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Screw and Nail-Holding Capacities of Combi Plywood Produced From Eucalyptus, Beech and Poplar Veneer

Okaliptüs, Kayın ve Kavak Kaplamalarından Üretilmiş Kombi Kontrplağın Vida ve Çivi Tutma Kapasiteleri

Bekir Cihad BAL[1*], *Hasan ORHAN*[2], *Tuncay BOSTAN*[2]

[1]Kahramanmaraş Sütçü İmam University, Vocational School of Technical Sciences, Kahramanmaraş/Turkey
[2]Kahramanmaraş Sütçü İmam University, Graduate School of Natural and Applied Sciences, Kahramanmaraş/Turkey

*Corresponding Author:Bekir Cihad BAL, bcbal@ksu.edu.tr

ÖZET

Kombinasyon kontrplak farklı ağaç türlerinden soyulmuş iki ya da daha fazla kaplama levhasından oluşur. Kombinasyon kontrplak, düşük ağırlık, düşük maliyet, yeterli performans ve bol hammadde mevcudiyeti gibi bazı avantajlara sahiptir. Bu çalışmada, beş tabakalı kombinasyon kontrplak panelleri, üre formaldehit tutkalı ile okaliptüs, kayın ve kavak soyma kaplamaları kullanılarak üretilmiştir. Üç farklı kontrplak grubu üretilmiştir ve bu kontrplakların vida ve çivi tutma dirençleri araştırılmıştır. Ayrıca, üretilen kontrplak panellerinin rutubetleri ve hava kurusu yoğunlukları da belirlenmiştir. Test sonuçları, SPSS programı kullanılarak analiz edilmiştir. Elde edilen verilere göre, en yüksek vida ve çivi tutma kapasitesi kayın ve okaliptüs kaplamalarından üretilen kontrplaktan elde dilmiştir. Ayrıca, yoğunluk ile çivi-vida tutma kapasitesi arasında güçlü bir ilişki olduğu belirlenmiştir.

Anahtar Kelimeler: Vida tutma direnci, çivi tutma direnci, kombinasyon kontrplak

ABSTRACT

Combi plywood (combination plywood) consists of plywood made of two or more veneer sheets peeled from different species of wood. Combi plywood has some advantages such as its low weight, low cost, satisfactory performance, and the availability of abundant raw materials. In this study, five-ply combi plywood panels were produced from eucalyptus, beech, and poplar using urea formaldehyde adhesive to combine rotary-peeled veneer sheets. Three plywood groups were produced, and we investigated the screw withdrawal and nail holding capacity of the combi plywood. In addition, we determined the air-dried density and equilibrium moisture content of the plywood panels that were produced. The test results were analyzed using the SPSS software program. According to obtained data, the highest screw and nail holding capacity were obtained from plywood produced from beech and eucalyptus veneers. In addition, it was determined that there was a strong relationship between nail-screw holding capacity and density.

Keywords: Screw holding capacity, nail holding capacity, combi plywood

1. INTRODUCTION

Plywood is the one of the engineered wood-composite materials, and it is used in many different areas. There are two classes of plywood, i.e., 1) construction and industrial plywood and 2) hardwood and decorative plywood (Youngquist 1999). Construction plywood is used in wooden buildings, film-faced plywood is used in forming concrete, and decorative plywood is used in furniture and decorations. Plywood also is used as a component in other engineered wood products and systems in applications, such as prefabricated I-joists, box beams, stressed-skin panels, and panelized roofs. Construction plywood panels are produced from veneer sheets that are made from soft woods, such as fir, pine, and hemlock. Decorative plywood is made from many hardwood tree species (Stark et al., 2010).

Some properties of the wood used in veneer production affect the physical and mechanical properties of plywood. For example, as the density of the wood increases, the mechanical properties (Bal et al., 2013) and thickness swelling (Bal and Bektaş 2013) of plywood also increase. In addition, as the density increases, surface roughness (Aydın 2004) and bonding performance increase. In addition, the density of the wood changes from the pith to the bark and from the base of the tree to its crown (Bal et al., 2011; Bal et al., 2012; Bal and Bektaş 2012). Therefore, there are some differences among veneer sheets produced from the same tree trunk. The differences are evident in the fast-growing tree species. Especially, some fast-growing tree species such as *Eucalyptus* supps., have broad juvenile wood (Bao et al., 2001; Bal 2012). Fast-growing tree species are used extensively for the production of wood-based composite products, such as plywood, particleboard, and fiberboard.

Some fasteners, such as nails, screws, and bolts, are used for connecting plywood and some structural composite lumbers to each other in wooden constructions. It is well known that different plywood panels, which were produced from different wood species, have different fastener holding capacities. Combination plywood (combi plywood) consists of plywood made of two or more veneer sheets peeled from different species of wood. Combi plywood has some advantages, such as low weight, low cost, satisfactory performance, and the availability of abundant raw materials. In some previous studies, the physical and mechanical properties of combi plywood produced from poplar, beech, and okume veneers were addressed (Biblis 1965; Örs et al., 2002). But, to the best of the author's knowledge, there is no study about the fastener-holding capacity of combi plywood produced from eucalyptus, beech, and poplar veneer sheets. Therefore, in this study, five-ply combi plywood panels were produced from eucalyptus, beech, and poplar veneer sheets. Three plywood groups were produced with different combinations, and we investigated the screw holding capacity and nail holding capacity of the combi plywood.

2. MATERIAL AND METHODS

Eucalyptus (*Eucalyptus grandis* W. Hill ex Maiden), poplar (*Populus x euramericana* I-214), and beech (*Fagus orientalis* L.) logs were used to produce veneer sheets in a plywood factory. Beech and poplar logs were obtained from the Yenice-Karabük region, and eucalyptus logs were obtained from the Karabucak-Tarsus region. Rotary-peeled veneers (3 mm thick) were obtained from the logs and dried until the moisture content was 7±1%. The veneers were used to manufacture plywood using UF adhesives. The percentage of solid content in the UF adhesive was 52±1%. The UF adhesive consisted of a mixture of 100 units of adhesive, 30 units of wheat flour, and 10 units of hardener that had a concentration of 15% $(NH_4)_2SO_4$. The temperature of the press was 110 ºC.

Five-ply plywood panels were produced. Three different types were set up using veneer sheets. Group I had two beech veneers on the surfaces, and three eucalyptus veneer sheets as the inner parts. Group II had two beech veneers on the surfaces, and three poplar veneer sheets as the inner parts. Group III had two eucalyptus veneers on the surfaces, and three poplar veneer sheets as the inner parts. The press pressures for Group I, Group II, and Group III were 12, 8, and 8 kg/cm^2, respectively.

Table 1. The combinations of Combi plywoods

Layers	Group I	Group II	Group III
Layer I	Beech veneer	Beech veneer	Eucalyptus veneer
Layer II	Eucalyptus veneer	Poplar veneer	Poplar veneer
Layer III	Eucalyptus veneer	Poplar veneer	Poplar veneer
Layer IV	Eucalyptus veneer	Poplar veneer	Poplar veneer
Layer V	Beech veneer	Beech veneer	Eucalyptus veneer

The adhesives were spread manually on the loose side of the veneers with a gluing machine, such that the adhesive coverage was approximately 200 g/m^2. After gluing, five veneer sheets with a nominal size of 600 x 600 x 3 mm (length x width x thickness) were positioned with the fiber directions perpendicular to each other. These panels were pressed in a hot press in the laboratory. The panels were stored for a week after pressing. Then, 30-mm edges of the panels were trimmed off. Thereafter, test samples were prepared from these boards. The same number of test samples was cut from the boards so that homogeneous groups were set up.

The air-dried density (D), the moisture content (R), and the screw and nail holding capacity were determined according to TS EN 323; TS EN 322; and TS EN 13446, respectively. The screw and nail holding capacity were determined according to following formula (1);

$$f = F_{max} / d \times l_p \tag{1}$$

Where, *f* is the holding capacity (N/mm^2), F_{max} is the maximum force at the end of test (N), *d* is the diameter of the screw or nail, *lp* is the screw length entering samples.

Fifteen test samples were prepared for each group. The dimensions of the samples were 14 x 50 x 50 mm (thickness x width x length). The test samples were stored in climatic chamber at 20 °C and 65% relative humidity. Ring nails were used for the tests. The screws and nails were fixed to the test samples manually, and they protruded from the samples. The dimensions of the screws were 4 x 50 mm. The dimensions of the nails were 2.6 x 60 mm. The test speed was 4 m/min. Fig. 1 shows test machines with which the tests were conducted. The data were evaluated with One-way ANOVA ($\alpha = 0.05$) using the SPSS statistical software program, and significant differences were determined by Tukey HSD (Honestly Significant Difference) multiple comparison test.

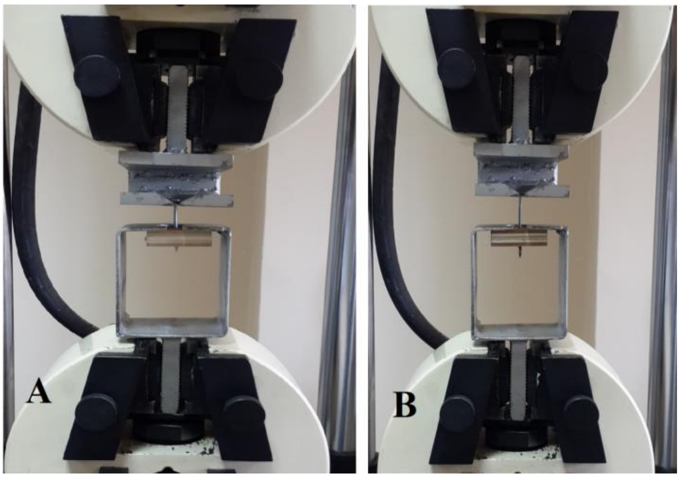

Fig. 1. Holding capacity tests: (A) screw; (B) nail

3. RESULTS and DISCUSSION

Table 2 provides the air-dried density, equilibrium moisture content, and the holding capacity of the screw and nail tests. When the data in Table 1 were analyzed, it was determined that the densities of the samples in group I, group II, and group III were 0.663, 0.543, and 0.510 g/cm^3, respectively. The differences among the groups were statistically significant ($p < 0.001$). The greatest density was obtained for group I, and the lowest density was obtained for group III. These results were expected, because the density of the plywood is affected by the species of trees used. In general, the density of softwood plywood is less than that of hardwood plywood. The denser the wood of a tree is, the denser the plywood made from it will be (Özen 1981; Çolak et al., 2003). In addition, some additives and filler materials affect the density of plywood. In previous studies, several researchers determined and reported this situation (Özen 1981; Örs et al., 2002; Çolak et al., 2003). Density is the one of most important properties of plywood. The greater the density of a panel is, the greater its mechanical properties are (Bal et al., 2013; Özen 1981). In addition, the durability of the bonding performance of veneer sheets increases as the density increases (Özen 1981; Örs et al., 2002; Çolak et al., 2004; Bal et al., 2013).

The moisture content of the plywood panels was between 10.5 and 10.8%. There were no significant differences between the groups ($p > 0.05$). No group reached the moisture content percentage of 12%. It can be said that the reason of this is the hysteresis phenomena and filling the gaps on the veneer surfaces with adhesive. In previous studies, it was demonstrated that the equilibrium moisture content of the veneer-based panels bonded with UF, such as plywood and LVL, cannot reach 12% at the temperature of 20 °C and 65% relative humidity (Özen 1981; Çolak et al., 2004; Bal and Bektaş 2013). Moisture content affects the mechanical properties of the plywood panels, and they are inversely proportional, i.e., the mechanical properties of the panels decrease as their moisture content increases. In some previous studies, the effects of moisture content on the mechanical properties of plywood were reported (Wu 1999; Aydın et al., 2006).

Table 2. Density, moisture content, and holding capacity of the screw and nail test samples

		Group I			Group II			Group III		
		D	MC	HC	D	MC	HC	D	MC	HC
		g/cm^3	%	N/mm^2	g/cm^3	%	N/mm^2	g/cm^3	%	N/mm^2
Screw tests	x	0.663A	10.8	47.8A	0.543B	10.6	35.1B	0.510C	10.7	31.2C
	ss	0.044	0.2	6.6	0.021	0.2	2.3	0.029	0.4	2.2
Nail tests	x	0.661A	10.7	22.2A	0.544B	10.5	17.8B	0.513C	10.5	15.3C
	ss	0.042	0.2	1.8	0.024	0.4	1.1	0.032	0.5	2.0

D: density, MC: moisture content, HC: holding capacity, x: arithmetic means, ss: standard deviation, capital letter indicates significant difference by Tukey mean separation test.

The screw holding capacity results of groups I, II, and III were 48, 35, and 31 N/mm^2, respectively, whereas the nail holding capacity results were 22, 18, and 15 N/mm^2, respectively. The differences for two tests between the groups were statistically significant ($p < 0.001$). The greatest results were obtained from group I (beech-eucalyptus-beech combination). For these results, it can be said that, as the density of the plywood panel increased, the screw and nail holding capacity increased. It is well-known that the fastener holding capacities of solid wood and wood-based panels are affected by the density of the wood. Concerning this issue, many researchers have reported the effects of the density and moisture content of the plywood in previous studies. For example, Winistorfer and Soltis (1995) determined the effects of some factors, such as screw type, density, and moisture content, on the withdrawal strength, and they reported that these factors had significant effects on the withdrawal strength. In addition, Wu (1999) reported that tree species and moisture content have a significant effect on the withdrawal strength of plywood. Erdil et al. (2002) also determined the effects of density and the pilot hole on the withdrawal strength of plywood and oriented strand board. Also, similar results were obtained from wood-based panels other than plywood. For example, Wang et al. (2007) determined the effects of localized density on the fastener holding capacity of particleboard, oriented strand board, and medium density fiber board. As a result, they reported that density affected the fastener holding capacity of the boards, especially in particle board and oriented strand board. Similarly, Herzog et al. (2006) reported some of the factors that affect nail holding capacity.

The relationship between screw holding capacity and plywood density is given in Fig. 2. The relationship between nail holding capacity and density is given in Fig. 3. Both relationships were strong and positive. The coefficients of determinations (R^2) were 0.90 and 0.75, respectively. It was inferred from the data that the holding capacity of the panel increased as the density of the panel increased.

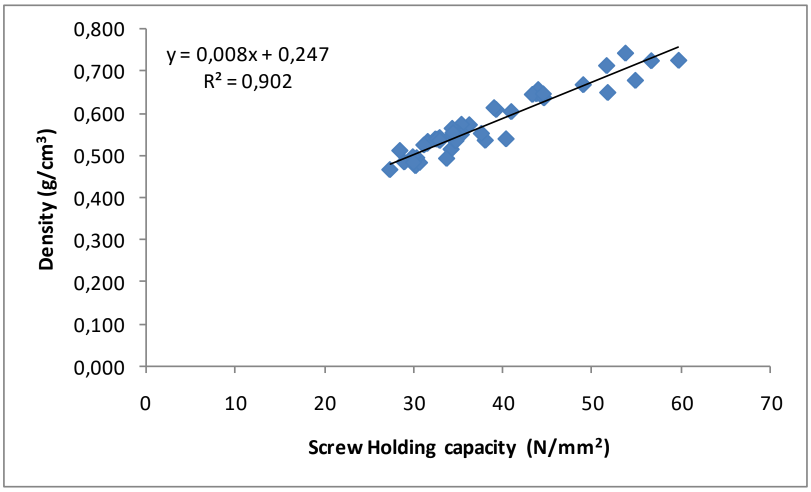

Fig. 2. The relationship between screw holding capacity and density

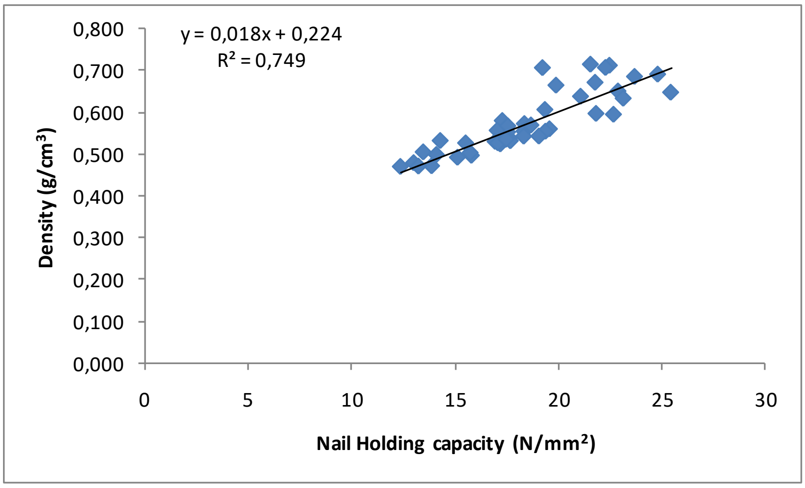

Fig. 3. The relationship between screw holding capacity and density

4. CONCLUSIONS

In this study, five-ply combi plywood panels were produced from eucalyptus, beech, and poplar. Three plywood groups were produced with different combinations, and we investigated the screw and nail holding capacity of the combi plywood. According to the data that were obtained, the following results can be inferred: the screw holding capacity of all combi plywood groups was greater than that of ring nail holding capacity. The greatest holding capacity was obtained for group I. In addition, the relationship between density and withdrawal strength was strong and positive. It is recommended that eucalyptus veneers can be used for the production of combi plywood.

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