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EFFECT OF CHEMICAL ADDITIVES ON CEMENT-BONDED PARTICLE BOARDS PRODUCED WITH SAWDUST

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ABSTRACT

Effect of chemical additives (NaCl and $AlCl_3$) at concentration levels ranging from 0 – 5% on cement-bonded particle boards (CBPB) produced with sawdust from mixed species was investigated. The objective of the study was to examine the optimum chemical concentration required for better particle board production. The percentage stress loss by different boards under compression and the reversible swelling after cyclic swelling and shrinking were measured. The thickness swelling percentage (T.S %), water absorption percentage (W.A %) and modulus of rupture (MOR) for both sodium chloride – 46.44%, 41.22% and 34.73N/mm^2 - and aluminum chloride boards – 48.58%, 48.78% and 32.51N/mm^2 - were both high and comparable. The results obtained indicated that boards produced from sodium chloride (NaCl) at concentration level of 5% gave high dimensional stability of the boards produced. Therefore, the utilization of sodium chloride (NaCl) as chemical additive in the production of cement-bonded particle boards is highly recommended.

Keywords: Chemical additives; Cement-bonded particle boards; Saw dust and Modulus of rupture

INTRODUCTION

Cement-bonded particle board is a construction material with excellent qualities. As the name implies, wood sawdust is mixed with cement and in some cases chemicals at appropriate ratio that brings about improvement in the physical and mechanical properties of the board. Over the years, these reconstituted wood products have become acceptable as materials for constructing low cost housing in Nigeria. The composite boards are used for non-structural and structural applications such as partitioning, wall cladding, ceiling and roofing (Moslemi, 1989) as well as for bracing walls and flooring (EST, 2006). Among the amazing potentials of cement-bonded board in building construction are its high dimensional stability, good fire resistance and non-susceptibility to attack by fungi and insects. The high interest in the production of cement-wood board in developing countries is associated with low price of cement when compared with resin and the possibility of using wood wastes from saw mills and plywood industries as raw materials for the manufacture of value-added products. Bending strength and board stiffness improve with increase in flake length (Moslemi, 1974; Vital *et al.,* 1980). The properties exhibited by cement-bonded particle boards must be related to those of its two principal components which include the hardened cement paste and the wood.

Due to hygroscopic nature of wood, cement-bonded particle board, just like resin board, swells and shrinks both in the thickness and in the length directions of the board in response to change in moisture content. These changes in dimension of the board are considerably greater in the direction of the board thickness (thickness swelling) than the linear expansion. In comparison with the resin board, the thickness swelling of cement particle board is low, while the linear expansion of the two types of boards are almost equal (Deppe, 1974; Dinwodie, 1983). The use of sodium chloride (NaCl) and aluminium chloride ($AlCl_3$) in the production of composite board has not received much attention. Boards treated with these additives which are not harmful to human beings are good for use in households and industries. The objective of this research was to determine the effect of chemical additives - sodium chloride (NaCl) and aluminum chloride ($AlCl_3$) on the production of cement-bonded particle boards (CBPB) from sawdust mixed of tree species.

MATERIALS AND METHODS

Study Area

The study was conducted at the Forestry Research Institute of Nigeria (FRIN) Ibadan. The institute is located on Jericho hills (Latitude 7^o 22'N and Longitude 3^o 35'S). Sawdust was obtained from the Industrial Development Unit (IDU) FRIN, Ibadan. Portland cement was purchased along Magazine Road, Jericho, Ibadan while chemical additives were purchased at the Ogunpa and Dugbe markets, Ibadan.

Experimental Procedure

The sawdust was pre-treated with hot water at temperature of 80^oC for 2 hrs inside an aluminum bath to eliminate the microorganisms in the wood chips according to standard procedure (Badejo, 1989). This was then washed for 5 min and air-dried for 7 days to dissolve chemical constituents contained in the wood chips which may inhibit the setting of the binder to a minimal level.

The board produced from each treated wood raw materials emanated from the comparison of two chemical additives which are aluminium chloride and sodium chloride, at concentration levels of 0, 1, 2, 3, 4 and 5% of the cement weight in board. Each board was made at constant factors of 6mm thickness, 3:1 cement/wood ratio and board density of $1200kg/m^3$. The required quantities of sawdust and water containing $AlCl_3$ were measured into a bowl and thoroughly mixed together manually. Thereafter, the required quantity of Portland cement was added and mixed together to form cement-wood paste free of lumps. A wooden mould of 35 x $35cm^2$ was placed on a wooden tray covered with polythene sheets in order to prevent the mat from sticking to the plate and to enhance easy decoupling. The furnish was immediately hand formed inside the mould and covered with another polythene sheet while a hand presser was used to pre-press the moulded mat before it was transferred to the hydraulic press where it was cold pressed at a pressure of $1.23N/mm^2$ for 24 hrs. During the pressing time, further moisture elements in the board were drained. The boards were then removed and kept inside sealed polythene bags for further curing for 28 days. They were finally cut into sample sizes of $152cm^3$ x $152cm^3$ x $0.6cm^3$ for thickness swelling and water absorption test respectively and $172cm^3$ x $55cm^3$ x $0.6cm^3$ for MOR. Similar procedure was used to produce boards from sodium chloride (NaCl).

The treatments applied were sodium chloride (NaCl) and aluminum chloride ($AlCl_3$) at concentration levels of 0, 1, 2, 3, 4 and 5%. Aluminum chloride is represented by CWC_1 and sodium chloride by CWC_2. Three samples were produced per concentration level making three replicates for further testing.

Water Absorption Percentage Test

The initial weight of the test samples was taken before immersion horizontally in cold water at room temperature for 24 hrs. The final weights of the boards were recorded after 24 hours of soaking in water and allowed to dry. Water absorption (W.A.) was calculated using the formula:

$$\mathrm{W.A.\%} = \frac{\mathrm{W_2 - W_1}}{\mathrm{W_1}} \mathrm{X100}$$

Where,
W_1 = initial weight before soaking
W_2 = final weight after soaking

Thickness Swelling Percentage Test

The initial thickness of the boards was taken before immersion in water and the final thickness after 24 hrs of soaking as in W. A. above. These measurements were taken using vernier caliper. The samples were then dried before the final thickness swellings were observed. The thickness swelling was expressed as the percentage of the increase in thickness of the board over the initial thickness. The thickness swelling (T.S.) was calculated using the formula:

$$\mathrm{T.S.\%} = \frac{\mathrm{T_2 - T_1}}{\mathrm{T_1}} \mathrm{X100}$$

Where
T_1 = initial thickness before soaking
T_2 = final thickness after soaking

Modulus of Rupture

The modulus of rupture (MOR) is the maximum bending strength of the boards. The equipment used in carrying out this test is the Hound’s field tensiometer. The test samples were placed between the jig of the machine and the electric motor is switched on. As the jig advances forward, the mercury rises and punch is indicated on the graph sheet attached to the drum of the machine per increase in mercury level. The mercury rises until failure occurs on the test sample. The point at which the mercury stops rising and starts declining is the maximum load which the test sample can carry. MOR is calculated using the formula below:

$$MOR = \frac{3PL}{2bd^2}$$

Where

P = maximum load (N)
b = width of test specimen (mm)
d = thickness of test specimen (mm)
L = span of the board (mm)

Data Analysis

The Statistical Package Software for the Social Sciences (SPSS) was used to analyze the data obtained. Multiple comparison tests were performed to determine significant differences between sample means at 0.5% level of statistical probability.

RESULTS AND DISCUSSION

Table 1 shows the result of the influence of the chemical additives on the boards produced. The boards produced from sodium chloride (NaCl) recorded the mean values of 46.44%, 41.22%, and 34.73 N/mm^2 for thickness swelling, water absorption, and MOR, respectively. The value for water absorption was significant.

Table 1: Characteristics of boards produced as influenced by additives.

Chemical additive	Thickness swelling (%)	Water absorption (%)	MOR (N/mm^2)
NaCl	46.44	41.22	34.73
$AlCl_3$	48.58	48.78	32.51
S.E±	0.874	0.900	0.641
LSD	0.097^{ns}	0.001*	0.02^{ns}

ns = not significant (P>0.05). * = Significant (P<0.05)

On the other hand, the boards produced from aluminum chloride ($AlCl_3$) recorded the mean values of 48.58%, 48.78%, and 32.51 N/mm^2 for thickness swelling, water absorption and MOR, respectively. From the results above, it can be deduced that sodium chloride (NaCl) in comparison with aluminum chloride ($AlCl_3$) gives better results in all the desirable properties – low water absorption and thickness swelling and higher modulus of rupture, and as such can replace aluminum chloride ($AlCl_3$) with respect to the effervescence characteristics of aluminum chloride.

Table 2 shows the effects of concentration level on both physical and mechanical properties of the boards produced. The highest value of 50.52 N/mm^2 for MOR was achieved at 5% concentration level and the least value 18.97 N/mm^2 at 0%. Furthermore, the least values of 22.58% and 24.17% were recorded at concentration level 5% both for thickness swelling and water absorption, respectively while the highest value of 73.00% and 67.83% were recorded at concentration level 0% for thickness swelling and water absorption. The thickness swelling, water absorption and MOR were significantly affected by increase in concentration level. The implication of this is that the higher the concentration, the higher the MOR and the lower the thickness swelling and water absorption, respectively.

Table 2: Effects of additive concentration levels on the physical and mechanical properties of boards produced

Concentration	Thickness swelling (%)	Water absorption (%)	MOR (N/mm^2)
0	73.00	67.83	18.97
1	59.17	58.33	24.87
2	54.50	46.67	27.20
3	46.83	40.17	35.90
4	29.00	32.83	44.25
5	22.58	24.17	50.52
S.E±	1.513	1.559	1.111
LSD	0.001*	0.001*	0.001*
C.V(%)	2.8	5.3	1

* = Significant ($P<0.05$)

The study revealed that $NaCl_2$ produced boards with the lowest values of 19.33%, 20.33% for thickness swelling, water absorption, and highest value of 52.70 N/mm^2 for MOR though without significant difference. The boards produced with sodium chloride (NaCl) showed that the higher the concentration level, the higher the MOR, while at the highest concentration level boards with less thickness swelling and water absorption values were produced. There was an inverse relationship between the thickness swelling and water absorption on one hand and MOR on the other**.** Similar trend was observed with boards produced with aluminum chloride ($AlCl_3$). This result is in agreement with the findings of Ajayi and Fuwape (2005) and Fuwape and Fuwape (1995). In comparison with this work, Oyagade (1995) recorded similar trend. Clay paste yielded boards with the largest total swelling values, calcium hydroxide paste gave intermediate total swelling values compared to clay and Portland cement boards, whilst Portland cement gave the lowest values. The total swelling values were 12.67, 12.95 and 27.78% for Portland, calcium hydroxide and clay bonded boards respectively (Oyagade, 1995).

Finally, the result from the interaction between the two chemical additives (Table 3) showed that, there was no significant difference as shown in the LSD 0.217^{ns}, 0.73ns and 0.825^{ns} for T.S, W.A and MOR, respectively. The coefficient of variation (CV) showed 2.8, 6.3 and 1.3% for T.S., W.A. and MOR, respectively.

CONCLUSION

Sodium chloride (NaCl), the common table salt was found to be better than aluminum chloride ($AlCl_3$) in all the desirable characteristics – low water absorption and thickness swelling and high MOR. From the results of the investigation, boards produced using sodium chloride at concentration level of 5% brought about a high dimensional stability of the product. The utilization of sodium chloride (NaCl) as chemical additive in the production of cement bonded particle board is recommended over and above aluminum chloride ($AlCl_3$). Further investigations are recommended involving higher concentrations of this chemical additive for more effective performance of composites.

Table 3: Properties of boards produced as influenced by the interaction between types of chemical additives and concentration levels

Additive type	Thickness swelling (%)	Water absorption (%)	MOR Concentration (N/M^2)
NaCl			
0	72.67	67.00	18.97
1	58.67	56.00	25.73
2	51.00	44.00	28.13
3	48.00	34.67	37.40
4	29.00	25.33	45.43
5	19.33	20.33	52.7
$AlCl_3$			
0	73.33	68.67	18.97
1	59.67	60.67	24.00
2	58.00	49.33	26.00
3	45.00	45.67	34.40
4	29.00	40.33	43.07
5	25.83	28.00	48.33
S.E±	2.140	2.204	1.571
LSD	0.217^{ns}	0.73^{ns}	0.825^{ns}
C.V%	2.8	6.3	1.3

ns = not significant (P>0.05).

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