over heat treated Oriental beech and Scots pine wood. The varnishes were applied to all surfaces and sides of the treated and untreated pine specimens with a spray gun according to the ASTM D3023-98 standard (ASTM D3023-98 2017). The filler was used as the first coating applied to the wood surface was for filling the voids, and the second and third 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 were reached, controlled by consecutive weighting. The specimens were left at ambient conditions for 24 hours according to the manufacturer's recommendations after the first coating, and then the surfaces were gently sanded using a fine-grit sandpaper (220 grit) to obtain a smooth surface before the top coating. After the top coating of varnishes to the surfaces, specimens were conditioned for six weeks.

Glossiness test

The glossiness of samples was determined using a BYK Gardner, Micro-TRI-Glossmeter at the same five points on the surface before and after weathering. Gloss test was performed according to ASTM D523-08 (ASTM D523-08 2008). The chosen geometry was an incidence angle of 60°. Results were based on a specular glossiness value of 100, which relates to the perfect condition under identical illuminating and viewing conditions of a highly polished, plane, black glass surface. The gloss measurements were made parallel to the fiber direction. Five replicates were made for each treatment groups.

Surface roughness test

The surface roughness of specimens was measured by the MitutoyoSurftest SJ-301 (Mitutoyo Corporation, Tokyo, Japan) according to DIN 4768 (DIN 4768 1990). The surface roughness measurement instrument includes a pick-up unit which includes a 5 µm tip radius containing diamond stylus and tip detector of the conical taper angle of 90° and the main unit. The stylus scans the surface with the constant speed of 0.5 mm·s^{-1} over 8 mm sampling length (Zhong at al. 2013). Three roughness parameters which are typically used in previous studies for evaluation of wood and wood-based materials surface characteristics: mean arithmetic deviation of the profile (Ra), mean peak-to-valley height (Rz), and root mean square (Rq) (Hiziroglu 1996, Hiziroglu and Graham 1998).The surface roughness measurements were made parallel to the fiber direction. Five replicates were made for each treatment groups.

Natural weathering test

Each group consisted of 5 individual wood specimens. In total, 20 groups of wood specimens for each species were exposed to weathering conditions during April-May-June and 15 June-15 October in 2015. The wood panels were prepared for weathering exposure according to ASTM D 358–55 (ASTM D 358-55 1970).

Tab. 1: Details of the climate condition of Mugla city during April-May-June and 15 July-15 October in 2015.

Mugla	April	May	June	15 July - 15 August	15 August - 15 September	15 September - 15 October
The highest temperature per month (°C)	24.7	31.8	32.0	36.0	34.60	27.2
The lowest temperature per month (°C)	1.3	6.4	10.6	20.7	19.5	14.5
Average temperature per month (°C)	11.4	18.2	20.8	27.7	26.60	19.7
Humidity per month (%)	60.5	61.9	61.7	45.9	42.7	69.8
Sunbathing time per month (hour)	233.6	227.6	254.8	288.5	235.7	176.6
The number of the rainy days per month	6	6	7	2	-	8
Total rainfall per month (mm=kg·m^{-2})	25.2	89.1	59.0	49.6	-	106

A test site was established close to the Regional Meteorological Observation Station of Mugla which is in Southern Aegean Region to enable practical assessments. The details of the climate condition of Mugla city in Tab. 1 are informed by the Turkish State Meteorological Service database.

RESULTS AND DISCUSSION

Glossiness changes of Scots pine after natural weathering

Glossiness values of the Scots pine wood surfaces at a 60° incidence angle measured before and after weathering are given in Tab. 2.

Tab. 2: Glossiness changes of Scots pine before and after weathering.

Temperature (°C)	Duration (Hour)	Varnishes	Before weathering		After 6 months of weathering		Change
			Mean	SD	Mean	SD	(%)
Only PV coated		PV	96.58	7.13	41.32	1.69	-57.22
205	1		94.98	6.63	50.54	4.23	-46.79
	2		97.28	8.78	53.78	3.54	-44.72
	3		94.78	6.93	58.62	1.90	-38.15
215	1		83.90	6.98	48.20	2.34	-42.55
	2		96.58	8.92	54.46	8.01	-43.61
	3		88.84	4.54	55.92	4.49	-37.06
225	1		95.08	7.23	53.81	2.01	-43.41
	2		93.32	6.84	57.54	3.56	-38.34
	3		96.30	7.41	61.32	5.58	-36.32
Only CV coated		CV	89.90	7.97	46.58	1.35	-48.19
205	1		88.12	6.52	54.72	4.13	-37.90
	2		77.22	6.83	49.36	4.59	-36.08
	3		81.88	4.89	54.06	3.59	-33.98
215	1		90.58	8.67	54.88	5.70	-39.41
	2		74.76	6.12	48.10	4.25	-35.66
	3		82.08	7.25	53.76	3.41	-34.50
225	1		85.78	6.54	54.10	6.35	-36.93
	2		86.24	7.13	56.12	7.35	-34.93
	3		83.16	8.91	55.72	4.93	-33.00

Note: Five replicates were made for each group, PV: Polyurethane varnish,
CV: Cellulosic varnish, SD: Standard deviation

Glossiness a property of reflecting light in a mirror-like fashion is very important for an aesthetic and decorative appearance of the coated wood surface (Cakicier et al. 2011). The highest glossiness value was 97.28 for heated at 205°C for 2 hours and PV coated Scots pine before weathering. Generally, heat treatment before varnish coating caused decrease on glossiness of wood. Our results showed that glossiness values of heat treated and PV coated Scots pine were higher than heat treated and CV coated Scots pine before weathering.

Our results showed that weathering-induced glossiness change is due to the changes to the structure of surface layers in the coating itself. 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 glossiness 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). In our study, natural weathering decreased gloss of Oriental beech in some extent.

While the decrease of gloss was 57.22 % and 48.1 % for PV and CV coated Scots pine, respectively, the decrease of gloss ranged from 36.32 to 46.79% and 33.00 to 39.41% for heated and PV coated and heated and CV coated Scots pine, respectively. Our results showed that generally, glossiness loss values of Scots pine wood specimens decreased with increasing treatment temperature and duration of treatment after weathering. Moreover, glossiness loss of heat treated and PV coated Scots pine were higher than heated and CV coated Scots pine after weathering.

Glossiness changes of Oriental beech after natural weathering

Tab. 3 shows glossiness changes of Oriental beech wood before and after weathering. Glossiness values of PV coated Oriental beech gave nearly same glossiness values with heated and PV coated Oriental beech before weathering.

Tab. 3: Glossiness changes of Oriental beech before and after weathering.

Temperature (°C)	Duration (Hour)	Varnishes	Before weathering		After 6 months of weathering		Change
			Mean	SD	Mean	SD	(%)
Only PV coated		PV	92.84	4.18	45.32	1.69	-51.18
205	1		94.74	2.64	50.16	5.97	-47.06
	2		93.02	2.84	49.86	2.19	-46.40
	3		91.16	2.94	53.07	5.98	-41.78
215	1		87.80	7.73	45.22	3.58	-48.50
	2		95.40	3.94	52.88	2.22	-44.57
	3		88.24	7.05	51.12	9.11	-42.07
225	1		92.20	4.90	51.06	6.71	-44.62
	2		92.72	7.62	53.62	5.18	-42.17
	3		92.84	1.29	57.56	6.58	-38.00
Only CV coated		CV	86.56	2.49	48.92	2.44	-43.48
205	1		88.72	4.47	52.70	7.92	-40.60
	2		79.78	6.50	46.52	5.90	-41.69
	3		83.44	6.61	51.76	3.78	-37.97
215	1		84.28	5.71	49.78	4.39	-40.93
	2		85.44	5.17	50.18	6.14	-41.27
	3		81.12	7.52	52.06	4.25	-35.82
225	1		80.96	4.93	51.24	3.60	-36.71
	2		86.28	2.14	56.12	2.97	-34.96
	3		76.20	8.01	52.62	6.06	-30.94

Note: Five replicates were made for each group, PV: Polyurethane varnish,
CV: Cellulosic varnish, SD: Standard deviation

Glossiness values of heated and PV coated Oriental beech were higher than heated and CV coated Oriental beech. Our results showed that heat treatment before CV coating generally caused some decrease in glossiness values of Oriental beech before weathering. Glossiness losses were observed in all treatment groups after weathering. For example, while the decrease of gloss was 51.18 % and 43.48 % for PV and CV coated Scots pine, respectively, the decrease of glossiness ranged from 38.00 to 48.50 % and 30.94 to 41.64 % for heated and PV coated and heated and CV coated Scots pine, respectively. Our results showed that generally glossiness loss values of Oriental beech wood specimens decreased with increasing treatment temperature and duration of treatment after weathering. Glossiness loss of heat treated and PV coated Oriental beech were higher than heated and CV coated Oriental beech after weathering.

Surface roughness changes of Scots pine after weathering

Surface roughness parameters such as Ra, Rz, and Rq values of heated and varnished Scots pine wood are given in Tab. 4.

Tab. 4: Surface roughness of Scots pine before and after weathering.

Temperature (°C)	Duration (Hour)	Varnishes	Before weathering						After 6 months of weathering						Change (%)		
			Ra	SD	Rz	SD	Rq	SD	Ra	SD	Rz	SD	Rq	SD	Ra	Rz	Rq
Only PV coated		PV	0.13	0.03	1.29	0.16	0.19	0.04	0.47	0.02	4.77	1.02	0.66	0.10	362	370	347
205	1		0.14	0.06	1.17	0.69	0.22	0.13	0.37	0.08	4.33	0.51	0.63	0.13	264	370	286
	2		0.28	0.34	1.27	0.74	0.19	0.10	0.47	0.24	4.53	1.19	0.54	0.32	168	357	284
	3		0.12	0.03	1.01	0.80	0.18	0.09	0.24	0.05	3.02	1.36	0.39	0.13	200	299	217
215	1		0.25	0.21	2.24	0.30	0.41	0.30	0.45	0.21	4.26	1.07	0.69	0.15	180	190	168
	2		0.31	0.08	2.07	0.83	0.42	0.11	0.41	0.09	3.25	1.28	0.64	0.17	132	157	152
	3		0.09	0.03	1.12	0.67	0.13	0.05	0.17	0.07	2.27	0.89	0.24	0.14	189	203	185
225	1		0.17	0.14	1.93	1.15	0.26	0.23	0.33	0.17	3.98	1.69	0.49	0.29	194	206	188
	2		0.08	0.02	1.11	0.74	0.12	0.05	0.19	0.17	2.16	0.89	0.29	0.23	238	195	242
	3		0.11	0.03	1.38	0.92	0.17	0.06	0.17	0.10	2.20	1.27	0.25	0.17	155	159	147
Only CV coated		CV	0.24	0.03	1.98	0.21	0.42	0.03	0.62	0.02	5.79	0.97	0.96	0.08	258	292	229
205	1		0.47	0.17	1.59	2.02	0.32	0.34	0.80	0.17	4.99	1.38	0.82	0.34	170	314	256
	2		0.25	0.07	2.52	0.91	0.35	0.12	0.42	0.08	5.16	0.58	0.62	0.10	168	205	177
	3		0.16	0.02	1.13	0.09	0.21	0.02	0.25	0.06	2.95	1.00	0.38	0.13	156	261	181
215	1		0.22	0.08	1.71	0.98	0.30	0.16	0.43	0.11	4.18	1.49	0.73	0.19	195	244	243
	2		0.20	0.07	1.96	0.92	0.30	0.12	0.36	0.07	3.50	0.85	0.52	0.15	180	179	173
	3		0.23	0.06	1.48	0.31	0.30	0.06	0.31	0.09	2.62	0.63	0.48	0.12	135	177	160
225	1		0.27	0.17	2.40	1.12	0.42	0.29	0.42	0.09	4.32	1.46	0.64	0.18	156	180	152
	2		0.18	0.03	2.19	0.65	0.27	0.02	0.29	0.19	3.84	1.04	0.44	0.23	161	175	163
	3		0.24	0.08	1.90	0.63	0.33	0.11	0.31	0.07	2.40	0.60	0.47	0.11	129	126	142

Note: Five replicates were made for each group, PV: Polyurethane varnish, CV: Cellulosic varnish, SD: Standard deviation.

Only PV and CV coated Scots pine wood specimens had an average Ra, Rz, and Rq values 0.13,1.29, 0.19 and 0.24, 1.98, 0.42, respectively before weathering. Our results showed that heat treatment before varnish coating have no significant effect on surface roughness of Scots pine specimens. Natural weathering highly increased surface roughness of Scots pine. While the increase of Ra was 362%, Rz was 370 %, and Rq was 347% for PV coated Scots pine, the increase of Ra was 258%, Rz was 292%, and Rq was 229% for CV coated Scots pine. Heat treatment before varnish coating resulted in lower surface roughness of Scots pine after weathering. This increase in smoothness is very important for many applications of solid wood. In addition, losses occurring in the planning machine are reduced and high quality surfaces are attained (Unsal and Ayrilmis 2005).Yildiz et al. (2011) reported that heat treatment seemed to protect wood surface from becoming rougher after weathering for softwood. Baysal et al. (2014) investigated surface roughness of heat treated Scots pine (*Pinus sylvestris* L.) wood specimens after 500 hours artificial weathering exposure. The results showed that surface roughness of thermally modified Scots pine were lower than un-heated Scots pine after artificial weathering. Our results are in good agreement with this researcher's finding.

Surface roughness changes of Oriental beech after weathering

Surface roughness parameters such as Ra, Rz, and Rq values of heated and varnished Oriental beech wood are given in Tab. 5.

Tab. 5: Surface roughness of Oriental beech before and after weathering.

Temperature (°C)	Duration (Hour)	Varnishes	Before weathering						After 6 months of weathering						Change (%)		
			Ra	SD	Rz	SD	Rq	SD	Ra	SD	Rz	SD	Rq	SD	Ra	Rz	Rq
Only PV coated		PV	0.16	0.02	1.50	0.44	0.24	0.03	0.57	0.09	4.36	1.43	0.65	0.18	356	291	271
205	1		0.10	0.02	1.04	0.43	0.15	0.04	0.35	0.68	3.50	0.97	0.45	0.09	350	337	300
	2		0.14	0.03	1.54	1.31	0.20	0.05	0.33	0.18	3.17	1.08	0.45	0.23	236	206	225
	3		0.14	0.02	1.31	0.63	0.20	0.06	0.26	0.13	2.43	1.69	0.39	0.20	186	185	195
215	1		0.27	0.19	1.89	0.58	0.37	0.24	0.48	0.03	4.23	0.43	0.68	0.04	178	224	184
	2		0.11	0.03	1.23	0.56	0.14	0.04	0.27	0.10	3.06	0.77	0.36	0.15	245	249	257
	3		0.23	0.07	2.24	0.61	0.36	0.10	0.36	0.06	3.13	0.45	0.52	0.08	157	140	144
225	1		0.14	0.04	1.12	0.49	0.20	0.09	0.30	0.03	3.07	0.56	0.49	0.12	214	274	245
	2		0.11	0.03	1.18	0.72	0.17	0.08	0.23	0.08	3.41	1.51	0.35	0.13	209	289	206
	3		0.09	0.03	1.08	0.73	0.14	0.08	0.19	0.09	1.64	1.06	0.26	0.12	211	152	186
Only CV coated		CV	0.23	0.03	1.84	0.30	0.33	0.06	0.70	0.10	4.98	2.31	0.79	0.25	304	271	239
205	1		0.19	0.07	1.50	0.46	0.26	0.09	0.47	0.09	4.11	1.08	0.70	0.22	247	274	269
	2		0.28	0.06	2.31	1.04	0.40	0.10	0.43	0.08	4.67	0.79	0.63	0.12	154	202	158
	3		0.18	0.02	2.79	2.40	0.29	0.11	0.31	0.17	4.02	2.40	0.49	0.20	172	144	169
215	1		0.23	0.10	1.53	0.43	0.29	0.12	0.47	0.10	4.34	1.41	0.65	0.18	204	284	224
	2		0.16	0.05	1.54	0.43	0.22	0.07	0.33	0.09	4.00	1.53	0.47	0.21	206	260	214
	3		0.33	0.14	3.10	0.73	0.51	0.28	0.43	0.12	4.06	1.13	0.69	0.14	130	131	135
225	1		0.26	0.04	2.92	1.02	0.39	0.12	0.44	0.08	4.94	0.63	0.71	0.10	169	169	182
	2		0.25	0.10	1.88	0.73	0.34	0.16	0.48	0.07	3.58	1.10	0.55	0.14	192	190	162
	3		0.25	0.03	2.74	0.87	0.37	0.03	0.33	0.10	3.42	0.28	0.51	1.24	132	125	135

Note: Five replicates were made for each group, PV: Polyurethane varnish, CV: Cellulosic varnish, SD: Standard deviation.

Importance of surface roughness as a significant parameter for determination of the surface quality of wood products is well recognized, and the surface quality of the wood is affected by many factors (Yildiz et al. 2011). Furthermore, the wooden materials with rough surface require much more sanding process compared to one with the smooth surface, which leads to decrease in thickness of material and, therefore, increases the losses due to the sanding process (Dundar et al. 2008). However, wood is a heterogeneous, anisotropic and brittle material. The surface roughness of wood products depends on many factors such as wood anatomical features (vessels, cell lumen, annual ring width, hardness etc.), machine conditions (feed rate, spindle speed etc.) and cutting properties (Karagoz et al. 2011). Our results showed that only PV and CV coated Scots pine wood specimens had an average Ra, Rz, and Rq values of 0.16, 1.50, 0.24 and 0.23, 1.84, 0.33, respectively before weathering. Our results showed that heat treatment before varnish coating has no significant effect on the surface roughness of Oriental beech specimens. Natural weathering highly increased surface roughness of Oriental beech. While the increase of Ra was 356 %, Rz was 291 %, and Rq was 271 % for PV coated Oriental beech, the increase of Ra was 304 %, Rz was 271 %, and Rq was 239 % for CV coated Oriental beech. Heat treatment before varnish coating resulted in the lower surface roughness of Oriental beech after weathering. Turkoglu et al. (2017) investigated surface roughness of heat treated and PV coated Oriental beech after 500 h accelerated weathering. They found that surface roughness of heated and varnished Oriental beech was lower than only varnished (control) Oriental beech after 500 h accelerated weathering. Our results are in good agreement with data Turkoglu et al. (2017). According to our results, heated and varnished Oriental beech wood gave better surface roughness than only varnished oriental beech after accelerated weathering.

CONCLUSIONS

The natural weathering process was caused an increase in the surface roughness of the test specimens according to the test results. The Scots pine (*Pinus sylvestris* L.) and Oriental beech (*Fagus orientalis* L.) test specimens which were heat treated and varnished gave more favorable results compared to only varnished test specimens after natural weathering in terms of physical properties such as surface roughness and glossiness. Generally, as the heat treatment time and temperature increase, it is observed that the physical properties of the Scots pine and Oriental beech wood specimens improve positively. According to the results of the tests, the samples varnished with polyurethane varnish gave better results in terms of surface roughness at the end of the natural weathering process, whereas the samples varnished with cellulosic varnish gave better results in terms of glossiness values.

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