ISSN impresa 0717-3644
ISSN online 0718-221X

Maderas. Ciencia y tecnología 22(1): 83 - 92, 2020

DOI: 10.4067/S0718-221X2020005000108

EFFECT OF PRESS TEMPERATURE ON SOME PROPERTIES OF CEMENT BONDED PARTICLEBOARD

Husnu Yel[1,♠], Ayfer Donmez Cavdar[2], Sevda Boran Torun[3]

ABSTRACT

It is known that there is a correlation between hydration heat and physico-mechanical properties of wood based cement panels. Cement hydration is affected by many variables, such as chemical composition, water/cement ratio, wood/cement ratio, wood chemical properties, mineral additions and producing conditions. This study mainly aimed to investigate the effects of press temperature on some properties of three-layer cement bonded particleboard made from the particles of spruce (*Picea orientalis*) and poplar (*Populus tremula*). For this purpose, a total of 16 experimental board groups with 1200 kg/m^3 target density and 1/3 wood-cement ratio were produced at the press temperatures of (20, 30, 40, 50, 60, 70 and 80) °C. As cement curing accelerator, $CaCl_2$ was used at a rate of 5 % (cement weight basis). The physical, mechanical and thermal properties of the boards were determined. The results indicated that the press temperature substantially affected the properties of cement-bonded particleboard depending on the wood species. In the light of this study, the optimum temperatures in producing of cement-bonded particleboard were found as 40 °C for poplar wood and 60 °C for spruce wood.

Keywords: Mechanical properties, physical properties, *Picea orientalis*, *Populus tremula*, thermal properties.

INTRODUCTION

Wood based cement panels have been rapidly accepted in the construction industry due to their perfect exterior properties (Maail *et al.* 2011). These panels have been recently preferred for exterior walls, external cladding, protective elements for fireproofing, roof shingles, tiles, specialized flooring and sound insulation etc. The major advantages of the panels are their good acoustical and thermal insulating properties and high performance to resist decay, fungi, insects, moisture, fire (Fan *et al*. 2004, Tabarsa and Ashori 2011, Yel *et al*. 2011, Tittelein *et al*. 2012, Yel *et al*. 2017). According to the morphology of the wood particles used in the panel manufacture, wood cement panels are named wood wool cement boards, cement bonded fiberboard, cement bonded particleboard, and wood strand cement boards, respectively (Jorge *et al*. 2004, Kalaycioglu *et al*. 2012, Donmez Cavdar *et al*. 2017, Yel *et al.* 2017).

The compatibility indicates cement-curing degree after mixing with water and wood particle/fiber and significantly affects the strength properties of wood cement composites. Therefore, the compatibility between wood and cement is very important. The presence of wood is the most important factor because of its water-soluble extractive compounds, which can inhibit cement curing. Polysaccharides in wood extractives prevent the forming of the main hydrates ($Ca(OH)_2$ and C–S–H) of cement (Tittelein *et al.* 2012, Biblis and Lo 1968, Weatherwax and Tarkow 1964, Thomas and Birchall 1983). In the presence of sugar acids, sugars and

[1]Department of Material and Material Processing Technologies, Artvin Vocational School, Artvin Coruh University, Artvin, Turkey.
[2]Department of Interior Architecture, Faculty of Architecture, Karadeniz Technical University, Trabzon, Turkey.
[3]Department of Woodworking Industry Engineering, Faculty of Technology, Karadeniz Technical University, Trabzon, Turkey.
♠Corresponding author: yel33@artvin.edu.tr
Received: 23.03.2019 Accepted: 27.11.2019

lignosulfonates, cement grains are surrounded by acicular hydrates and are formed around un-hydrated cement grains, which prevent the curing of cement (Fischer *et al*. 1974, Sandermann and Kohler 1964). It is known that some methods such as mineral additives, CO_2 injection, cold-hot water and NaOH extractions are applied to reduce the incompatibility between wood and cement (Jorge *et al*. 2004). In addition to wood species, many factors such as wood-cement ratio, cement type, water-cement ratio, manufacturing conditions, mineral additions (curing accelerator types) and their mixing ratio affect the quality of wood based cement panels.

The quality of wood-based cement panels is mostly related to the maximum hydration temperature of cement during curing. Sanderman and Kohler (1964) have reported a relationship between wood-cement compatibility and cement hydration temperature. In another study, it was also concluded that direct heat treatment during the pressing process accelerated curing of cement in wood-based cement panels (Cabangon 1997). To the best of authors' knowledge, a comprehensive research has not been done about what the temperature should be and how the optimal temperature varies according to wood species during hydration reaction of wood-cement-water mixture. Therefore, the aims of this study are to investigate the effect of the press temperature applied during pressing on the properties of cement-bonded particleboards (CBPBs), to determine the optimal press temperature for producing these boards and if the optimum temperature value has changed according to the wood species.

MATERIALS AND METHODS

Poplar (*Populus tremula* L.) and spruce (*Picea orientalis* (L.) Link.) samples were obtained from Trabzon Sozenler Forest Products Co., Turkey. The commercial ordinary Portland cement, CEM II B-M (P-LL) 32,5 R type, used as binder, was supplied by Askale Cement Co. in Turkey. Calcium chloride ($CaCl_2$) was bought in solid form from Merck Chemicals Ltd.

Sawmill residues were firstly chipped in a laboratory-type hammer mill and then refined into fine particles for manufacturing three-layer particleboard in a knife-ring chipping machine. Afterwards, all the particles were sieved with a vibrating horizontal screen to generate surface and core layers particles. The particles, which passed through the 3 mm sieve and retained on 1,5 mm sieve, were used for core layer, while the particles, which passed through the 1,5 mm sieve and retained on 0,5 mm sieve, were used for surface layers. The core/surface layers ratio was 65/35 for each board group. The wood/cement ratio, based on the oven dry weight, was selected as 1/3 for producing the three-layer CBPBs. Calcium chloride ($CaCl_2$) was used as an accelerator to reduce the incompatibility between wood and cement. The accelerator ratio was chosen according to Yel *et al*. (2010). They reported that optimum $CaCl_2$ content was 5 percent based on cement weight for CBPBs. The amount of distilled water was calculated by Equation 1 below, developed by Simatupang (1979).

$$Water\ (liter) = 0,35C + (0,30 - MC)W \qquad (1)$$

Where

C= cement weight (kg)

MC= wood moisture content (oven dry basis)

W = oven-dry wood weight (kg).

The experimental design is given in Table 1.

Table 1: Experimental design of the production of CBPBs.

ID	Wood Species	Press Temp. (°C)	ID	Wood Species	Press Temp. (°C)
P2	Poplar	20	S2	Spruce	20
P3	Poplar	30	S3	Spruce	30
P4	Poplar	40	S4	Spruce	40
P5	Poplar	50	S5	Spruce	50
P6	Poplar	60	S6	Spruce	60
P7	Poplar	70	S7	Spruce	70
P8	Poplar	80	S8	Spruce	80

The mixture of wood/cement/water was hand formed inside a wooden mold. Afterwards, the hand-formed panel was removed from the wooden mold and compressed in a hot press under a pressure of (18-20) kg/cm^2 for 24 hrs. In the first 8 h of pressing, 8 different temperatures for each group were applied (Table 1) and then the pressing continued for 16 h at ambient temperature. Three replicates were made at a dimension of 45 cm x 45 cm x 1 cm and a target density of 1200 kg/m^3 for each board type. In order to complete the cement hydration, the boards were conditioned at 20 °C and 65 % RH for one month and then the test samples were prepared, based on the principles specified in the European Standards.

The density BS EN 323 (BSI 1993), moisture content ASTM D1037-12 (ASTM 2012), water absorption BS EN 322 (BSI 1993), thickness swelling BS EN 317 (BSI 1993), bending properties BS EN 310 (BSI 1993), internal bonding strength BS EN 319 (BSI 1993) and screw withdrawal strength BS EN 320 (BSI 1993) for CBPB samples were determined by the given standards. Ten samples were tested for each type of board.

TGA/DTA analyses were performed by means of a simultaneous DTA-TGA thermal analyzer apparatus (Shimadzu DTG-60, Japan) under nitrogen atmosphere at a rate of 10 °C/min from (30 to 900) °C.

Mechanical test results of all the CBPBs were evaluated statistically with One Way ANOVA and Duncan's mean separation test by using SPSS 21.0 (IBM 2018).

RESULTS AND DISCUSSION

Mechanical properties

The bending properties of the boards are given in Figure 1. Letters in Figure 1 represent Duncan's mean separation test results. According to the variance analysis test-One Way ANOVA, wood species and press temperatures affected substantially all tested mechanical properties of CBPBs (p values: 99 %).

Modulus of rupture (MOR) and modulus of elasticity (MOE) values depending on the press temperature and wood species ranged from 2,72 MPa to 11,96 MPa and 2093 MPa to 5627 MPa, respectively. The highest MOR and MOE values were recorded by board type of P4 produced with poplar particles at 40 °C press temperature while the boards produced with spruce particles at 60 °C had highest MOR and MOE values. However, over 60 °C, a sharp decrease in the bending properties of the CBPBs was observed. All the groups excluding P7, P8, S7 and S8 produced at 70 °C and 80 °C met the minimum MOR (9 MPa) and MOE (class 1: 4500 MPa and class 2: 4000 MPa) requirements stated in BS EN 634-2 (BSI 1997). It was shown that the press temperatures above 60 °C led to a significant decrease in the MOR and MOE values of the boards made from both spruce and poplar.

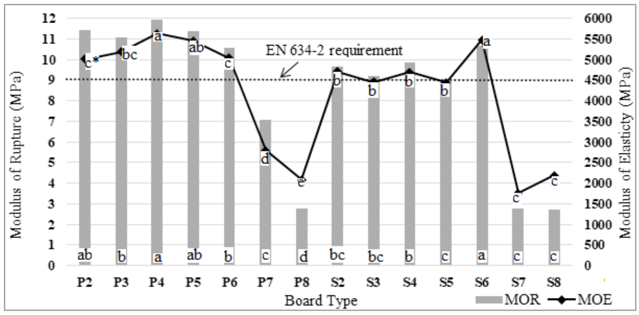

Figure 1: Effect of press temperature on the bending properties of the CBPBs.

*Groups with same letters signify that there is no statistical difference (p < 0,001) between the board types based on Duncan's multiply range test.

The poplar boards had generally higher MOR and MOE values than the spruce boards because poplar had higher pH values (6,32) than spruce (5,03) (Yel 2015). The hydration reaction of the cement is carried out in alkaline environment (pH: 12,5) and wood with low pH value may negatively affect the cement board properties (Hachmi and Moslemi 1990). For this reason, the pH of poplar wood is more suitable than that of spruce wood for manufacturing cement bonded particleboards.

The wood extractives induce a complexity with the metal ions in the cement solution, causing the reduction of Ca^{2+} concentration in the cement, and disrupting the stability of the solution. This inhibits the formation of $Ca(OH)_2$ and C-S-H gel which are hydration products of cement (Janusa *et al*. 2000), and leads to a significant decrease in the properties of CBPBs. This caused a decrease in MOR and MOE of the boards produced at 70 °C and 80 °C because the amount of soluble substances, which inhibit the hydration of cement, in wood increases with an increase in press temperature and alkali environment.

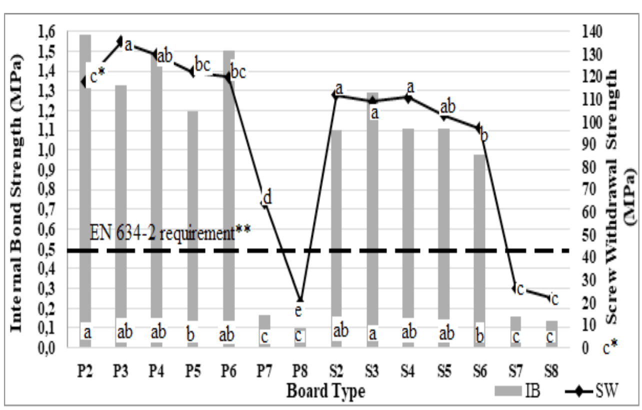

Figure 2: Effect of press temperature on internal bond (IB) and screw withdrawal (SW) strength of the CBPBs.

*Groups with same letter are not statistically different (p < 0,001) based on Duncan's multiply range test. **The standard value is only for internal bond strength.

Figure 2 shows the results of internal bond strength (IB) and screw withdrawal strength (SW) of the CBPBs and their homogeneity groups. IB and SW values of the samples were within the range of (0,1 to 1,58) MPa and (20 to 135) MPa, respectively. The highest IB values were found in the P2 group of poplar boards and

S3 group of spruce boards, while the highest SW values were found in the P3 group of poplar boards and S2 group of spruce boards. The results were supported by other researchers. Ashori *et al.* (2012a) evaluated press temperatures of 25 °C and 60 °C on wood-based cement panels. They found that the mechanical properties of the samples decreased with an increase in the press temperature. Del Menezzi *et al.* (2007) and Ashori *et al.* (2012b) reported that the manufacturing of wood cement boards was successful when pressing at room temperature. The lowest IB and SW values were found in the groups produced at 70 °C and 80 °C. All the groups excluding the board groups (P7, P8, S7 and S8) produced at 70 °C and 80 °C met the minimum IB strength requirements (0,5 MPa) stated in BS EN 634-2 (BSI 1997). Similar to the bending properties, the press temperatures above 60 °C leaded to a significant decrease in the IB and SW values of the samples for both spruce and poplar.

Physical properties

The densities of the CBPBs with poplar and spruce particles were about 1210 kg/m^3 and 1130 kg/m^3, respectively. The samples with poplar particles had a little higher density than those of spruce particles. This may be related to density differences between the wood species. The water absorption (WA) and thickness swelling (TS) values of the cement-bonded particleboards are given in Figure 3. The WA and TS values of the samples made with spruce were higher compared to the samples produced with poplar due to differences in their density. It is known that the WA and TS rates increase with decreasing of composite density (Ashori *et al.* 2012a).

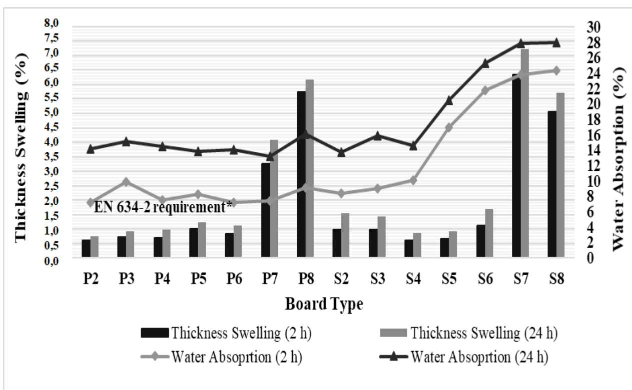

Figure 3: Water absorption and thickness swelling of the CBPBs.

*The standard value is only for thichness swelling -24h.

It was observed that the press temperature had a significant adverse effect on WA and TS of the boards above 70° C. The lowest values of WA and TS were obtained from P2 and S4 groups, while the highest values were attained from the boards produced at 70 °C and 80 °C. It was observed that the press temperatures of up to 50 °C led to an improvement in the WA and TS properties of the boards made of spruce particles.

The moisture contents (7 - 11) % of all the board groups met the requirements (6 - 12) % in BS EN 634-1 (BSI 1995). The BS EN 634-2 (BSI 1997) standard requires 1,5 % of the 24 h-maximum thickness swelling for Ordinary Portland Cement-OPC bonded particleboards. The TS values of all the board groups excluding the board groups (P7, P8, S7 and S8) produced at 70 °C and 80 °C met the TS requirements for 24 h in BS EN 634-2 (BSI 1997) standard as shown in Figure 3. This indicates that the press temperature should not exceed 60 °C in producing of the cement-bonded particleboards from both poplar and spruce.

Some substances in wood, such as hemicelluloses, starches, sugars, phenols and hydroxylated carboxylic acid, inhibit the hydration of cement (Weatherwax and Tarkow 1964). The alkaline environment in wood-cement paste arises during cement hydration and may dissolve hemicelluloses (Miller and Moslemi 1991). The increase in the press temperature and alkaline environment may have caused an increase in the solubility of the extractive substances and hemicellulose in the wood particles, which can prevent the hydration reaction of cement. The cement could not prevent water uptake of wood particles and TS of the wood particles since the boards produced at 70 °C and 80 °C had weak bonds in cement-wood and cement-cement (Ashori *et al.* 2012a).

Thermogravimetric analysis (TGA/DTG)

TGA-DTG curves of the cement-bonded particleboards made from spruce and poplar woods at different press temperatures were illustrated in Figure 4. In the figures, four endothermic peaks appeared for the cement-bonded particleboards. The first peak arose at approximately 100 °C due to the dehydration of pore water. The second peak arose at about 350 °C due to decomposition of wood components. According to Kim *et al.* (2006), wood components decompose at different temperatures; hemicellulose at (180 to 350) °C, cellulose at (275 to 350) °C and lignin at (250 to 500) °C. The third peak arose at approximately 430 °C due to the dehydration of calcium hydroxide ($Ca(OH)_2$). The last peak arose at approximately 740 °C due to decarbonation of calcium carbonate ($CaCO_3$).

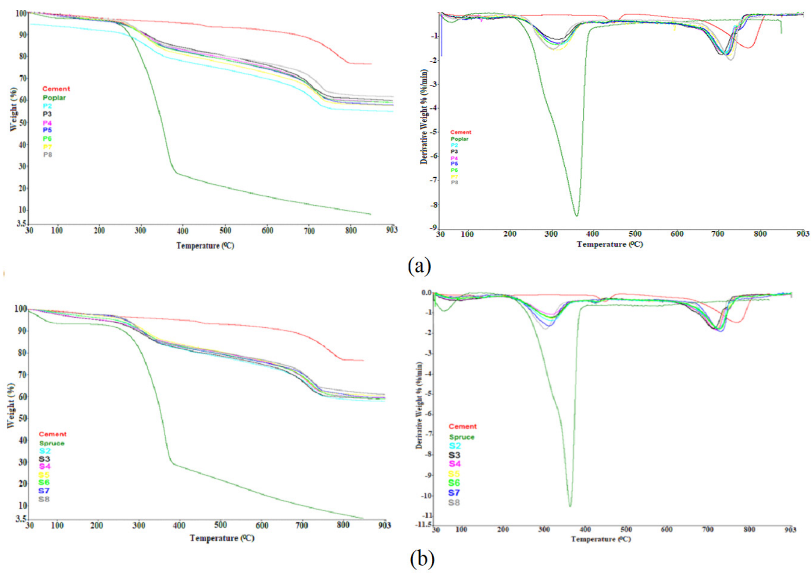

Figure 4: Thermogravimetric anlysis (TGA) / the derivative thermo-gravimetric (DTG) curves of the CBPBs produced with poplar (a) and spruce (b).

Calcium carbonate is not a hydration product as calcium hydroxide and calcium silicate hydrate. It is a result of reaction of calcium hydroxide with carbon dioxide (Shafiq and Nuruddin 2010, Cabrera and Lynsdale 1996) as shown in Equation 2.

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O \qquad (2)$$

The degree of cement hydration is calculated using the amount of calcium carbonate and calcium hydroxide detected in the TGA/DTG output (Cabrera and Lynsdale 1996). The calcium hydroxide and calcium carbonate decompose at (420 to 550) °C and (600 to 800) °C as following Equation 3 and Equation 4, respectively (Shafiq and Nuruddin 2010, Cabrera and Lynsdale 1996).

$$Ca(OH)_2 \rightarrow CaO + H_2O \tag{3}$$

$$CaCO_3 \rightarrow CaO + CO_2 \tag{4}$$

The weight losses of CBPB at four different temperature ranges were summarized in Table 2. The results indicate that the carbon dioxide reacted with calcium hydroxide to produce calcium carbonate ($CaCO_3$). The least weight losses at (420 to 550) °C and (600 to 800) °C were obtained from the board groups (P8 and S8) produced at a press temperature of 80 °C. This may be due to the fact that the wood extractives, which are more soluble at high temperatures, inhibits cement hydration. The physical and mechanical properties of the boards are compatible with the values mentioned above. It was shown that the press temperature under 60 °C improved the hydration of cement and the properties of the cement-bonded particleboards made from both spruce particles and poplar particles.

Table 2: Weight losses of the CBPBs at four different temperature ranges.

	Weight loss (%) at the temperature ranges (°C)					Weight loss (%) at the temperature ranges (°C)			
ID	0-180	180-400	420-550	600-800	ID	0-180	180-400	420-550	600-800
P2	2,45	14,31	5,80	14,05	S2	3,37	14,61	5,61	15,41
P3	2,85	13,06	5,76	14,97	S3	4,31	13,35	5,31	15,15
P4	2,87	14,16	5,77	14,98	S4	4,14	11,96	5,43	15,78
P5	3,37	14,12	5,90	15,45	S5	2,61	13,18	5,57	15,31
P6	3,13	14,66	5,52	14,76	S6	3,37	13,33	5,40	15,67
P7	2,71	14,21	5,11	14,02	S7	2,29	14,80	5,12	14,11
P8	2,55	14,01	4,74	14,01	S8	2,14	14,31	4,90	14,01

CONCLUSIONS

The study investigated the effect of press temperature on some properties of cement-bonded particleboard produced with spruce and poplar wood species. It was observed that press temperature applied during the hydration reaction of cement had a significant effect on physical and mechanical properties of cement bonded particleboards and this effect varied according to wood species. The optimal press temperature was 40 °C for the boards from poplar wood and 60 °C for the board produced from spruce to achieve the best physical and mechanical properties. In the light of obtained results, the press temperature should not exceed 60 °C because it caused serious declines in the properties of cement-bonded particleboards.

ACKNOWLEDGMENTS

The authors gratefully thank Sozenler Forest Products and Yilmazlar Sawmill Companies for supplying poplar and spruce woods.

REFERENCES

Ashori, A.; Tabarsa, T.; Amosi, F. 2012a. Evaluation of using waste timber railway sleepers in wood-cement composite materials. *Constr Build Mater* 27(1): 126-129. https://doi.org/10.1016/j.conbuildmat.2011.08.016.

Ashori, A.; Tabarsa, T.; Sepahvand, S. 2012b. Cement-bonded composite boards made from poplar strands. *Constr Build Mater* 26(1): 131-134. https://doi.org/10.1016/j.conbuildmat.2011.06.001.

ASTM. 2012. ASTM D1037-12: Standard test method for evaluating properties of wood-base fiber and particle panel materials. ASTM International, West Conshohocken, PA, USA. https://www.astm.org/Standards/D1037.htm.

Biblis, E.J.; Lo, C.F. 1968. Sugars and other wood extractives: effect on the setting of southern pine cement mixture. *Forest Prod J* 18(8): 28-34.

BSI. 1993. BS EN 310: Wood-based panels. Determination of modulus of elasticity in bending and bending strength. BSI, London, UK. https://shop.bsigroup.com/ProductDetail/?pid=000000000000299457.

BSI. 1993. BS EN 317: Particleboards and fibreboards-determination of swelling in thickness after immersion in water. BSI, London, UK. https://shop.bsigroup.com/ProductDetail/?pid=000000000000299500.

BSI. 1993. BS EN 319: Particleboards and fiberboards, determination of tensile strength perpendicular to plane of the board. BSI, London, UK. https://shop.bsigroup.com/ProductDetail?pid=000000000000299524.

BSI. 1993. BS EN 322: Wood-based panels. Determination of moisture content. BSI, London, UK. https://shop.bsigroup.com/ProductDetail/?pid=000000000000299551.

BSI. 1993. BS EN 323: Wood-based panels, Determination of density. BSI, London, UK. https://shop.bsigroup.com/ProductDetail/?pid=000000000000299563.

BSI. 1995. BS EN 634-1: Cement-bonded particleboards. Specifications - part 1: general requirements. BSI, London, UK. https://shop.bsigroup.com/ProductDetail/?pid=000000000000611493.

BSI. 1997. BS EN 634-2: Cement-bonded particleboards. Specifications - part 2: Requirements for OPC bonded particleboards for use in dry, humid and external conditions. BSI, London, UK. https://shop.bsigroup.com/ProductDetail/?pid=000000000000934407.

BSI. 1993. BS EN 320: Particleboards and fibreboards - determination of resistance to axial withdrawal of screws. BSI, London, UK. https://standards.globalspec.com/std/1389134/BS%20EN%20320.

Cabangon, R.J. 1997. Rapid curing of wood wool cement boards from yemane (*Gmelina arborea* R.Br.) by direct heat application during pressing. M.S. Thesis. University of the Philippines, Los Baños, Laguna, Philippines.

Cabrera, J.G.; Lynsdale, C.J. 1996. The effect of super-plasticisers on the hydration of normal Portland cement (in Italian). *L'industria Italiana del Cemento* 66(712): 532-541.

Del Menezzi, C.H.S.; Gomez de Castro, V.; Rabelo de Souza, M. 2007. Production and properties of a medium density wood-cement boards produced with oriented strands and silica fume. *Maderas-Cienc Tecnol* 9(2): 105-115. http://dx.doi.org/10.4067/S0718-221X2007000200001.

Donmez Cavdar, A.; Yel, H.; Boran, S.; Pesman, E. 2017. Cement type composite panels manufactured using paper mill sludge as filler. *Constr Build Mater* 142: 410-416. https://doi.org/10.1016/j.conbuildmat.2017.03.099.

Fan, M.Z.; Bonfield, P.W.; Dinwoodie, J.M.; Boxall, J.; Breese, M.C. 2004. Dimensional instability of cement-bonded particleboard: The effect of surface coating. *Cement Concrete Res* 34(7): 1189-1197. https://doi.org/10.1016/j.cemconres.2003.12.010.

Fischer, F.; Wienhaus, O.; Ryssel, M.; Olbrech, J. 1974. Die wasserlöslichen kohlenhydrate des holzes und ihr einfluss auf die herstellung von holzwolle-leichtauplatten. *Holztechnologie* 15(1): 12-19.

Hachmi, M.H.; Moslemi, A.A. 1990. Effect of wood pH and buffering capacity on wood cement compatibility. *Holzforschung* 44(6): 425-430. https://doi.org/10.1515/hfsg.1990.44.6.425.

IBM SPSS Statistics. 2018. SPSS Statistics V21.0. IBM. New York, USA. URL: https://www.ibm.com/support/pages/release-notes-ibm-spss-statistics-210.

Janusa, M.A.; Champagne, C.A.; Fanguy, J.C.; Heard, G.E.; Laine, P.L.; Landry, A.A. 2000. Solidification/stabilization of lead with the aid of bagasse as an additive to Portland cement. *Microchem J* 65(3): 255-259. https://doi.org/10.1016/S0026-265X(00)00120-X.

Jorge, F.C.; Pereira, C.; Ferreira, J.M.F. 2004. Wood-cement composites: A review. *Holz Roh Werkst* 62(5): 370-377. https://doi.org/10.1007/s00107-004-0501-2.

Kalaycioglu, H.; Yel, H.; Donmez Cavdar, A. 2012. Wood wool cement boards and its applications (in Turkish). *Kastamonu Univ Orman Fak Derg* 12(1): 122-133. https://dergipark.org.tr/tr/download/article-file/159615.

Kim, H.S.; Kim, S.; Kim, H.J.; Yang, H.S. 2006. Thermal properties of bio-flour-filled polyoefin composites with different compatibilizing agent type and content. *Thermochim Acta* 451(1-2): 181-188. https://doi.org/10.1016/j.tca.2006.09.013.

Maail, R.S.; Umemura, K.; Aizawa, H.; Kawai, S. 2011. Curing and degradation processes of cement-bonded particleboard by supercritical CO_2 treatment. *J Wood Sci* 57(4): 302-307. https://doi.org/10.1007/s10086-011-1179-9.

Miller, D.P.; Moslemi, A.A. 1991. Wood-cement composites: effect of model compounds on hydration characteristics and tensile strength. *Wood Fiber Sci* 23(4): 472-482. https://wfs.swst.org/index.php/wfs/article/view/2119.

Sandermann, W.; Kohler, R. 1964. Über eine kurze eignungsprüfung von hölzern für zementgebundene werkstoffe. *Holzforschung* 18(1-2): 53-59. https://doi.org/10.1515/hfsg.1964.18.1-2.53.

Shafiq, N.; Nuruddin, M.F. 2010. Degree of hydration of OPC and OPC/FA pastes dried in different relative humidity. *J Concr Res Lett* 1(3): 81-89. https://pdfs.semanticscholar.org/be70/a3b11316fec3751f3d9d298e5d35001ebcb5.pdf?_ga=2.41600235.856399216.1574850643-1886985546.1572353688.

Simatupang, M.H. 1979. Water requirement for the production of cement-bonded particleboard. *Eur J Wood Wood Prod* 37(10): 379-382. https://doi.org/10.1007/BF02610947.

Tabarsa, T.; Ashori, A. 2011. Dimensional stability and water uptake properties of cement-bonded wood composite. *J Polym Environ* 19(2): 518-521. https://doi.org/10.1007/s10924-011-0295-3.

Thomas, N.L.; Birchall, J.D. 1983. Retarding action of sugars on cement hydration. *Cement Concrete Res* 13(6): 830-842. https://doi.org/10.1016/0008-8846(83)90084-4.

Tittelein, P.; Cloutier, A.; Bissonnette, B. 2012. Design of a low-density wood–cement particleboard for interior wall finish. *Cement Concrete Comp* 34(2): 218-222. https://doi.org/10.1016/j.cemconcomp.2011.09.020.

Weatherwax, R.C.; Tarkow, H. 1964. Effect of wood on setting of Portland cement. *Forest Prod J* 14(12): 567-570.

Yel, H.; Kalaycioglu, H.; Donmez Cavdar A.; Oran, B. 2010. Effects of $Al_2(SO_4)_3$ and Na_2SiO_3 on some physical and mechanical properties of cement-bonded oriented strand boards with hybrid aspen (*populus euroamericana* cv.) strands., In: The 1st International Symposium on Turkish & Japanese Environment and Forestry. Vol 2: 665-677. Trabzon, Turkey.

Yel, H.; Donmez Cavdar, A.; Kalaycioglu, H. 2011. Mechanical and physical properties of cement-bonded particleboard made from tea residues and hardboards. *Key Eng Mater* 471-472: 572-577. https://doi.

org/10.4028/www.scientific.net/KEM.471-472.572.

Yel, H. 2015. Effects of some manufacturing factors on the properties of cement bonded particleboards. PhD. Dissertation. Karadeniz Technical University, Trabzon, Turkey.

Yel, H.; Kalaycioglu, H.; Aras, U. 2017. Utilization of silica fume in manufacturing of cement bonded particleboards. *Pro Ligno* 13(4): 257-263. http://www.proligno.ro/ro/articles/2017/4/YEL.pdf.