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An investigation of adhesion performance under various conditions using heat-treated wood

Isıl işlem görmüş ahşap kullanılarak çeşitli koşullar altında yapışma performansının incelenmesi

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An Investigation of Adhesion Performance Under Various Conditions Using Heat-Treated Wood

Highlights

- *It was determined that heat-treated wood absorbs less moisture and undergoes less density change than untreated wood.*
- *It was determined that the adhesion performance decreased the most in A5 and then A4 holding media.*
- *The highest adhesion performance was achieved on pine which was glued in 20/35 climate conditions and kept in A5 environment, tested under 20/35 climate conditions and oak tested under 20/65 climate conditions.*

Graphical Abstract

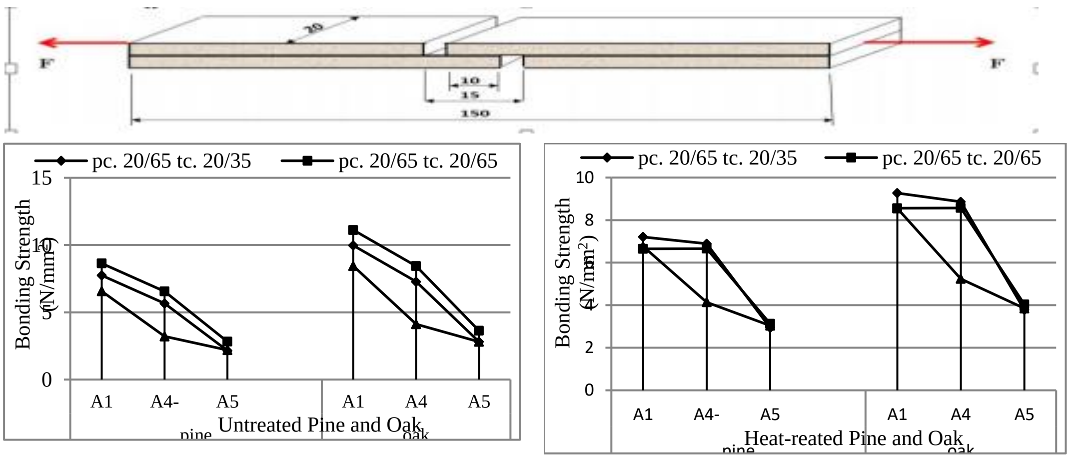

Figure. Bonding strength of untreated and heat-treated wood samples under A1, A4, A5 holding conditions for gluing of pc.20/65 and testing in climatic conditions of 20°C/35%, 20°C/65%, 20°C/95% .

Aim

The samples (untreated and heat treated) were hold under different climatic conditions at 20°C/35%, 20°C/65%, 20°C/95% and three different holding environments (A1, A4, A5) (Table 1). It was aimed to determine the adhesion strength of these samples by applying tensile tests according to BS EN 205 (2003) standard and determined adhesion performances.

Design and Methodology

Test samples were glued under different climatic conditions (20 / 35,20 / 65,20 / 95), kept in different environments (A1, A4, A5) and then tested under different climatic conditions (20 / 35,20 / 65,20 / 95). they were made.

Originality

It has been determined that it would be beter to use heat treated oak than heat treated pine in different climatic condition and holding environment

Findings

The highest adhesion performance was found to be

A1: 7,61 N/mm2 in heat-treatment pine, 9,79 N/mm2 in heat-treatment oak

A4: 7,51 N/mm2 in heat-treatment pine, 9,53 N/mm2 in heat-treatment oak

A5: 3,48 N/mm2 in heat-treatment pine, 4,4 N/mm2 in heat-treatment oak

Conclusion

Consequently, the advantages of heat treated wood are that it can be used in humid conditions; however, the study determined that under different conditions the bond resistance will depend on the properties of the glue.

Declaration of Ethical Standards

The author of this article declare that the materials and methods used in this study do not require ethical committee permission and or legal-special permission.

An Investigation of Adhesion Performance Under Various Conditions Using Heat-Treated Wood

Research Article

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ABSTRACT

In this study, the adhesion performance of oak (Quercus petrea Liebl.) And Scotch pine (Pinus Silvestris L.) wood samples that were heat treated and glued with 1K-PUR adhesive were kept under different conditions (A1-A4-A5) and moisture contents (20°C /% 35, 20°C /%65 ve 20°C /% 95), and then the adhesion performance was investigated. Rough sized pieces of both types of wood were heat treated at 195°C for 2 hours. Test samples were prepared from untreated and heat treated blanks (DIN EN 204). Tensile tests according to DIN EN 204 were applied to samples kept at 20°C/35%, 20°C/65% and 20°C/95% temperature and relative humidity, respectively, and the adhesion performance was determined in three climatic conditions. At the end of these tests, it was found that the holding environment and climatic conditions have a significant effect on the adhesion resistance. It was observed that the samples that were kept under A1 conditions and tested had wood rupture (error) between 70% and 100%, and the samples tested after holding in A4 and A5 conditions mostly broke off from the glue joint.

Keywords: Heat treatment, holding environment, moisture content, shear test, adhesion strength, scotch pine, oak.

1. INTRODUCTION

Adhesives are indispensable when using wood as a building material in indoor and outdoor environments. However, in glued (laminated) wood, the behavior changes in the glue layer depend on temperature and relative humidity in outdoor conditions. Depending on the temperature and relative humidity variables, internal stresses and cracks occur during the swelling and shrinkage of the wood. At the same time, partial opening occurs due to delamination and increases moisture in the glue layer [1,2,3].

In the published literature Volkmer et al. (2012) examined the performance of glued wood using melamine glue. Significant differences were obtained in the amount of wood defects among adhesives depending on the humidity [4] . Samples adhered with 1K PUR and aged under A4 and A5 holding conditions failed to meet the required wood defect levels before testing [5].

When tests were applied following the A4 holding conditions, it was observed that the type of adhesive and surface treatment had a significant effect on the adhesion performance [6]. It is known that the differences and changes in humidity between the dried layers of industrially processed laminated wood affect the usage performance. According to Hering (2011), the effects of the elasticity module and the year ring of wood, and the glue layer containing different amounts of moisture determine the adhesion performance [7].

Clad (1964) and Brockmann et al. (2005) found that for every 1% change of wood moisture, shear strength changes by 0,12 N/mm2, but also softening of the glue layer contributes to poor adhesion performance [8,9]. It has been reported that the adhesion performance of wood increases up to 80% when it is dried [6] . It has been found that a temperature change in heat-treated wood affects the glue layer [10,11]. Şahin Kol et al. (2009) reported that heat treatment negatively affected the shear strength of Tali wood (Erythrophleum ivorense) and Iroko wood (Chlorophora excelsa) [12]. Dilik and Hızıroğlu (2012) examined the effect of heat treatment and pressure on the adhesion strength of Eastern red cedar (Juniperus virginiana). They declared that samples exposed to 120°C, 160°C and 190°C respectively showed a decrease of 23,6%, 44,4% and 64,1% in adhesion strength [13]. They reported that after heat treatment, wood became hydrophobic, which increased the absorption of the glue solution by the wood surface and the penetration of the solution into porous wood [14,15,16].

Altunok et al. (2012) investigated an adhesion performance only in untreated and heat-treated beech wood [5]. However, it is known that scotch pine and oak wood are increasingly used in outdoor conditions, in the production of marine vehicles and coastal structures. In this context, unprocessed and heat treated woods were prepared from Scots pine (Pinus sylvestris L.) and oak (Quercus petraea Liebl.) Wood, which are widely used in open air conditions. The samples were hold under different climatic conditions at 20°C/35%, 20°C/65%, 20°C/95% and three different holding environments
1, A4, A5) (Table 1). It was aimed to determine the adhesion strength of these samples by applying tensile tests according to BS EN 205 (2003) standard.

2. MATERIALS AND METHODS

A sufficient amount of coarse sized pine and oak wood pieces (solid wood) remained untreated, while the other part was heat treated under the protection of hot water vapor in a laboratory-type heat treatment oven controlled

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at ± 1°C for 2 hours at 195°C. has been applied. A total of 540 test specimens from untreated and heat-treated wood were prepared at three different temperature and relative humidity for each type of wood, 10 at each examination level (Figure 1).

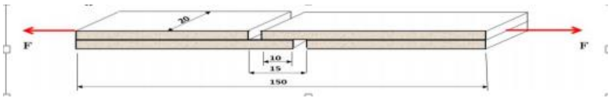

Figure 1. Test sample

The test samples were adhered with the Purbond Company product polyurethane adhesive (1K PUR) HSB 309. 220 gr/m2 glue was applied on the wooden surface, 0,8 N/mm2 pressure was applied and kept under pressure (press) for 120 minutes. Since the heat treatment reduces the moisture content of the wood and requires a minimum 8% moisture content in curing of 1K PUR glue, some water was sprayed on the wood surface before gluing [17]. Test samples were prepared and kept for one week under three different holding conditions (A1, A4, A5) given in Table 1.

In Table 1, the numbers of the samples made of untreated and heat treated wood, the holding environments and the test application climate conditions are given. Three groups of samples were separated at each level in order to meet the holding conditions and achieve moisture balance in different climatic conditions. After these samples were kept in different environments for a week, shear test was applied in Universal Test Machine according to BS EN 205 (2003) standard. The density values of the test samples were determined according to TS 2472 (1976). Thus, the adhesion performance was determined for each holding and climatic condition for each wood type.

3. RESULTS AND DISCUSSION

Table 2 shows the equilibrium moisture values of unprocessed and heat treated pine and oak samples, density values under gluing and test conditions, and oven dry density values. According to Table 2, the density and equilibrium moisture content values of the heat-treated samples in both wood types decreased compared to the untreated samples.

The decrease in density may be due to a decrease in moisture content and degradation of hemcelluloses, the most thermally sensitive polymer of wood components [18,19,20]. Equilibrium moisture content of all heat treated samples decreased compared to untreated samples. The decreases in equilibrium humidity can be explained by the decrease of OH groups after heat treatment and / or the splitting of chains and material losses [21]. Similar results showing that heat-treated wood produces a decrease in equilibrium moisture values [22,23].

In general, heat treatment appears to reduce the adhesion performance in both types of wood. The adhesion strength of heat treated wood can be affected by various factors such as the pH of the wood and its equilibrium moisture value. Heat treatment causes a decrease in the pH and equilibrium humidity of the wood [24,25]. Changes in the pH value of the wood surface may delay or accelerate the curing of adhesives, depending on the type of adhesive used for Bonding [26]. Equilibrium moisture of heat-treated wood is used as an indicator of a change in hygroscopicity [27]. This can change the distribution of the adhesive on the wood surface and the penetration of the adhesive into the porous wood structure [26]. Humphrey and Ren (1989) examined the effects of temperature and equilibrium moisture content of wood on adhesion strength [28]. He reports that low equilibrium humidity values significantly delay the resin bonding performance. A series of studies have shown that the shear strength of wood is negatively affected by heat treatment temperature and processing time [29, 27, 24, 30, 31]. The adhesion strength, wood rupture and elongation values of the test samples after A1, A4 and A5 holding conditions are shown in Tables 3, 4 and 5, respectively (Figure 2).

After the A1 retention conditions, the wood rupture values of both types of wood samples tested were found to be close to each other in the range of 70% to 100%. In addition, it has been found that heat treatment increases the brittleness of the wood. After the A4 and A5 holding conditions, the rate of wood breaking and elongation decreased (Tables 4, 5 and Figure3,4,5). Chow (1971), examining the shear strength properties of PF-bonded spruce [Picea glauca (Moench) Voss] coatings, found that there was a decrease in bond strength and a higher rate of wood failure as temperature and processing time increased [32]. Kariz and Sernek (2010) reported that the more severe the heat treatment, the lower the shear strength and wood failure [33].

According to Tables 3 to 5, between the gluing conditions (preparation of test samples) and the test conditions, the difference in wood moisture content had a significant effect on the bond strength. As the moisture content decreases in the samples, compressive stress occurs from the size reduction. Otherwise, mechanical stress and deterioration occur with increased humidity. Due to this situation, the change in moisture content negatively affects the adhesion strength. Both types of wood and changes in each different bonding and testing climatic conditions depend on the moisture content of the wood and the change in the bonding performance (resistance) of the glue layer. This reduction has been reported to be greater in untreated wood samples compared to wood heat-treated using the least squares method [17]. While there was a decrease of approximately 0,48 N/mm2 in the adhesion strength of untreated wood specimens corresponding to a 1% increase in moisture content, the adhesion resistance of heat-treated wood specimens decreased by 0,12 N/mm2 [5].

Generally, wooden products are produced in climatic conditions of 20°C and 65% relative humidity. Therefore, samples that were unprocessed and heat treated under these conditions (20/65) were prepared after weathering conditions and tested by holding them under A1, A4 and A5 holding conditions to determine the adhesion performance values. According to these values (in Figure 2b), the adhesion performance of the untreated samples of each tree species tested under 20/35 climatic conditions has decreased. (Figure 2a shows the increase in internal stress due to the decrease in moisture content). This value increased again in the heat treated sample (especially at 1c with A5 holding conditions and 20/95 climatic conditions).

4. RECOMMENDATIONS

In this study, it was found that small change (differences) in humidity during gluing (sample preparation) climatic conditions (gc.) And test climatic conditions (tc.) Were effective (Altunok et al.2012; Hering 2011). This reduced the bond strength due to the difference in moisture and its effect on the shear stress of the wood. Due to the heat treatment of the glue layer, the bonding strength of A1-normal material components has decreased [5,34, 35, 36, 10, 11]. The adhesion strength values of heat-treated wood samples obtained under A5 holding conditions were slightly higher than the untreated samples. It can be said that this is due to the fact that heat treated samples with less swelling show lower stress on the glue layer of heat treated samples [5,37,38].

Consequently, the advantages of heat treated wood are that it can be used in humid conditions; however, the study determined that under different conditions the bond resistance will depend on the properties of the glue.

DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

YAZARLARIN KATKILARI (AUTHORS' CONTRIBUTIONS)

Mustafa ALTUNOK: Performed the experiments and analyses the results and wrote the manuscript.

ÇIKAR ÇATIŞMASI (CONFLICT OF INTEREST)

Bu çalışmada herhangi bir çıkar çatışması yoktur. / There is no conflict of interest in this study.

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