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EFFECTS OF $AI_2(SO_4)_3$ AND Na_2SiO_3 ON SOME PHYSICAL AND MECHANICAL PROPERTIES OF CEMENT-BONDED ORIENTED STRAND BOARDS WITH HYBRID ASPEN (Populus euroamericana cv.) STRANDS

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Abstract

This study aimed to determine the effects of the amount of curing accelerators ($Al_2(SO_4)_3$ and Na_2SiO_3) on physical and mechanical properties of cement bonded strandboards made from hybrid poplar strands and to reveal the optimum amount of curing accelerator. For this purpose, $Al_2(SO4)_3$ and Na_2SiO_3 were used at dosages of 3, 5 and 7 % by mass of cement. $Al_2(SO_4)_3$ /Na_2SiO_3 ratio was selected as 7/3, in accordance with the literature. Cement/wood ratio and target density were selected as 2.75/1 and 1.2g/cm3, respectively. Physical (thickness swelling, water absorption and density) and mechanical (modulu of rapture, modulus of elasticity, internal bond strength) tests of the strandboards produced were carried out in accordance with the relevant standards. The results showed that the amount of the curing accelerators significantly affected the physical and mechanical properties of cement bonded strandboards. It was determined that the optimal accelator dosage (ratio) for poplar-strand cement boards was 5% ,based on cement weigth.

Keywords: Hybrid poplar, cement bonded strandboard, curing accelerators, physical and mechanical properties

1. Introduction

Inorganic bonded composite (IBC) materials have many advantageous attributes that have led to their becoming the basis of a large and growing global industry. Some possess good insulating properties and are inherently durable in terms of resistance against termites, rot and fire- particularly attractive features for building use in tropical regions. It is of particular interest in contries where climatic environmental conditions require exremely durable products (Eusebio, 2003).

Wood-cement panels (WCPs) and their application in the building industry have been rapidly accepted in many countries as a result of their excellent properties. Compared with wood-based particleboard, in which there were conventional problems associated with urea- and phenolformaldehyde, WCPs have high fire, insect, and fungat resistance in addition to good weatherability and acoustic insulation (Moslemi, 1974; Goodell and Daniel,1997). These desirable qualities could provide a larger potential market and application field in the predictable future.

However, some problems still impede the development of wood-cement composites, including high variation in the compatibility of wood species mixed with cement due to soluble sugar and extractives (Weatherwax and Tarkow, 1964; Yoshimoto, 1978). During setting not-yet hydrated cement grains are surrounded by acicular hydrates. In the presence of sugar acids, sugars, and lignosulfonates, impermeable hydrates are formed around unhydrated cement grains, which inhibit or delay the setting of cement (Fischer et al. 1974; Sandermann and Kohler, 1964; Sandermann et al. 1960; Sauvat et al. 1999). The influence of soluble sugar and extractives in wood results in board strengths being highly sensitive to a change of wood species (Blankenhorn et al, 1994; Goodell and Daniel,1997).

Because of the unfavorable effect of water-soluble substances in wood, the addition of chemical additives is believed to be an important, uncomplicated treatment method to improve the compatibility of wood-cement-water mixtures. To deal with the inhibitory differences of wood (e.g., birch) the addition of effective chemical additives would lead to restraints on the inhibitory traits of wood and to the acquisition of good board properties based on the results of comparison and selection of set-accelerating effects in terms of the hydration reaction of the wood-cement-water mixture. Many studies have focused on understanding the inhibitory properties of wood species, the compatibility of wood when mixed with cement, and the effects of chemical additives on set-acceleration of wood species based on the results of hydration reactions of wood-cement composites. However, because WCP is used mainly for building applications, it appears logical to pay more attention to the relation between the hydration process of wood-cement-water mixtures and the strength development of board. In some studies, it was noted that a correlation existed between hydration characteristics and strength, such as compressive strength and tensile strength, of wood-cement composites (Miller and Moslemi, 1991; Blankenhorn et al,1994; Fischer et al, 1974).

The objectives of the present study were to determine the effects of the amount of an composite accelerator [$Al_2(SO_4)_3$ and Na_2SiO_3] on some properties (thickness swelling, water absorption, modules of rapture, modules of elaticity, internal bond strength) of oriented wood-cement boards (OWCB) produced from hybrid aspen strands and porthland cement.

2. Studies having been done

2.1. Materials

The addition of an accelerator is the simplest and the most used treatment for manufacturing cement-bonded board. The wood species used in this study is Hybrid aspen (Populus euroamericana cv.). The size of the aspen strands is appr. 100x10x0.5mm (LxWxT). The binder used was Type I ordinary Portland cement (OPC) while sodium silicate (Na_2SiO_3) and aluminium sulphate [$Al_2(SO_4)_3$] were used at a mixing ratio of 3/7 [Na_2SiO_3 /$Al_2(SO_4)_3$] as cement setting accelerators. The percentage of water used were 61%, based on cement weight.

2.2. Methods

Three-layed oriented wood cement boards (400 mmx400 mm), 10 mm thick, with a target density of 1.2g.cm^{-3} were produced at laboratory conditions. The upper layer and lower layer of the boards were oriented at same direction, but the core layer was laid perpandicular to the surface layers. The wood:cement ratio of all the board samples was selected as 1/2.75. In order to determine the accelator effects on cement bonded wood boards, an accelator mixing (Na_2SiO_3 /Al2(SO4)3 mixture) was used at ratios of 3, 5 and 7 %, by mass of the cement. The boards conditioned at 20±2^{o}C temp. and 65±5% rel. humidity were cut into dimensions of 250x50x10 mm for the bending test and 50x50x10mm for the internal bond strength test. Flexural properties (MOR and MOE) and Internal bond strength values of the board goups were determined by means of Instron 50kN Universal test machine, according to EN310 and EN319 standards, respectively. In order to determine some phsical properties of the boards, the boards were cut into dimensions of 50x50x10mm and the samples obtained were soaked in water at an ambient atmosphere (temp. 20^{o}C, rel. humidity 65%) for 2 and 24 hours. Water absorption and thickness swelling values of the board groups were determined, according to ASTM D1037 and EN 317, respectively.

3. Conclusion

3.1. Phsical properties

According to the tickness swelling test results, the best values were obtained from the board groups added 7% accelator mixture [Al2(SO4)3+Na2SiO3] for 2 h and the board groups added 5% accelator mixture [Al2(SO4)3+Na2SiO3] for 24 h, as shown in Tablo 1. However, there is statistically no difference between the thickness swelling values of the board groups added 5% and %7 the accelator mixtures for 24 h.

Tablo 1. Mean, standard deviation, variance coefficient values and Duncan test results of thickness swelling (%) regarding to the board groups

Board groups		Thickness Swelling Ratios (%)	
		2 h	**24 h**
Control (without accelator)	$\overline{X}$ (%)	7 **a**	10 **a**
	S	0.5	0.4
	V	7.1	4
%3 accelator $[Al_2(SO4)_3 + Na_2SiO_3]$	$\overline{X}$ (%)	5 **b**	10 **a**
	S	0.2	0.3
	V	4	3
%5 accelator $[Al_2(SO4)_3 + Na_2SiO_3]$	$\overline{X}$ (%)	5 **bc**	8 **b**
	S	0.4	0.2
	V	8	2.5
%7 accelator $[Al_2(SO4)_3 + Na_2SiO_3]$	$\overline{X}$ (%)	4 **c**	9 **b**
	S	0.1	0.2
	V	2.5	2.2

$\overline{X}$: Mean, *S:* Standard deviation, *V:* Variance coefficient

The thickness swelling values of the boards decreased with increasing accelator mixture ratio. As shown in Figure 1, the accelator positively affected the thickness swelling of the oriented wood strand cement boards for both 2h and 24h and it can be said that the best ratio of the accelator mixture is %5, based on cement weigth.

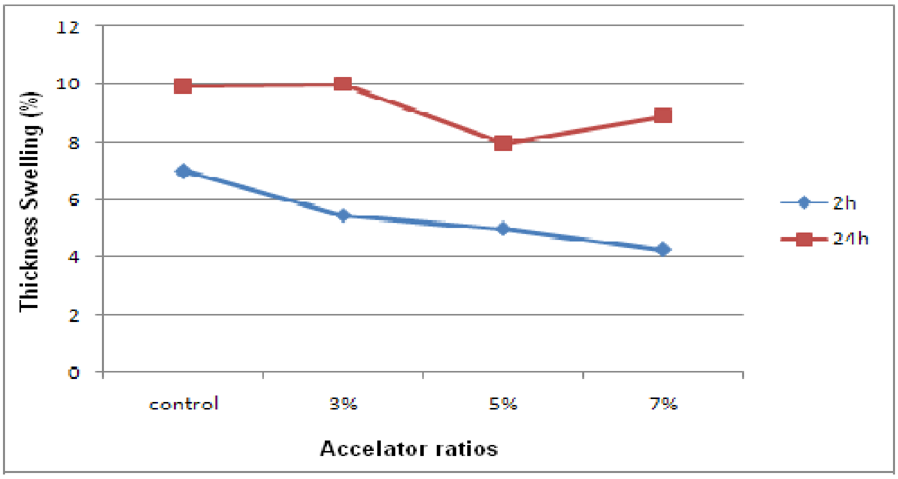

Figure 1. The effect of accelator percentage on thickness swelling of the samples soaked in water for 2h and 24h.

Tablo 2 demonstrates the mean, standard deviation, variance coefficient values and Duncan test results of water absorption regarding to the board groups. The accelator significantly decreased the water adsorption values of the boards. In contrast to the thickness swelling values, the best water adsorption values were obtained from the board groups containing 3% the accelator mixture, while the worst values were obtained from the control board groups (without the accelator mixture) for both 2h and 24h. In addition, there is statistically no difference between the board groups containing 5% and %7 the accelator mixtures for both 2h and 24h.

Tablo 2. Mean, standard deviation, variance coefficient values and Duncan test results of water absorption(%) regarding to the board groups

Board groups		**Water Absorption**	
		2 h	**24 h**
Control	$\bar{X}$ (%)	17 **a**	24 **a**
	S	1.0	1.2
	V	5.8	5
%3 accelator [$Al_2(SO4)_3$+ Na_2SiO_3]	$\bar{X}$ (%)	10 **b**	17 **b**
	S	0.4	0.4
	V	4	2.3
%5 accelator [$Al_2(SO4)_3$+ Na_2SiO_3]	$\bar{X}$ (%)	14 **c**	21 **c**
	S	0.7	0.6
	V	5	2.8
%7 accelator [$Al_2(SO4)_3$+ Na_2SiO_3]	$\bar{X}$ (%)	13 **c**	21 **c**
	S	0.3	0.5
	V	2.3	2.3

$\bar{X}$: Mean, *S:* Standard deviation, *V:* Variance coefficient

In Figure 2, it is showed that the accelator positively affected the water absorption values of the boards for both 2h and 24h. However, the accelator mixture in using more than 3% accelator did not significantly affect the water absorption for both the time periods. This means there is no need to use the accelator mixture more than 3% in order to decrease the water absorption ratio of the boards.

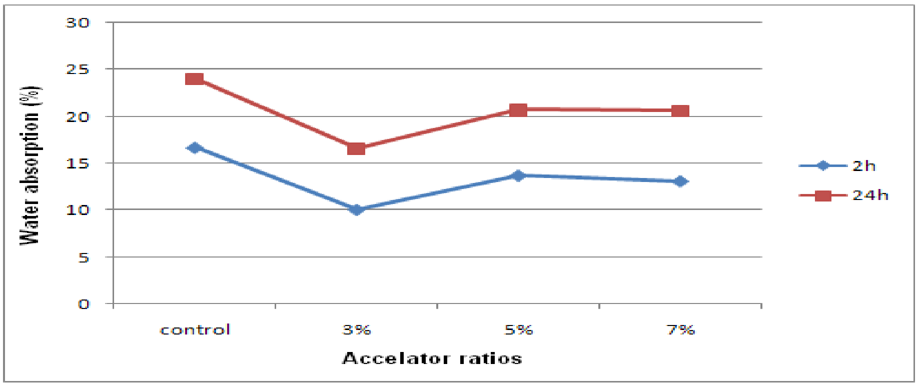

Figure 2. The effect of the accelator ratios on water absorption of the samples soaked in water for 2h and 24h.

3.2. Mechanical properties

The mechanical properties resulted in different trend from phsical properties of the boards. Tablo 3 show the mean, standard deviation, variance coefficient values and Duncan test results of MOR, MOE, IB strength regarding to the board groups.

Table 3. Mean, standard deviation, variance coefficient values and Duncan test results of MOR, MOE, IB strength regarding to the board groups

Board groups		**Mechanical Properties (N/mm²)**		
		MOR	**MOE**	**IB**
Control	$\bar{X}$	14,23 **a**	3446 **a**	0,64 **a**
	S	0,71	170	0,04
	V	4.9	4.9	5,4
%3 accelator $[Al_2(SO4)_3 + Na_2SiO_3]$	$\bar{X}$	18,64 **b**	4809 **b**	0,87 **b**
	S	0,94	267	0,03
	V	5.01	5.5	3,4
%5 accelator $[Al_2(SO4)_3 + Na_2SiO_3]$	$\bar{X}$	24,47 **c**	5957 **c**	0,88 **b**
	S	1,15	262	0,04
	V	4.6	4.4	4.1
%7 accelator $[Al_2(SO4)_3 + Na_2SiO_3]$	$\bar{X}$	9,23 **d**	1634 **d**	0,77 **b**
	S	0,38	103	0,03
	V	4.1	6.3	3.2

$\bar{X}$: Mean, *S:* Standard deviation, *V:* Variance coefficient, MOR: Modules of Rapture, MOE: Modules of Elasticity, IB: Internal Bond Strength

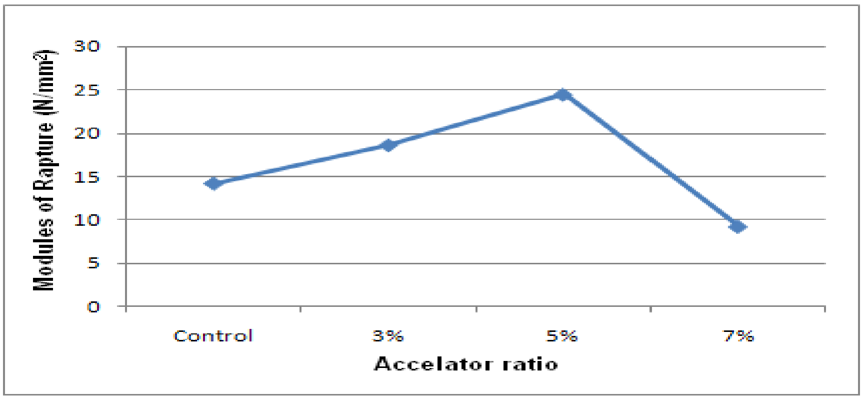

Figure 3. The effect of the accelator ratios on modules of rapture (MOR) of the wood strand cement boards.

The highest values in mechnical properties (MOR, MOE and IB strength) of the boards were obtained from the board groups containing 5% the accelator mixture [$Al_2(SO_4)_3$+ Na_2SiO_3], as shown in Table 3. The modules of rapture increased with increasing the accelator ratio till 5%.

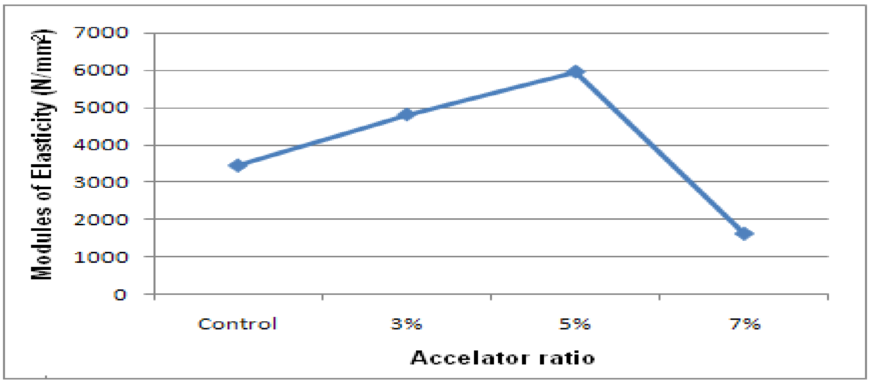

Figure 4. The effect of the accelator ratios on modules of elasticity (MOE) of the wood strand cement boards.

When used more than 5% the accelator mixture, modules of rapture of the boards sharply decreased, Figure 3. In addition, there is a statistically significant difference between all the board groups for modules of rapture.

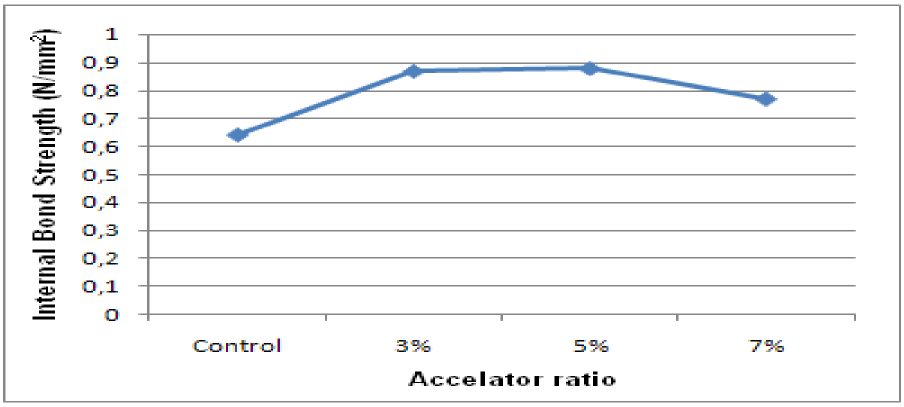

Figure 5. The effect of the accelator ratios on internal bond strength (IB) of the wood strand cement boards.

Modules of elasticity of the boards drawn similar curves to the modules of rapture, Figure 3 and 4. Modules of elasticity of the boards significantly increased until 5% the accelator ratio and then sharply decreased after 5% the accelator ratio. As in MOR, there is a statistically significant difference between all the board groups for modules of elasticity.

Internal bond strength increased with increasing the accelator ratio till 5% ratio and then decreased sligthly. However, there is statictically no significant difference between the board groups containing 3%, 5% and 7% the accelator mixture ratios.

4. Discussion

Some reports (Miller and Moslemi, 1991; Lee and Hong, 1986; Blankenhorn, 1994) noted that a correlation existed between hydration characteristics and strength, such as compressive strength and tensile strength, of wood-cement composites. The results obtained from this study are compatible with that of the studies mentioned above.

The test results showed that 7% accelator ratio did not significantly affected thickness swelling and water absorption while it decreased sharply modules of rapture and elasticity, and sligthly internal bond strength. This means that the using accelator mixture more than %5 ratio decreases mechanical properties of wood strand cement boards.

In the previous studies (Wei et al, 2000; Eusebio et al, 2000; Liu and Moslemi,1986; Moslemi et al, 1983), it was noted that kind of cement curing accelators significantly affected the properties of cemen bonded wood composites. The present study proved that amount of curing accelators, as well as kind of curing accelators, significantly affected properties of wood-cement composites.

Generally when considering the effects of the curing accelator on both mechanical and physical properties of the boards, it can be said that 5% the curing accelator additive [$Al_2(SO_4)_3$ +Na_2SiO_3] is the best accelator ratio for the hybrid aspen strand-cement boards. However, 3% the curing accelator additive [$Al_2(SO_4)_3$ +Na_2SiO_3] can be an alternative in order to decrease the product cost.

5. Proposals

Selection of curing accelator ratio as well as kind of curing accelator is very important for wood-cement composites because curing accelator ratios less or more than required negatively affect properties (especially mechanical properties) of the wood-cement composites. Optimal curing accelator ratio can vary according to wood species. Therefore, furher studies should be done for other wood species.

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