

Effect of Cement and Accelerator Types on the Physico-Mechanical Properties of Cement-Bonded Particleboards^[*]

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Abstract: In this study, it is aimed to determine the effect of the use of different types cement and accelerator on the physico-mechanical properties of cement-bonded particleboards. Within this scope, two types of cements (calcium aluminate cement and Super white CEM I 52.5 R) and accelerators (aluminum sulfate and calcium chloride) were used in the production of boards. Therefore, CBPBs with 1200 kg/m³ target density and 1/2.75 wood-cement ratio were produced. Based on cement weight 1.5% accelerators were used. The test results obtained were evaluated according to EN 634-2 (2009). According to result, density values of the boards were changed with using depending on cement and accelerator types. The use of super white cement and calcium chloride positively affected the both mechanical properties and dimensional stability of the boards. The use of calcium aluminate cement and aluminum sulfate resulted in lower strength properties.

Keywords: Cement-bonded particleboard, cement types, accelerator, physico-mechanical properties.

Çimento ve Priz Hızlandırıcı Tipinin Çimentolu Yongalevhaların Fiziksel ve Mekanik Özellikleri Üzerine Etkisi

Öz: Bu çalışmada farklı tip çimento ve priz hızlandırıcı kullanımının çimentolu yongalevhaların fiziksel ve mekanik özellikleri üzerine etkisi araştırılmıştır. Bu kapsamda yobgalevhaların üretiminde iki tip çimento (kalsiyum alüminat çimento ve Süper beyaz CEM I 52.5 R) ve priz hızlandırıcı (alüminyum sülfat ve kalsiyum klorür) kullanılmıştır. Üretilen levhaların hedef yoğunluğu 1200 kg/m³ ve odun-çimento oranı 1/2.75'dir. Çimento ağırlığına göre %1.5 priz hızlandırıcı kullanılmıştır. Elde edilen test sonuçları EN 634-2 (2009)'a göre değerlendirilmiştir. Elde edilen sonuçlara göre levhaların yoğunluğu çimento ve priz hızlandırıcı türüne göre farklılık göstermiştir. Süper beyaz çimento ve kalsiyum klorür kullanımı, levhaların hem mekanik özelliklerini hem de boyutsal stabilitesini olumlu yönde etkilemiştir Kalsiyum alüminat çimento ve alüminyum sülfat kullanımı, daha düşük direnç özellikleri ile sonuçlanmıştır.

Anahtar sözcükler: Çimentolu yongalevhalar, Çimento türü, Priz hızlandırıcı, fiziksel ve mekanik özellikler.

INTRODUCTION

Wood composites are products obtained by combining wood (fiber, particle or particle) with other materials (plastics, synthetic fibers, glue, fillers, cement etc.) under temperature and pressure (Moloney, 1993). Nowadays, the decline of forest areas and the increase in wood prices, as well as the development of the chemical and adhesive industry, have evolved in wood composite materials (Ayrılmış et al., 2012).

Cement-Bonded Particleboards (CBPBs) are much more resistant to fire, fungi and insects, as well as strong resistance to outdoor weather conditions, sound and heat insulation and wood composites are advantageous both in terms of production line and binder cost. They are advantageous both in terms of production line and binder cost. Moreover, the ability of the cement to self-harden makes the production process more economical. Because simple machines can be used during the production phase and high temperature pressing is not required. Cement is also a much cheaper binder than adhesives. Therefore, the use of wood-cement composites is increasing (Tittlein et al., 2012).

Depending on the developments in concrete technology, high-performance concretes (HPC), which are superior in terms of strength and durability, are currently being developed from concrete produced from traditional portland cement (NSC) (Khaliq & Khan, 2015). The calcium aluminate cement (CAC) is composed of calcium oxide and alumina oxides. It has applications not only in infrastructure works such as sewerage networks but also in hydraulic dams where wear resistance is required at the same time. It is also a used as refractory material in kilns and steel industry (Karadeniz et al., 2007). The studies have shown that concretes produced with CAC are resistant to aggressive environmental conditions and corrosion (Scrivener et al., 1999). While the super white cement (SWC) gives a very high early strength compared to the gray cement with the superior strength characteristic. Stabilization value allows the production of stabilized products. In addition, the Product provides advantages in cement dosage as less cement is used to achieve the same target strength values. Super white cement is highly resistant to alkaline-silica reactions and has a long service life (Web-1, 2018)

Compatibility in wood-cement composites can be expressed as the hardening level of the cement after mixing water and a certain amount of wood with cement. It is stated that when the cement is mixed with the wood, it is compatible if there is no restriction in cement hardening, otherwise it is incompatible. The extractive substances and sugars in the wood delay the cement hydration and cause the crystal structures to change (Jorge et al., 2004). So the accelerators are used in wood-cement composites to reduce the adverse effect of wood on the cement hydration reaction. The studies have shown that different types of accelerators

are significantly effective on hydration heat changes and technological properties of cementitious wood composites (Semple et al., 2000; Soriano et al., 2000; Yel, 2014).

Therefore, the main goal of this work was to find out the possibility of using calcium aluminate and super white cement for making cement-bonded particleboards. In addition, the effects of accelerator types on some mechanical and physical properties of boards produced have been investigated.

MATERIAL and METHODS

Materials: The particles obtained from the poplar woods (*Populus Tremula L.*) were used in production of the boards. It was supplied as sawmill wastes by Trabzon Organized Industrial Zone, Turkey. ISIDAÇ 40 (calcium aluminate cement) and Super White CEM I 52.5 R cements used in the production were supplied by Çimsa Cement Industry and Trade Co., Turkey. The chemical properties of the CAC and SWC are given in Table 1.

Table 1. Chemical properties of the CAC and SWC.

Chemical properties (%)	CAC	SWC
SiO ₂	3,60	21,6
Al ₂ O ₃	39,80	4,05
Fe ₂ O ₃	17,05	0,26
CaO	36,20	65,7
MgO	0,65	1,30
SO ₃	0,04	3,30
Loss of ignition	0,30	3,20
Na ₂ O	0,16	0,30
Chloride (Cl-)	0,009	0,01

Methods: Firstly, sawmill wastes chipped using a drum chipper before grinded into smaller particles in a knife ring flaker. Then the wood particles were classified using a laboratory type-vibrating screen. The particle size used in production is 0.5-3 mm. The wood-cement ratios were 1/2.75 based on the oven dry weight for the single layer CBPB manufacture. Solid Aluminum sulphate (Al₂(SO₄)₃), calcium chloride(CaCl₂) was prepared 25% solution and the mixture was added. 1.5% used on both accelerator types based on the cement weight. Hand formed mats were compressed in a laboratory type hot press using a pressure of 18-20 kg/cm³ for 4hrs. The press temperature is 60 °C. The amount of water used in production is determined according to the following formula (Simatumpang, 1979),

$$\text{Water (liter)} = 0.35C + (0.30 - MC)W \quad (1)$$

where C is the cement weight (kg), MC is moisture content (oven dry basis) of wood particles, and W is oven dry wood particle weight (kg).

The dimensions of the CBPBs were 42,5 x 42,5 x 1 cm. The target density was 1200 g/cm³. Two panels were made for each group. After pressing, the particleboards were conditioned for 30 days at a temperature of 20 ± 2°C and 65 ± 5% relative humidity and then cut to obtain test samples according to the European Standards. Experimental design is given in Table 2.

Table 2. Experimental desing.

Board types	Cement types	Accelerator types
A	CAC	Al ₂ (SO ₄) ₃
B	CAC	CaCl ₂
C	SWC	Al ₂ (SO ₄) ₃
D	SWC	CaCl ₂

Density (D), water absorption (WA) and thickness swelling (TS), modulus of elasticity (MOE), modulus of rupture (MOR), internal bonding strength (IB) and screw withdrawal strength (WS) properties of the produced boards were determined according to EN 323, ASTM D1037, EN 317, EN 310, EN 319, EN 320, respectively. The test results obtained were evaluated according to EN 634-2 (2009). The data were analysed using SPSS 22 procedure for the analysis of variance (ANOVA) at 95% confident level ($P \leq 0.05$). Duncan test was performed to determine the difference between the groups. The general view of the CBPBs produced is given in figure 1.



Figure 1. General view of produced CBPBs.

RESULTS and USSION

Physical properties of the cement bonded particleboards are presented in figure 2. The physical properties of the plates using SWC and ABC were higher when the results were examined. It was determined that the MC of the boards produced with Al₂(SO₄)₃ was higher than those produced with CaCl₂. This may be due to the hygroscopic nature of the Al₂(SO₄)₃ and its inability to form sufficient bonds with the wood phenol groups. According to EN 634-1 (1999); the MC of the CBPB should be between 6% and 12%. MC values of all board groups conform to the standard. The D values were found particularly higher in

boards produced using SWC. It has been determined that the thicknesses of the boards are very effective on the D values. It has been found that the CAC produced boards have much more spring back than the SWC At the end of the 4 hour pressing period. Zhou & Kandem (2002) have determined that thickness changes due to spring back after pressing process. It has been found that the use of CaCl₂ in wood cement composites produced using waste railway sleepers reduced the WA values (Ashori, 2012). The maximum TS of CBPB should be 1,5% according to EN 634-2 (2009) standard. TS values of boards produced with SWC conformed to the EN standard. The dimensional stability of the boards was greatly increased with the use of SWC. The use of SWC in boards increased dimensional stability compared to CAC.

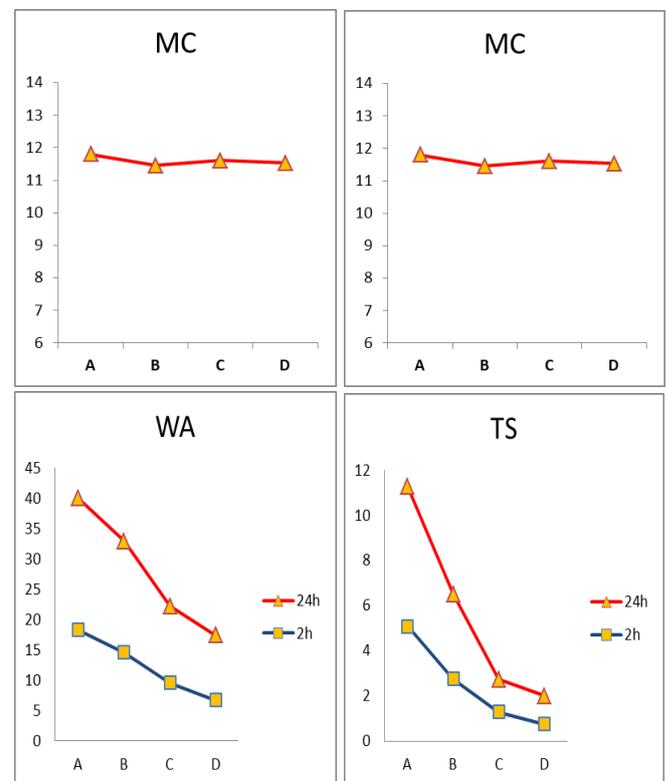


Figure 2. Properties of physical properties of the CBPBs.

Mechanical properties of the CBPBs are presented in figure 3. It was determined that the curing accelerator and cement types affected the mechanical properties of the boards. The MOR, MOE, IB and WS values of CBPB increased parallel with using CaCl₂ and SWC. The MOR and MOE values should be 9 N/mm² and 4000 N/mm² according to EN 634-2 standard. The MOR and MOE values of boards produced with SWC conformed to the EN standard. The use of SWC and CaCl₂ increased the MOR and MOE by 40% and 45%, respectively. The Al⁺³ ion in the Al₂(SO₄)₃ complexes with polyphenol groups in the wood to prevent the delay of cement hydration. However, CaCl₂ has a more inhibitory effect on polyphenols (Yousuf, 1995). Therefore, the use of CaCl₂ in the boards resulted in higher mechanical properties. The SWC provides superiority to NSC with

advantages such as aesthetics, high early strength, low alkalinity, durability and faster processing. It has been determined that the same performance is achieved even when using less than 50% of the NSC. When the dosage rate is increased, very high compressive strengths are obtained (Delibaş & Kırca, 2017).

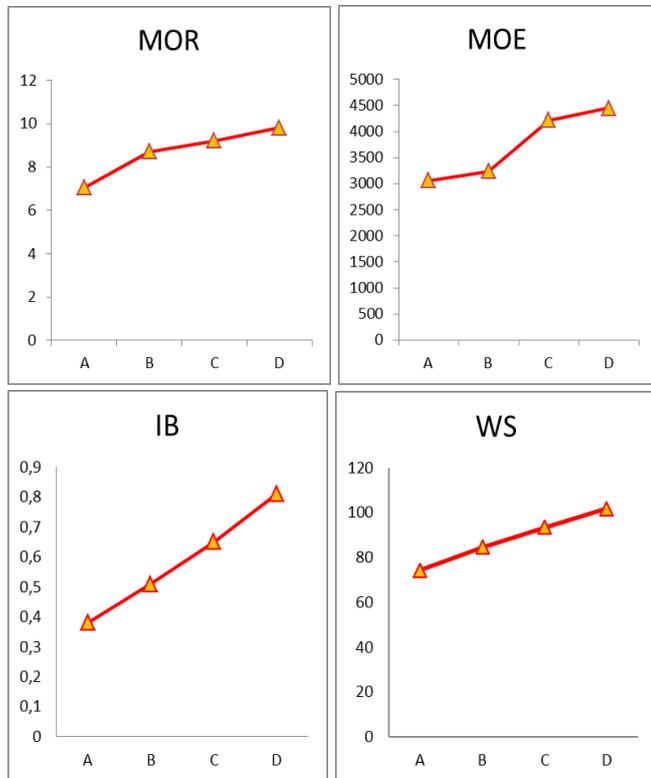


Figure 3. Properties of mechanical properties of the CBPBs.

IB values should be 0,5 N/mm² according to EN 634-2 standard. Except for A type of the panels, other groups met the required level of IB values. The WS values are highest when CaCl₂ and SWC are used. The SWC is a very hydraulically reactive linker due to the high content of C₃A and C₃S compounds in the structure. It has much higher performance than NSC due to its high reaction rate and gains earlier strength (Web-2, 2018). Cement and accelerator types have a significant effect on physical and mechanical properties based on the results of statistical analysis. The results of homogenous subsets of the board were given in Table 3.

Table 3. Homogenous subsets for physico-mechanical properties of boards.

Board types	MC	D	WA	TS	MOR	MOE	IB	WS
A	a	b	d	d	d	d	d	d
B	b	b	c	c	c	c	c	c
C	b	a	b	b	b	b	b	b
D	b	a	a	a	a	a	a	a

CONCLUSION

The effects of cement and accelerator types on the physical and mechanical properties of CBPBs were investigated. Nowadays, the use of recycled materials is of great importance due to the decreasing natural resources. It has been determined that poplar sawmill waste used for this purpose is suitable for wood cement composites. Cement and accelerator types and their interaction significantly influenced the strength of CBPBs. It has been determined that the use of CAC is not suitable for CBPB for the under current production conditions. Therefore, the pressing time can be extended to produce with CAC. In addition, the laying height of boards produced using CAC is less than on SWC. This also leads to a sufficient bond between particle and cement due to the reduction in the amount of connecting. On the contrary, SWC has been found to be very suitable for CBPB production. CaCl₂ has been more compatible with CBPBs and improved properties as an accelerator type. The use of CaCl₂ increased the compatibility of cement with wood particles (figure 1).

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