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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

The Effect of Press Parameters on the Physical and Mechanical Properties of Cement-Bonded Particleboards Produced from Veneer Wastes

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Abstract: This study aims to investigate the effect of press temperature and time changes on the physical and mechanical properties of cement-bonded particleboards produced by using poplar veneer waste (*Populus tremula* L.). In this study, single-layer cement-bonded particleboards with a target density of 1200 kg/m^3 and a size of 500 x 500 x 10 mm^3 were produced with five different pressing parameters. The physical (moisture content, density, water absorption, and thickness swelling) and mechanical (modulus of rupture, modulus of elasticity, internal bond strength, and screw withdrawal strength) properties of the boards were investigated. According to the results, the changes in press time and temperature did not cause a significant change in water absorption values, while the increase in the pressing time reduced the thickness swelling. While the mechanical properties increased with the increase in pressing time, suitable values for the standard were obtained in all board groups. In addition, it was also determined that the most suitable time for production was 24 hours, and the temperature application did not have a significant effect on the board properties.

Keywords: Cement bonded particleboards, veneer wastes, press parameters, physico-mechanical properties.

Kaplama Atıklarından Üretilen Çimentolu Yongalevhaların Fiziksel ve Mekanik Özelliklerine Pres Parametrelerinin Etkisi

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Öz: Bu çalışmanın amacı, kavak kaplama atıkları (*Populus tremula* L.) kullanılarak üretilen çimentolu yongalevhaların fiziksel ve mekanik özelliklerine pres sıcaklık ve süre değişiminin etkisinin araştırılmasıdır. Bu çalışmada, 5 farklı presleme parametresi kullanılarak 1200 kg/m^3 hedef yoğunluğa ve 500 x 500 x 10 mm^3 boyutlarına sahip tek tabakalı çimentolu yongalevhalar üretilmiştir. Üretilen levhaların fiziksel (rutubet içeriği, yoğunluk, su alma ve kalınlık artımı) ve mekanik (eğilme direnci, eğilmede elastikiyet modülü, yüzeye dik çekme direnci ve vida tutma direnci) özellikleri incelenmiştir. Elde edilen sonuçlara göre, pres süresi ve sıcaklıktaki değişimler su alma değerlerinde önemli bir değişikliğe neden olmazken, presleme süresindeki artış kalınlık artımı değerlerinin azalmasına sebep olmuştur. Pres süresinin artmasıyla mekanik özellikler artarken, tüm levha gruplarında standarda uygun değerler elde edilmiştir. Ayrıca üretim için en uygun sürenin 24 saat olduğu ve sıcaklık uygulamasının levha özellikleri üzerinde önemli bir etkisinin olmadığı belirlenmiştir.

Anahtar kelimeler: Çimentolu yongalevhalar, kaplama atıkları, pres parametreleri, fiziko-mekanik özellikler.

INTRODUCTION

Wood-cement composites, which have been used in the building industry as a construction material for more than 60 years, generally consist of wood raw material (particle, lignocellulosic material, saw or planer waste), portland cement, and hardening chemicals (Okino et al., 2004).

Wood-cement composites have many uses such as floor slabs, fence posts, railway sound barriers, laboratory benches, corrugated roofing material, heat-resistant wall and floor material, prefabricated house construction, and exterior cladding. They are highly resistant to biological pests such as rot, insects, and termites. Their usage areas are gradually expanding due to their fire resistance, thermal insulation, and acoustic performance (Fan et al., 2004; Tittelein et al., 2012; Aras et al., 2019). In addition, cement-bonded particleboards are increasingly gaining popularity with their advantages such as high mechanical strength (Fan et al., 2006), resistance to outdoor weather conditions (Tabarsa et al., 2011), high fire resistance (Pedieu et al., 2012), and low cost (Nazerian & Sadeghiipana, 2013) started to find wider usage areas (Hou et al., 2022).

Directing waste from landfills to reuse, recycling or recovery is important in terms of providing new commercial opportunities for the country as well as making a significant contribution to economic development (Godfrey et al., 2019). Environmental sustainability is an indicator of agricultural development and seeks a way to develop projects that reduce the harmful effects of overconsumption of natural resources. All wastes produced by industry and agriculture must be handled correctly to avoid for environment consequences (Arruda Filho et al., 2012). The use of these resources encourages system improvements, such as the elimination of waste, increasing resource efficiency, and achieving a more sustainable economy, environment, and societal balance (Kristensen & Mosgaard 2020). In this respect, reusing the waste generated in the production of wood-based composite products instead of using them as fuel will provide an important added value. Various studies, such as the use of particleboard-fiberboard waste (Qi et al., 2006; Yel et al., 2022), lignocellulosic wastes (Jarobo et al., 2013; Odeyemi et al., 2020; Aras et al., 2022) and industrial waste in the production of cement-bonded particleboard (CBPB) (Naghizadeh et al., 2011; Yel et al., 2017) have been carried out and it has been determined that these materials may have an important raw material potential to produce cement-bonded particleboard (CBPB).

Incompatibility between wood and cement is the main problem in the production of CBPB. Here, the amount and the chemical composition of wood in the production of CBPB are decisive. The soluble chemicals in the wood prevent the hydration of the cement and cause lower mechanical resistance properties (Zhengtian & Moslemi, 1985). Therefore, this incompatibility does not allow the use of all types of wood in the production of CBPBs. Species with low sugar content such as poplar, spruce, and birch are preferred in production due to their high compatibility and high physico-mechanical properties for this purpose (Okino et al., 2005; Papadopoulos, 2007). Other important factors affecting technological properties in CBPB production are chip size and geometry, chip orientation, wood/cement ratio, water/cement ratio, and hardener addition (Frybort et al., 2008). However, there are not many studies on pressing parameters in CBPB production.

The study aims to evaluate the effects of pressing time and press temperature on the mechanical and physical properties of cement-bonded particleboards that are produced from poplar veneer wastes.

MATERIAL AND METHOD

Poplar (*Populus tremula* L.) veneer wastes were used in the production of trial boards. CEM II/B-M (P-LL) 32.5 R Portland cement used in the production of the boards was supplied from Aşkale Cement Co. $CaCl_2$ (calcium chloride) (TEKKİM Chemistry) with 10% solids content was used as hardener.

Veneer wastes were chipped in a knife ring chipper consisting of 6 hammers and 16 knives. In the sieving of the particles, a 4-stage sieve with circular horizontal movement was used.1.5-3 mm sized particles were used in the production and single-layer production was carried out. Primarily, poplar particles with a moisture content of 12% were wetted with some of the water to be used and the humidity of the particles reached approximately 30%. After this process, cement was added, and mixing was continued. In order to improve the compatibility between cement and wood raw materials during board production, $CaCl_2$ was added to the mixture at a rate of 5% by weight of cement. The remaining water was added to the mixture last. The target specific gravity was taken as 1.2 gr/cm^3. The cement/wood ratio was determined as 3. A wooden forming mold with the size of 500 mm x 500 mm was used in the production of the board. After the homogeneous laying process, the pressing process was carried out. A total of ten boards were produced, two of each board type. The boards, which were conditioned for 30 days at 20 °C and 65% relative humidity, were prepared according to the sample sizes to be used for the tests.

Moisture content (EN 322), density (EN 323), water absorption (ASTM D1037), thickness swelling (EN 317), modulus of rupture (EN 310), modulus of elasticity (EN 310), internal bond strength (EN 319), and screw withdrawal strength (EN 320) values were determined. The results were assessed in accordance with EN 634-2 (2009). ANOVA analysis was performed on the produced boards using IBM SPSS 20.0 software. DUNCAN homogeneity test was performed to determine the significance ($p<0.05$) between the board groups. The board production plan is given in Table 1.

Table 1. Board groups and production plan.

Board types	Hot press time (h)	Cold press tim (h)	Total press time (h)	Other production parameters
A	4	-	4	Water/cement ratio: 0.61
B	8	-	8	Board size: 500 x 500 x 10 mm^3
C	12	-	12	Wood/cement ratio: 1/3
D	-	24	24	Board density: 1.2 g/cm^3
E	8	16	24	Hot press temperature: 60 °C
				Cold press temperature: 20 °C

RESULTS AND DISCUSSION

Physical Properties: The effects of press parameters on the physical properties of the boards are determined and the results are given in Figure 1. In addition, the statistical analysis results of the physical tests are given in Table 2.

The moisture content values of the boards were found to be between 11.42% and 14.06%. In EN 634-1 (1999), standard moisture content values are given between 6-12%. Moisture content values were slightly higher in boards with 4 and 8 hours of pressing time than the standard limit values. The low pressing time (4 and 8 hours) may have caused the boards not to be compacted sufficiently. This may have facilitated the boards to absorb moisture. While the density values of the boards were between 1.22-1.27 gr/cm^3, values close to the target density were obtained. The highest density values were found in D-type boards, and the lowest in A-type boards. The occurrence of springback in the boards can be attributed to the removal of the pressure before sufficient strength was reached. This may have resulted in a reduced contact area between the cement and wood particles, which may have contributed to the observed deviations in board density.

When the 2 hours water absorption values of the boards are examined, there was a decrease in the amount of water absorption when the pressing time was used for 12 hours or more, while there was no significant difference in the 24 hours water absorption values ($p<0.05$). Since the boards, pressed for 12 hours or more, maintained their compact structure, the number and size of voids in these boards were less, compared to those in the boards pressed for 4 and 8 hours. Therefore, this may be the reason for the low water absorption values of these boards. With the increase in pressing time, the boards' dimensional stability properties improved. The lowest values were obtained from the D type-board group which was cold-pressed for 24h (1.4%). According to EN 634-2 (2007), the maximum amount of water absorption values is given as 1.5% for CBPB. While the values in accordance with the standard were obtained in the board group that was cold pressed for 24 hours, the low pressing time negatively affected the dimensional stability. With the increase of the water soaking time, the water absorption and thickness swelling values increased.

Yel et al., (2020) produced CBPB using different wood species (poplar and spruce) and press temperatures (20 ℃ - 80 ℃). The results showed that the press temperature significantly affected the board properties depending on the wood species.

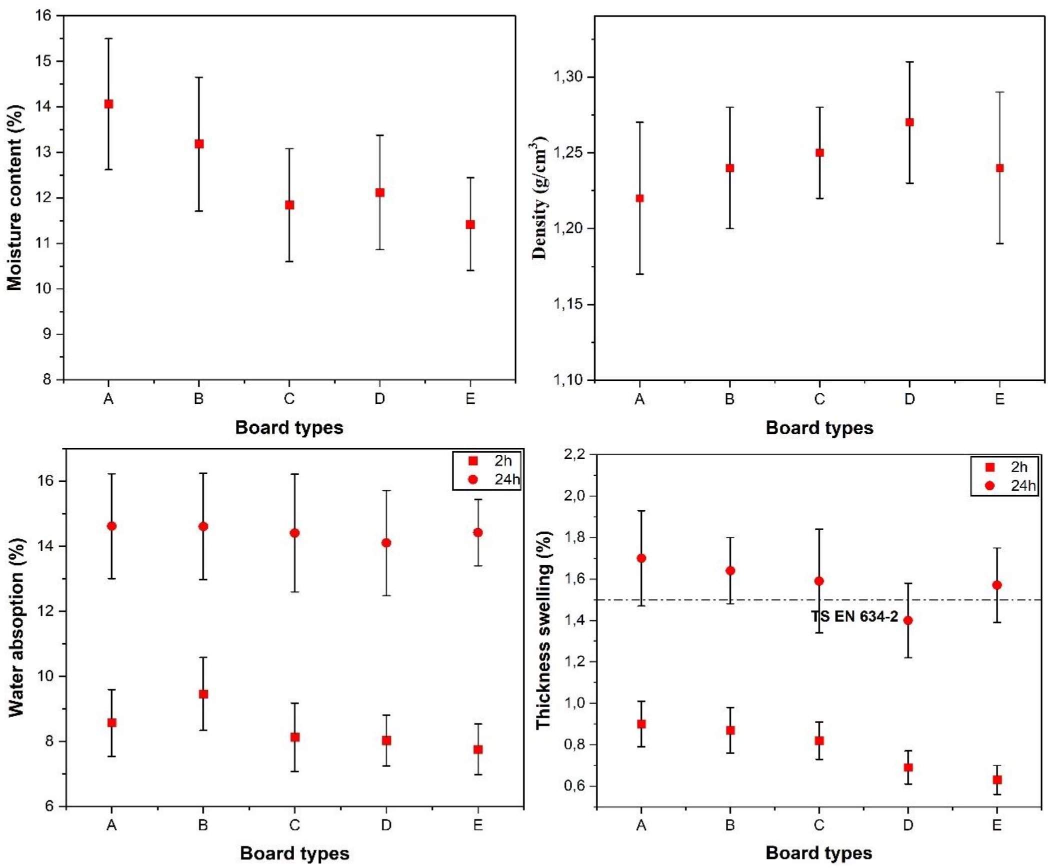

Figure 1. The effect of pressing time and temperature on the physical properties of CBPBs.

Another study by Rana et al., (2020) on the physical and mechanical properties of jute stick cement bonded-composites cold-pressed at the different pressing durations of 4, 6, 8, 12, and 16 hours indicated that, with the increase of press time, the density values increased while the water absorption and thickness swelling values decreased. Moreover, they reported that the addition of chemical hardeners ($CaCl_2$ and $MgCl_2$) to the cement-bonded composites reduced the press time.

Mechanical Properties: The effects of press parameters on the mechanical properties of the boards are determined and the results are given in Figure 2. In addition, the statistical analysis results of the mechanical tests are given in Table 2.

The lowest values for modulus of rupture and modulus of elasticity were obtained from the A type-board group that was hot-pressed for 8 hours (10.35 N/mm^2 and 5050 N/mm^2). The highest modulus of rupture and modulus of elasticity values were obtained from the board groups with a cold-pressing time of 24 hours (13.36 N/mm^2 and 6541 N/mm^2) ($p<0.05$). The increment in press time enhanced the flexural strength values of the boards. Similar results with our funding were found by Rana et al., (2020). According to EN 634-2 (2007), the required modulus of rupture and modulus of elasticity values for CBPBs are given as 9 N/mm^2 and 4500 N/mm^2, respectively.

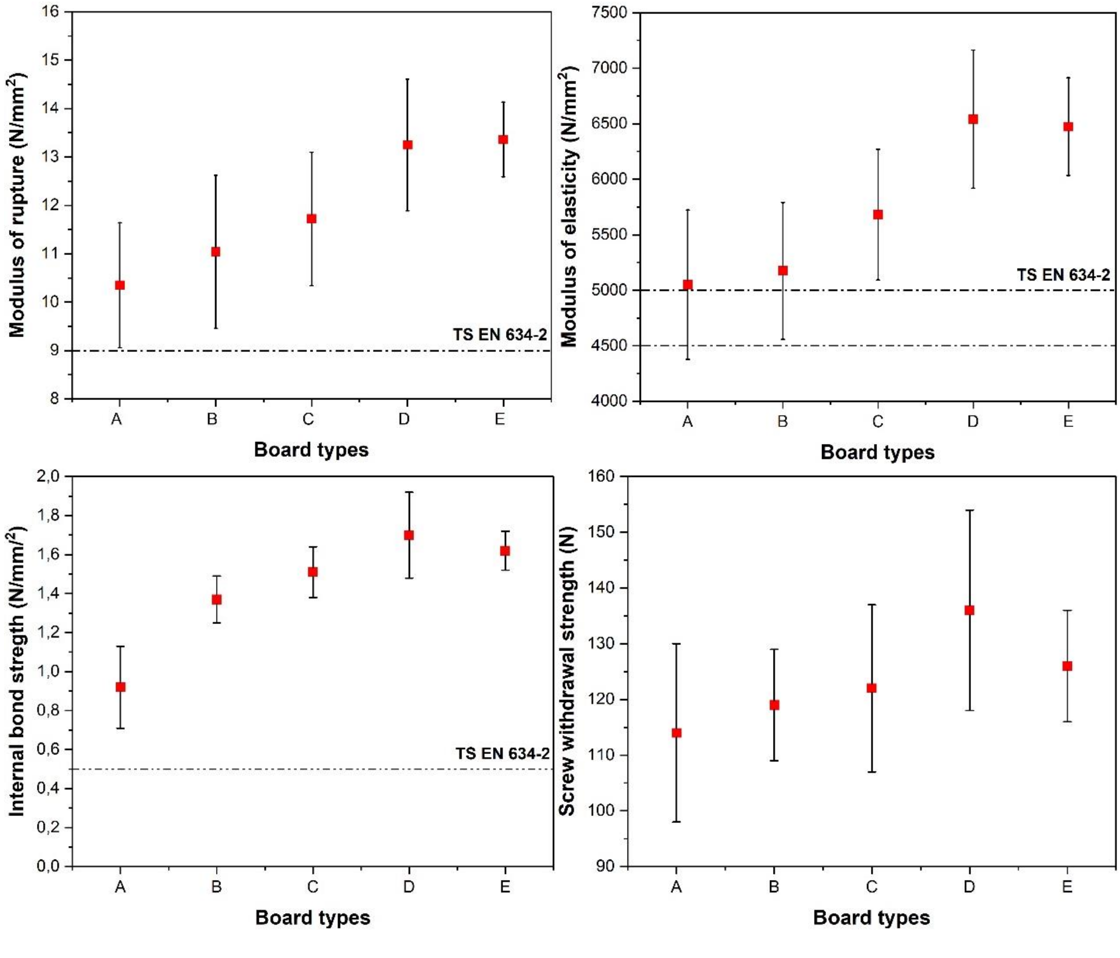

Figure 2. The effect of pressing time and temperature on the mechanical properties of CBPBs.

All board groups meet EN 634-2 (2007) standard values. The internal bond strength values of the boards were found between 0.92-1.70 N/mm^2. The standard minimum internal bond strength values, which are 0.5 N/mm^2 and are established in EN 634-2 (2007), have been met by all board groups. The internal bond strength values increased with the increase of the pressing time. In addition, it was determined that the hot press process did not have a significant effect on the internal bond strength values of the board groups with a pressing time of 24 hours ($p<0.05$). The screw withdrawal strength values of the boards were found to be between 114-136 N. The highest values were obtained from the board groups obtained as a result of cold pressing for 24 hours and the lowest screw withdrawal strength values were found in the A type-board group that was hot pressed for 4 hours. Ashori et al., (2012) investigated the effect of press temperatures of 25 °C and 60 °C on the properties of cement-bonded particleboards and reported the boards produced at low press temperatures had higher mechanical properties than the boards made at high press temperatures. Del Menezzi et al., (2007) stated that cement-bonded particleboards pressed at room temperature had sufficient strength properties.

Table 2. ANOVA and DUNCAN analysis results on the effect of press time and temperature on the properties of the boards.

Test	A	B	C	D	E	P**
Density	k*	k	k	k	k	0.284
Moisture content	k	kl	m	lm	m	0.0001
Thickness swelling (24h)	k	k	kl	l	kl	0.047
Water absorption (24h)	k	k	k	k	k	0.956
Modulus of rupture	m	lm	l	k	k	0.0001
Modulus of elasticity	l	lm	l	k	k	0.0001
Internal bond strength	n	l	lm	k	kl	0.0001
Screw withdrawal capacity	l	l	kl	k	kl	0.028

*The letters refer to the homogeneity groups (k: The highest arithmetic mean, m: The lowest arithmetic mean); ***p*-value: Significant level.

CONCLUSION

This study investigated the effects of press temperature and duration on the physical and mechanical properties of cement-bonded particleboards produced at 1/3 wood-cement ratio and 1,2 gr/cm^3 using poplar veneer wastes. According to the test results, the following conclusions can be drawn;

- The increase in press time considerably improved the mechanical and physical properties of boards.
- A heat application of 60 °C had no significant effect on the boards' properties compared to the cold-pressing application (20 °C).
- Application of low pressing time (4 and 8 hours) caused the boards to have more moisture content (above the standard limit) and lower density than that in the boards produced at the high pressing times (12 and 24 hours).
- Since the boards pressed for 12 hours or more, maintained their compact structure, the number and size of voids in these boards were less, compared to those in the boards pressed for 4 and 8 hours. Therefore, this may be the reason for the low water absorption values of these boards.
- The low pressing time (4 and 8 hours) may have led to the boards not being compacted sufficiently. This made it easier for the boards to swell to their thickness and absorb moisture and water.
- The boards, which were cold pressed for 24 hours, yielded the best mechanical and dimensional stability properties. This may differ depending on the tree species.
- The low pressing time decreased in the contact area between cement and wood particles and the springback in the boards. This may be the reason for the low mechanical properties of the boards.
- The mechanical properties of all the board groups satisfied the limit values specified in EN 634-2 (2007) standard. Therefore, the boards produced in this study are suitable for use as construction materials.

Future studies are needed to determine the effects of press conditions on the technological properties of cement-bonded particleboard produced using different factors such as wood/cement ratios, types and ratios of hardener, wood species, and cement types.

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