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Effect of Climate Factors on Wood Veneers Exposed to Outdoor Conditions in Black Sea Region

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Abstract:

In this study, 2×100×200 mm wood veneers obtained from Scots pine (Pinus sylvestris L.), European black pine (Pinus nigra Arn.) and beech (Fagus orientalis L.) wood were exposed to outdoor climate conditions at three different cities (Trabzon, Artvin, and Kastamonu) of Black Sea region in Turkey for totally 4 months from May to August, 2012. The aim of this study was to investigate the effect of climate factors on the changes occurred on different types of wood veneers that were subjected to outdoor weathering conditions. Weight losses, surface roughness, and color changes occurred on veneers were determined during natural weathering. Additionally, the weathering map of wood in three cities studied was calculated using Scheffer Climate Index (SCI) in order to characterize the potential decay risk of wood materials. Accordingly, at the end of the 4 months, the highest weight losses for Scots pine veneers were obtained from the weathering conditions in Artvin while the lowest weight losses were obtained in Kastamonu. For European black pine and beech veneers, the highest weight losses were obtained from Trabzon, and the lowest weight losses were obtained from Kastamonu. The highest color change value (ΔE^*) obtained from Trabzon and Artvin, the lowest ΔE^* obtained from Kastamonu for Scots pine veneers. For European black pine veneers, the highest ΔE^* obtained from Trabzon while the lowest ΔE^* was obtained from Artvin and Kastamonu. For beech veneers, the highest ΔE^* was obtained from Artvin, the lowest ΔE^* obtained from Kastamonu. For all veneers, the lowest surface roughness was determined in Trabzon. The highest surface roughness was obtained in Artvin for Scots pine and it was obtained in Kastamonu for European black pine and beech. Based on the result of SCI analysis, the most risky city for decay potential of fungi was Trabzon, then Artvin and Kastamonu, respectively.

Key Terms: Weathering map, Climate index, Wood veneer, Decay risk, Natural weathering.

Introduction:

Wood is a polymeric bio-material composed of cellulose, hemicelluloses, lignin, and extractives (Hon and Chang, 1984; Chang and Chang, 2001). Wood, beside its esthetic view, lower density, heat transfer, high mechanical strength, and easy to process, is a renewable material (Pandey, 1999).

Wood is widely used for varies purposes such as engineering and structural works as well as indoor and outdoor applications; however, it has been deteriorated by biotic and abiotic (Zhang et al., 2009). Abiotic factors are solar irradiation (ultraviolet, visible and infrared light), moisture (rain, snow, humidity, and dew), mechanical forces (wind, sand, and dirt), temperature and some atmospheric gases (O_2, SO_2, air, pollutant gases, etc.). These factors negatively affect the physical, biological, chemical, and mechanical properties of wood material (Feist and Hon, 1984; Fengel and Wegener, 1984).

The most degrading factor of wood is UV rays which are causing depolymerization of lignin in the cell wall matrix. A color change is initiated on wood surface due to UV rays. This color change is observed on surface and nearby of wood surface. Additionally, loss of brightness, roughness, and small cracks is observed (Temiz et al., 2007).

Lignin is a good UV absorbent because of having numerous chomophoric groups in its chemical structure. Wood absorbs UV at 295-400 nm wave range, and the formation of color change and chromophoric groups is observed (Zhang et al., 2009; Feist and Hon, 1984; Hon and Chang, 1984). The UV absorption rates of wood components as follow: lignin 80-95%, carbonhydrates 5-20%, and extractives 2% (Fengel and Wegener, 1984; Pastor et al., 2004). The UV rays absorbed by wood cause formation of free radicals which causes photo degradation in wood. The formation of photo degradation started with oxidation of phenolic hydroxyls, and this causes color change and content decreasing of methoxyl and lignin in wood. On the other hand, there is an increase on the rate of carboxyl and acidity. This degradation effect is removed from wood with the help of rain under outdoor climate conditions (Fengel and Wegener, 1984; Zhang and Kandem, 2000; Temiz, 2005).

In this study, thin wood veneers made of Scots pine *(Pinus sylvestris L.)*, European black pine *(Pinus nigra Arn.)* and beech *(Fagus orientalis L.)* were exposed to outdoor climate conditions at three different cities in Black sea region of Turkey for 4 months. Weight losses, surface roughness, and color changes occurred on veneers were determined based on the natural weathering. The aim of this study was to characterize the effect of climate factors on the changes occurred on different type veneers that were subjected to outdoor weathering conditions.

Materials and Methods

Wood Veneers and Outdoor Exposure of Veneer Surfaces: Veneers made of three wood species, namely; Scots pine *(Pinus sylvestris L.),* European black pine *(Pinus nigra Arn.)* and beech (*Fagus orientalis L.)* were used. These samples prepared at 2 mm thick, 100 mm wide and 200 mm length for this study**.** Veneers were dried for 24 hours at temperatures of 103±2 °C and oven dry weights measured. Samples were then conditioned at 65% relative humidity and 20°C before exposure. Veneers were exposed at the following three test cities in Turkey; Trabzon, Artvin, and Kastamonu. They are shown on the map in Figure 1. Table 1 shows the climatic conditions for each exposure cities. Figures 2 and 3 show the average temperature and average relative humidity, respectively. Ten replicates for each wood species were used. Veneers were placed on the weathering racks (facing to the east and horizontal). The exposure test ran for 4 month from May 2012 to August 2012.

Figure 1. Three test cities in Turkey

Table 1. Climatic conditions of three test cities.

Months	Cities	Climatic Conditions						
		Average temperature (°C)	Maximum temperature (°C)	Minimum Temperature (°C)	Average relative humidity (%)	Annual precipitation (mm)	Annual sunshine (hour)	Average solar radiation (Cal/cm²)
May	Trabzon	18,5	24	14,7	78,6	47,2	3,7	377,9
	Artvin	17,3	23,6	13,9	65,2	406	5,4	12587
	Kastamonu	14,8	28,6	4,3	69,7	86,6	159,9	14255,73
June	Trabzon	22,9	26,2	16,5	70,2	85,7	9	523,2
	Artvin	20,6	27,7	14,9	62,6	515,7	7,5	15469

	Kastamonu	19,8	34,6	6,2	57,3	39,2	258,8	18816,09
July	**Trabzon**	25,6	29,8	20	67,4	20,4	7,3	470,5
	Artvin	22,1	29,1	14,5	65	533,2	8,3	16530
	Kastamonu	22,2	39,8	8,6	54,9	49,6	237	17000
August	**Trabzon**	24,7	28,2	20,8	70	23	3,4	304,8
	Artvin	21,3	25	17,6	71,1	413,6	6	12820
	Kastamonu	19,7	38	4,8	59,3	28,8	196,5	15981,63

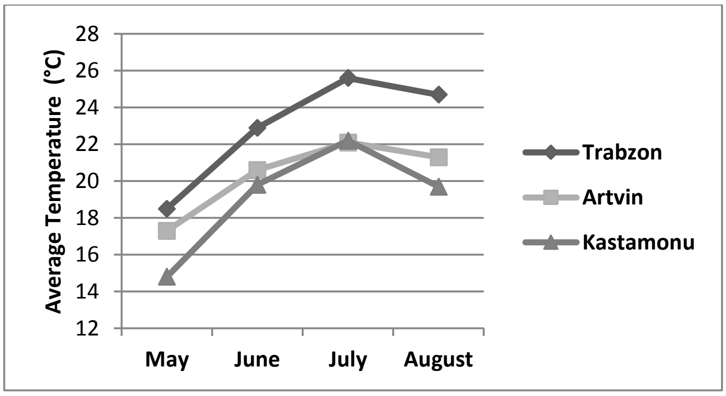

Figure 2. Average temperature in three test cities

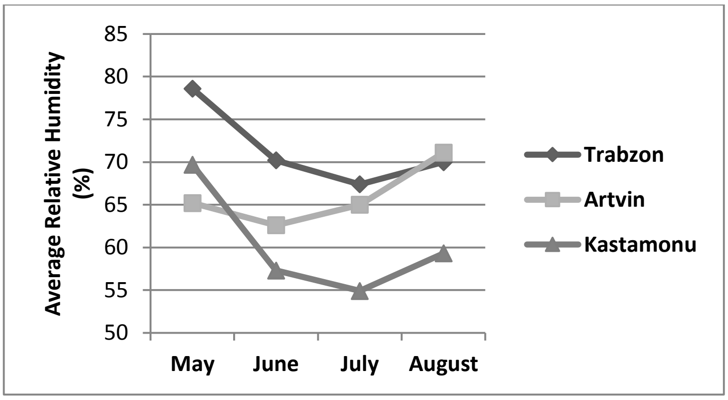

Figure 3. Average relative humidity in three test cities

Weight Losses and Moisture Content of Veneers:

Oven dry weight of wood veneers was recorded before and after the test. Weight losses of veneers were calculated according to Equation 1 after weathering test.

$$WL\ (\%) = \frac{Mo_{(b.t.)} - Mo_{(a.t.)}}{Mo_{(b.t.)}} \times 100 \qquad (1)$$

Where; WL is weight loss, Mo $_{(B.t.)}$ is oven dry weight before the test, Mo $_{(A.t.)}$ is oven dry weight after the test.

Weights of wood veneers were recorded every month and moisture content of wood veneers for every month was calculated according to Equation 2;

$$MC\ (\%) = \frac{W_2 - W_1}{W_1} \times 100 \qquad (2)$$

Where; MC is moisture content, W_2 is weight of veneers after test; W_1 is oven dry weight of veneers before test.

Color Measurement: Color measurement was determined according to ISO 7724-2, 1984 standard by using a spectrophotometer (Konica Minolta CM-700d/600d). Commission International on Illumination (CIEab) system is derived from CIE Standard Color Table by transforming the original X, Y and Z colorimetric coordinates (color values) into three new reference values of L*, a*, and b*. Here, L* axis represents the lightness, a* and b* are the chromaticity coordinates; +a* for red, -a* for green, +b* for yellow and -b* for blue. The L* varies from 100 (white) to 0 (black). The objective of this transformation is a color-space to aid in the numerical classification of color differences

L*, a* and b* color coordinates for each sample was determined before and after exposure to weathering. The color was measured on a color measurement devise using a D65 light source. These values were used to calculate the color change ΔE* as a function of the UV irradiation period according to the following equations:

$\Delta L^* = Ls^* - Li^*$ (3)

$\Delta a^* = as^* - ai^*$ (4)

$\Delta b^* = bs^* - bi^*$ (5)

$$\Delta E^* = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \quad (6)$$

Where ΔL*, Δa*, and Δb* are the changes before and after test. L*, a*, and b* contribute to the color change ΔE*. A low ΔE* corresponds to a low color change or a stable color.

Surface Roughness: Roughness parameters (Rz) were measured to evaluate surface roughness of veneer surfaces during outdoor exposure. Rz is the arithmetic mean of the 10-point height of irregularities (DIN 4768). TR 100 Surface Roughness Tester was employed for the surface roughness tests. Cut-off length was 2.5 mm, sampling length was 12.5 mm and detector tip radius was 5 mm in the surface roughness measurements.

Climatic Index of Cities: A parameter the "climate index value" was proposed by Scheffer (1971) to estimate decay risk for wood exposed above ground to exterior conditions. Scheffer Index is calculated by following equation.

$$Index = \sum_{\text{Jan}}^{\text{Dec}} [(\text{t}-2)(\text{g}-3)]/16{,}7$$

Where *t* is mean monthly average temperature (expressed in °C), *g* is mean number of days per month with 0.25 mm or more of precipitation, and $(T-2) \equiv 0$ if $T < 2$.

Climatological data for the cities of Trabzon, Artvin, and Kastamonu were obtained from Government Meteorology General Management.

Results and Discussion

Weight Losses and Moisture Content: At the end of 4 months, the weight losses of the wood veneers exposed to outdoor climate conditions at Trabzon, Artvin, and Kastamonu were shown in Figure 4.

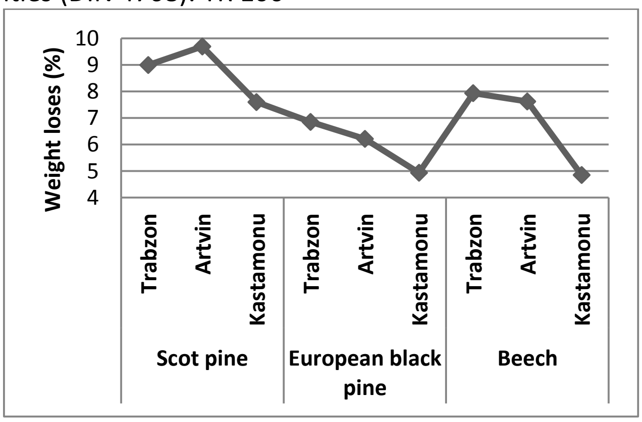

Figure 4. Weight losses of the veneers in three test cities.

As shown in Figure 4, for Scots pine veneers, the highest weight losses were observed in Artvin while the lowest weight losses were observed in Kastamonu. For European black pine and beech veneers, the most weight losses were observed in Trabzon, and the least weight losses were observed in Kastamonu. All veneers indicate that the lowest weight losses were acquired in Kastamonu due to its lower averaged temperature and relative humidity.

Weight losses of wood in outdoor conditions can be attributed to the washing away of degraded products by rain and microbial degradation. According to previous studies, the leaching of low molecular weight degradation products of lignin accelerated the roughening and checking of the exposed wood surface (Feist and Rowell, 1982; Temiz et al., 2007). In addition to gaseous and volatile products, the formation of water soluble products may cause weight loss of weathered specimens (Futo, 1974; Futo, 1976). Under natural weathering conditions, weight loss might be partly due to microbial attack. Mechanism of surface graying of weathered wood with fungal-action usually predominates particularly in the presence of moisture (Feist and Hon, 1984; Yıldız et al., 2010). Microorganisms may also produce dark colored spores and mycelia, which can produce the dark gray, blotchy and unsightly appearance of some weathered wood. All wood surfaces will eventually turn gray when exposed to sun and rain (Feist, 1992; Yıldız et al., 2010).

The weights of all veneers were monthly measured, and accordingly moisture contents of them were calculated at the end of each month. According to these, moisture contents were shown in Figure 5.

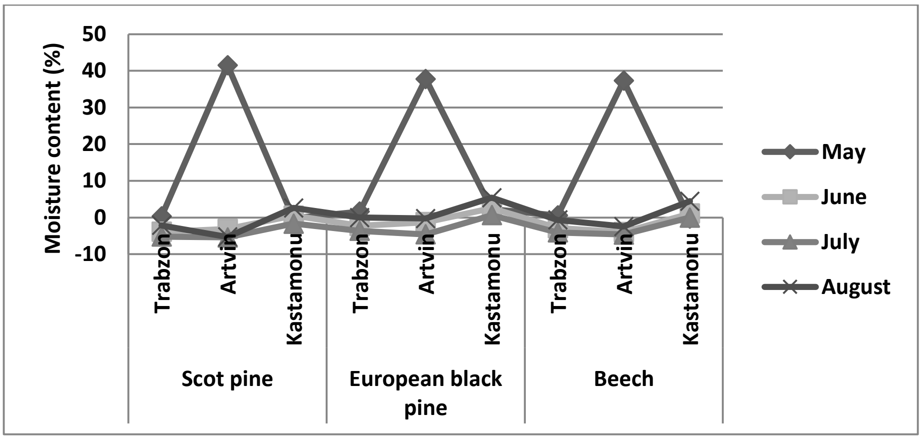

Figure 5. Moisture content (%) of veneers through the 4 months.

As shown in Figure 5, in May, the highest moisture content was observed in Artvin for all veneers since the annual precipitation in Artvin is higher than that of other cities. In June, July, and August, no big difference for samples moisture content was observed for all veneers and cities.

Color Measurement: At the end of 4 months, the color change of the veneers made of Scots pine, European black pine, and beech veneers were exposed to outdoor climate conditions at Trabzon, Artvin, and Kastamonu was summarized in Table 2.

Table 2. Color change values of veneers subjected to outdoor climate conditions.

	Trabzon				Artvin				Kastamonu			
	*ΔL**	*Δa**	*Δb**	*ΔE**	*ΔL**	*Δa**	*Δb**	*ΔE**	*ΔL**	*Δa**	*Δb**	*ΔE**
Scots pine	-33,65	-4,08	-22,24	40,64	-33,65	-4,08	-22,57	40,64	-27,69	-3,1	-18,21	32,92
European black pine	-35,22	-3,65	-19,65	42,01	-27,72	-3,33	-18,4	32,76	-27,72	-3,33	-20,72	32,76
Beech	-27,69	-7,35	-18,03	33,98	-29,66	-7,75	-18,4	37,05	-23,46	-7,54	-17,44	30,27

Positive values of *Δb** indicate an increment of yellow color and negative values indicate an increase of blue color. Positive values of *Δa** indicate a tendency of wood surface to reddish while negative values mean a tendency to greenish.

The negative lightness stability *(ΔL*)* values was observed during weathering because the surface becomes darker, which is opposite of the positive lightness stability *(ΔL*)* values. In the early stages of weathering, dark woods tend to become light and light woods are vice-versa. This could be a result of depolymerization of the lignin on the exposed surface. This surface color change to gray in wood is observed at the time the wood is exposed to the sun in climates with little precipitation (Feist and Hon 1984; Yıldız et al., 2010). Eventually all woods become gray if fully exposed to natural weathering. As can be seen in Table 2, *ΔL** values of all samples were negative after weathering. Scots pine and European black pine veneers showed the lowest values of *ΔL** in every city.

Besides being a visual defect on wood surfaces, color change is also a chemical modification of the components in wood due to photo-degradation. The carbonyl group of conjugated ketones, aldehydes, and quinines which are the products of modification of lignin and other related compounds induced color change. (Cestellan and Davidson, 2005; Forsskahal and Tylli, 1984; Temiz et al., 2005).

The typical anatomical structure of softwoods and hardwoods shows distinct differences. These structural differences of wood are the most important factors that affect weathering characteristic (William, 2005). The influences of the species on the member's characteristics are related to content of extractives on pine veneers was found to be different than that from beech samples. (Aloui et al., 2007). The color change ΔE* values were shown in Figure 6.

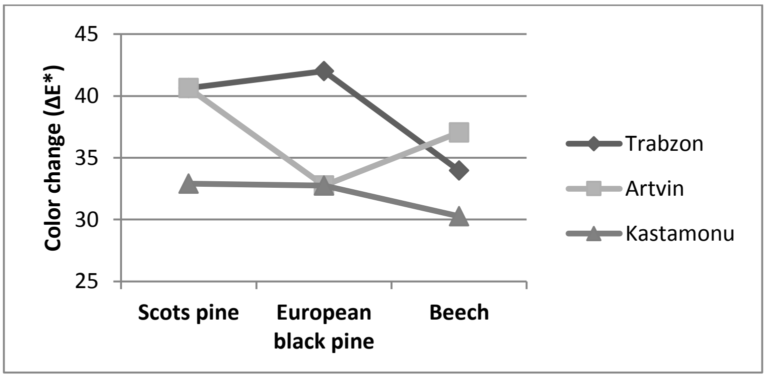

Figure 6. Color changes (ΔE*) of veneers according to cities.

For Scots pine veneers, the highest color change value (ΔE^*) was calculated in Trabzon and Artvin, the lowest ΔE^* was calculated in Kastamonu. For European black pine veneers, the highest ΔE^* was calculated in Trabzon while the lowest ΔE^* was calculated in Artvin and Kastamonu. For beech veneers, the highest ΔE^* was calculated in Artvin, the lowest ΔE^* was calculated Kastamonu.

Surface Roughness: The surface roughness values of veneers were shown in Figure 7. For all veneers, the lowest surface roughness was detected in Trabzon. The highest surface roughness was detected in Artvin for Scots pine; it was detected in Kastamonu for European black pine and beech.

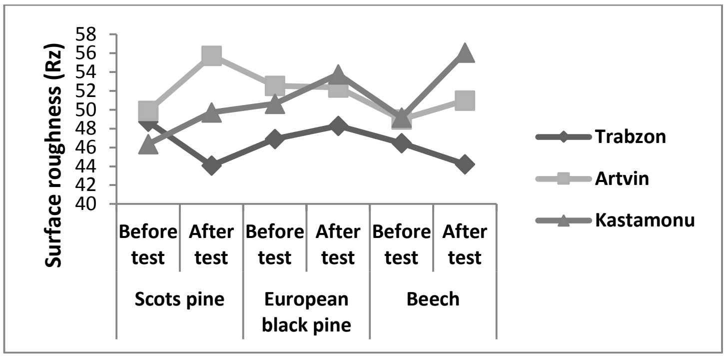

Figure 7. Surface roughness (Rz) of all veneers according to cities.

The wood surfaces subjected to weathering conditions show several checks, splits and cracks. Since wood is an anisotropic material, it has heterogeneous structure. Therefore, several factors such as anatomical differences, growing characteristics, machining properties of wood could be a reason for the surface roughness of wood (Aydın and Colakoglu, 2003; Temiz et al., 2005).

Climatic Index of Cities: By using climatological values, climate index values for some cities in Black sea region were listed in Tablo 3. As a result, the districts with index values under 35 show low decay risk; the districts with index values between 35 and 65 show medium decay risk, and the districts with the index values over 65 show high decay risk. The relationship between CI and the deterioration of veneer weathered at the 3 sites in Turkey was examined.

Table 3. Climatic index according to cities.

City	Index
Trabzon	79,7
Artvin	72,4
Kastamonu	23,2

According to results, Trabzon and Artvin are the cities where the highest decay risk was observed. It can be recommended that the wood materials used in these cities and exposed to outdoor climatic conditions should be treated to protect against biotic and abiotic factors. Since Kastamonu has lower precipitation than others, it has lower decay risk on veneers.

Conclusions:

In this study, the effect of climate factors on three types of veneers was investigated in three different cities. Accordingly, Scots pine, European black pine, and beech wood veneers were subjected to natural weathering in Trabzon, Artvin, and Kastamonu for totally 4 months from May to August, 2012. It was found that the greatest weight losses were determined in Artvin, and the lowest weight losses were determined in Kastamonu for all veneers. This could due to climate conditions of different cities because Artvin has the highest precipitation while Kastamonu has the lowest precipitation. For color change of veneers, the highest color change was determined in Trabzon because of its greatest averaged temperature. On the other hand, the lowest color change was determined in Kastamonu because of its lowest averaged temperature. In addition, wood species has an effect on color change. Thus, in general, the veneers obtained from softwood showed higher color change due to extractive content in its chemical structure. Comparisons of surface roughness results were not exactly associated with different cities but it may be associated with the differences of chemical compositions of two different wood species (hardwood and softwood). In accordance with result of SCI analysis, the most risky city for decay potential of fungi was Trabzon, following Artvin and Kastamonu, respectively.

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