Measurement 53 (2014) 30–39

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Changes in surface and mechanical properties of heat treated wood during natural weathering

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ARTICLE INFO

Article history:
Received 29 December 2013
Received in revised form 21 February 2014
Accepted 17 March 2014
Available online 26 March 2014

Keywords:
Color change
Heat treatment
Mechanical strength
Natural weathering
Surface roughness

ABSTRACT

In this study, it was aimed to investigate the changes in moisture content, color, surface roughness, compression strength parallel to grain, modulus of rupture and modulus of elasticity of heat treated ash, iroko, Scots pine and spruce wood species during natural weathering for two years. Samples were removed at 6-month intervals for performance evaluation, and test results were compared with the controls. Moisture content of heat treated samples was found to be lower than that of control samples for all exposure periods. Heat treatment significantly changed original wood color as well as weathering factors. Wood surfaces become rougher within longer weathering exposure period. Natural weathering factors caused a decrease for all strength properties. Reduction rate for strength properties of heat treated samples was relatively lower than that of control samples. Heat treatment also seemed to improve color stability and surface quality of samples after weathering.

1. Introduction

Versatile and high strength properties of wood make it one of the natural engineering and structural materials in many applications. However, environmental factors such as sunlight, moisture, oxygen, atmospheric pollutants, heat, cold, chemicals, abrasion by windblown materials and biological agents degrade wood components, and reduce aesthetic appearance, strength and durability [1,2]. All these factors cause an economical loss by shortening service life of wood. Wood treatments such as impregnation with preservatives and modification techniques can improve durability of wood in outdoors depending on the intended applications. Thermal modified wood generally known as heat treated wood is exposed to high temperatures in the range of 180–280 °C from 15 min to 24 h [3] to improve its properties and to provide wood an attractive dark color [3,4]. It is an alternative method to impregnation with traditional wood preservatives, and is being used in different end use applications.

The effectiveness of heat treatment against artificial weathering or UV irradiation [4–13], natural weathering [14–16], lap-joint field test [17] and ground contact [18,19] was extensively studied. Artificial weathering and UV irradiation exposure studies on heat treated wood showed that the color stability for heat treated wood was better than unheated (control) wood [5,8–10] probably due to the increase in lignin stability after the heat treatment [5]. The degree of color change with irradiation in softwood was greater than that in hardwood, and that might be related with the difference in lignin content of wood species [6]. Heat treated wood samples also showed less surface checks and volumetric swelling, and retained

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http://dx.doi.org/10.1016/j.measurement.2014.03.018
0263-2241/

their physical aspect better than controls after weathering/irradiating [4,10]. The SEM analysis showed that the effect of artificial weathering on the cell wall of control wood surface was more than that of heat treated samples [12]. However, improvement in color stability and strength properties, and getting smooth surfaces with heat treatment against weathering factors are losing in longer artificial weathering exposures [13]. Similar observations in color stability [11] and in surface structure degradation [4] with the long term artificial weathering were also reported. Natural weathering exposure studies also indicated that heat treated wood was more resistant to natural weathering factors than control wood [14]. Surface damages (cracking, flaking, and mould growth) on coated oil heat treated wood were found to be less than the painted control wood [15]. Metsa-Kortelainen et al. [17] observed that the control samples were severely attacked by decay fungi and reached failure rating while only small areas of incipient decay were detected in heat treated samples after 9 years in a lap-joint field test. Similar improvements on mechanical properties and decay resistance of heat treated OSB samples were found compared to controls after natural weathering by Menezzi et al. [16]. Ground contact tests showed the decay index of heat treated wood was lower than that of the controls, and heat treated samples showed greater strength resistance and color stability compared to controls after exposure to degradation factors for 3 years [19]. Edlund and Jermer [18] reported that the EN 252 stakes of heat treated wood showed a high rate of failure after exposure of 2 years probably a consequence of the strength loss caused by the heat-treatment itself, enhanced by the subsequent wetting in the ground and further chemical degradation. They also reported that heat treated wood seemed to be less susceptible to discoloring organisms than control wood but not as good as wood treated with copper based wood preservatives.

Increased awareness of wood and wood products without any toxic preservatives helped heat treated wood to become popular in the recent years. A complete understanding and predicting of the protection mechanisms involved in any type of climatic conditions or weathering process would allow development of new treatments and finishes, which would greatly enhance durability of heat treated wood and would increase service life of wood [4,13]. Most of the previous studies are focused on studying the effect of artificial weathering on wood properties. Ash (*Fraxinus excelsior* L.), iroko (*Chlorophora excelsa*), Scots pine (*Pinus sylvestris* L.) and spruce (*Picea orientalis* L.) are the main wood species used for industrial scale thermal modification in Turkey. The effect of artificial weathering on chemical composition, surface characteristic and mechanical properties of heat treated these wood species during exposure period of 400–1600 h was studied by Yildiz et al. [13]. In their study, longer weathering exposure period significantly increased color change for heat treated wood samples while compression strength, MOR and MOE of samples decreased both for heat treated and control samples due to severe delignification and hemicellulose degradation occurred in heat treated and control samples for all wood species during weathering from 400 h to 1600 h. A performance evaluation after natural weathering of these wood samples is needed since natural weathering in above ground test of wood can help in predicting more realistic outdoor performance.

The objectives of this study are to investigate the surface and mechanical properties of heat treated ash, iroko, Scots pine and spruce wood, and to identify stages of surface changes for various exposure periods. In order to attain these research goals, samples were exposed to natural weathering facing south and inclined at a 45° angle in Trabzon located in East Black Sea region of Turkey, and were removed at 6-month intervals for performance evaluation for total of 2 years. Changes in moisture content, color, surface roughness, compression strength parallel to grain, modulus of rupture and modulus of elasticity were measured, and test evaluations were made comparison with the results of controls.

2. Materials and method

Sapwood samples of ash (*Fraxinus excelsior* L.), iroko (*Chlorophora excelsa*), Scots pine (*Pinus sylvestris* L.) and spruce (*Picea orientalis* L.) with dimensions of 50 mm (radial) × 100 mm (tangential) × 800 mm (longitudinal) were subjected to the heat treatment in an industrial plant (Nova Wood, Gerede, Turkey). Softwoods were subjected to the heat treatment at 212 °C for 90 min while hardwoods were heated at 190 °C for 90 min under steam atmosphere. Heat treated samples were then cut in parallel to grain directions and sawn into samples with dimension of 20 mm (tangential) × 20 mm (radial) × 300 mm (longitudinal) at both ends. Preparation of wood samples had been described in detail in an earlier study by Yildiz et al. [13]. Ten replicates were used for each group for moisture content, color, surface roughness, modulus of rupture and modulus of elasticity determinations. Before the natural weathering, samples were first oven dried at 80 °C for 2 days to calculate the moisture contents (MC, %) during the natural weathering exposure periods, and then conditioned at 20 °C and 65% relative humidity for a week. The color and surface roughness were measured at the same points on the tangential face of the samples before and after natural weathering.

2.1. Natural weathering

Natural weathering tests were performed on heat treated and control samples facing south and inclined at a 45° angle and a height of 75 cm above the ground at Karadeniz Technical University campus, Trabzon, Turkey (40°59′18″ latitude and 39°46′7″ longitude) for a period of 2 years, from October 2011 to October 2013. Test samples were set outside without any cover from the weathering factors such as sun, rain and wind etc. Samples were removed at 6-month intervals for performance evaluation. Color and surface roughness measurements were done on the exposed surfaces, and moisture content of the samples was determined. After the measurements, samples were placed again on 45° angle anti-corrosion aluminum rack facing south.