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Effects of Pre-Treatment Methods on Wood Cement Bonded Board of *Afzelia africana* Rxb.

Adejoba O. R*; Oriire L. T; Olanrewaju C. M and Areo O. S
Department of forest Products Development and Utilization
Forestry Research Institute of Nigeria, PMB 5054, Ibadan, Oyo State, Nigeria
*Email: dejob_j@yahoo.com

Abstract

This study investigates the influence of three methods of pre-treatments on cement bonded particle board produced from sawdust of *Afzelia africana*. The sawdusts were collected from Bodija plank market in Ibadan. The pre-treatment methods used were: 24hours soaking of sawdust particles in cold water, 1hour soaking of sawdust in hot water heated to 80^{o}C, Combination of both 24hours soaks in cold water and 1hour hot water. These treatments were done prior to the use of the sawdust for production of wood cement board. Two different chemical additives: calcium chloride ($CaCl_2$) and ferric chloride ($FeCl_3$) were added each at two different concentration levels (3% and 4%) respectively. The result obtained indicated that the mean Modulus of rupture (MOR) ranged from 4.30 to 8.75N/mm^2, Modulus of elasticity (MOE) ranged from 2160 to 2990N/mm^2, water absorption level (WA) ranged from 12.96% to 15.32% and thickness swelling ranged from 0.68% to 4.31%. Combined treatment of 24 hours cold soak and 1 hour hot water soak produced the lowest percentage thickness swelling values (0.68 to 1.14%). Stronger and more dimensionally stable cement bonded particle boards were produced from the sawdust of APA through the application of the combined pre-treatment method of 24 hours cold water and 1hour hot water compared to other two pre-treatment methods. The use of $FeCl_3$ produces board of superior grade than when $CaCl_2$ was used. Similarly better boards were also produced when these chemical additives were applied at increased level of concentration.

Keywords: Pre-treatment, cement-board particle board, additives, *Afzelia africana*

Introduction

The pollution problems created by burning and dumping of agricultural residues, together with the concern for conservation of future resources, have engendered interest in finding utilization outlets for waste generated in the country. Waste generation is closely linked to population, urbanization and affluence observed. It was observed that waste generation is connected with everyday living: it cannot be avoided (Odewumi, 2001).

In the sawmills, the yield of final product may be as low as 20% more typically around 40-50% of the logs. The proportion of residues depends on such factors as the quality of the log, state of the machine, experience and motivation of the personnel involved and the size of the logs (Borgner *et al*., 2007). Huge waste is also generated when logs are converted to veneer, match splints and plywood, when making furniture, joinery, at building construction, demolition of house, old pallets and spoilt household wooden items. The uneconomical use of wood and the increasing demand for wood products has increased logging activities at alarming rate. In many developing countries like Nigeria, large quantities of wood residues are generated on daily basis during wood processing without recourse for economic use (Olufemi *et al*., 2012).

In order to diversify and maximise the utilization of wood which is already a versatile and the most widely used raw materials, several research activities that prompted the discovery of some major wood based among other has been on course.

An area of utilization which is worth looking into in an attempt to further enlarge the scope of utilization of wood is that of wood - cement composite board manufacture. The major raw materials for cement boards consist mainly of wood, cement and water with or without a catalyst (Ajayi, 2011; Papadopoulos, 2008; Ajayi, 2005). The acceptability of these products stems from their availability and widespread distribution of local raw materials.

These products have many advantages such as no emission of toxic during their manufacture and reduced cost due to cure without applying high temperatures (Lima *et al*., 2011; Iwakiri, 2005). Moreover, panels made from these composites have high versatility in terms of finish, may be sawn, nailed, screwed, glued and towed; allowing wide application (Matokoski, 2005) as flat roofing, prefabricated structures, mobile homes, permanent formwork, cladding, sound barriers and paving, because they work as structural insulation panels (Karade, 2010) .

Particle boards are made from a wide range of materials such as fibers obtained from trees. It provides uniform and predictable in service performance largely as a consequence of standards used to monitor and control their manufacture. The mechanical characteristics of particle board depend upon a variety of factors. This includes wood species, the type of adhesive used to bind the wood elements together, geometry of the wood elements (fibers, flakes, strands, particles, veneer, lumber) and density of the final product (Cai *et al*., 2006). This study therefore examined the effect of pre-treatment methods on the production of wood cement board from *Afzelia africana* residues

Materials and method

Wood residues were collected from sawmill located at Bodija plank market in Ibadan. The sawdust was screened to remove the unwanted particles that could negatively affect the quality of the wood cement board.

The sawdust collected was stored at Forestry Research Institute of Nigeria for four months to enable proper dryness of the sawdust at constant room temperature to allow for break down and degradation of wood components such as glucose, lignin and cellulose before pre-treatment.

The pre-treatment chemical used in form of additives in this study is calcium chloride and Iron Chloride. The percentage concentrations are two levels 2.0% and 3.0% of the cement weight in the board.

Pre-treatment methods

The three pre-treatment type used are as follows

Hot water pre-treatment: The hot water pre-treatment method allows for the extraction of sugar and other soluble chemical substances which inhibit settings of cement and this were air dried to 12% drained (Badejo, 2005). This was soaked for one hour.

Cold water pre-treatment: The portion of sawdust allocated to this method was soaked in cold water at ambient temperature for 24 hours. The water which contained extracted chemical substances was drained off. The wet sawdust was sprinkle with pure water and air dried to a moisture content of about 12% before use.

Hot water and cold water pre-treatment: Under this pre-treatment, the sawdust was soaked in hot water for a period of one hour before transferred into the cold water for 24hous.

Percentage concentration of chemical additives were used at two levels, the first level was 3.0%, second level 4.0% based on the cement weight in board. The combination of the above production variables were laid in 2x2x3 factorial layout, all boards at each of the treatment combination levels were made at the following specified levels,

(i) Cement wood mixing ratio at a level of 3:1, based on oven dry weight of the board

(ii) Board density at a level of oven dry weight basis 1200kg/m^2

(iii) Water and cement ratio at a level of 0.06

(iv) Pressing pressure at a level of 2.23-N/mm^2

(v) Board type: Homogenous

The materials used were measured accordingly and properly mixed in a plastic bucket in order to ensure good distribution of the solution on the wood particle surface. The mixture was spread with hand in a wooden box, the dimension of the box is 35cm x 35cm x 6cm, the top of this were covered with polythene sheet so as to let it be easily removed when the board has been formed (Tables 1and 2)

The hydraulic presser was used to press this board so as to get the required thickness. This board was then left for 24hours. The board produced was packed and kept in the conditioning

room, so that it will ensure the gradual curing of the cement binder. Data obtained were subjected to ANOVA

Results and discussion

Modulus of Rupture (MOR)

The data obtained from the static bending strength test carried out in the study are listed in Table 3, mean MOR (N/mm^2) values obtained for the cement – bonded particle boards made from sawdust of *Afzelia africana* (Apa) ranged from 4.44 to 8.78. The average values conform with the values reported on cement-boards made from different hardwood species grown in Nigeria (Badejo, 2005; Olanike *et al.*, 2008; Olufemi *et al*., 2012).

Differences in MOR were obtained in the strength of data obtained in panel made from the three different pre-treatment methods of 24 hours cold soak, hot water soak at the temperature of 80^oC for 1 hour and a combination of the cold and hot water soak. Cement – bonded particle boards made from combined treatment methods of 24 hours cold soak and 1hour hot water soak at temperature 80^oC were significantly superior at 5% level of probability to those made at 24 hours cold soak and 1hour hot water soak. This indicate that modulus of rupture (MOR) values were highest for panels made from the combined pre-treatment of cold water and hot water soak (7.88 to $8.78N/mm^2$) followed by those made with hot water soak (7.01 to $8.21N/mm^2$). Those made from the cold water soak exhibited the least strength value (MOR range of 4.30 to $5.02N/mm^2$).

Furthermore, MOR values of the experimental boards increased with increased in the content of the chemical additive content in board from 3% to 4%. Cement-boards made from use of $FeCl_3$ as chemical additive were superior to those made from calcium chloride $CaCl_2$

Modulus of elasticity (MOE)

The results of MOE test are presented in Table 4. Mean values obtained ranged from 2160 to $2990N/mm^2$. As observed, the trend of behaviour of the MOE results was similar to that of MOR. Cement-bonded particle boards made from the combined treatment methods of 24hours cold soak and hot water soak at temperature 80^oC were significantly superior at 5% level of probability in stiffness. Cement-boards made with 4% additive content in board were stiffer in static bending than those made with 3%. Furthermore, boards which contained $FeCl_3$ as additive produced higher MOE values than those made with $CaCl_2$ as additive.

Water absorption (WA)

The result of water absorption test carried out in the study is listed in Table 5. Mean WA values obtained ranged from 12.96% to 15.32%. The low values obtained are possible due to the fact that the boards are made from sawdust which constituted 100% of the wood input in the fabrication of the boards. Sawdust being homogenous generally manifested in the production of well compacted and less porous cement- bonded particle boards. The range of average WA values obtained in the study conforms to figures reported in literature on cement-boards manufactured from different wood species (Badejo, 2005; Ajayi, 2011). WA

values were least for boards made with the combined pre-treatment methods for 24hours cold soak and 1hour hot water soak (80^{o}C), percentage water absorption values were noted to decrease with increase in the content of chemical additive in board from 3% to 4%. This means in effect that boards made with 4% additive content were more dimensionally stable than those made at with 3%. More so, cement – bonded particle board made with $Fecl_3$ as chemical additive exhibited lower WA values than those made with calcium chloride $CaCl_2$. Based on this finding, cement –boards made with $FeCl_3$ as additive were more dimensionally stable than those made with $CaCl_2$.

Thickness swelling (TS)

Listed in table 6 are the result of the thickness swelling (TS) test carried out in the study, Average values obtained ranged from 0.68 to 5.31. These results conform with published data on cement bonded particle boards made from tropical hardwood (Ajayi, 2011). The trend of behaviour of the result was exactly similar to that of water absorption. Boards made with the combined treatment of 24 hours cold soak and 1 hour hot water soak produced the lowest percent thickness swelling values (0.68 to 1.14%) than those obtained from boards made using either of the two pre-treatments – 2.12 to 2.99%. The low values obtained are possibly due to the fact that the board are made from sawdust which constituted 100% of the wood input in the fabrication of the boards and less porous cement – bonded particle boards. The ranges of average WA values obtained in this study conform to figures reported in literature on cement – boards manufactured from different wood species (Badejo, 2005; Ajayi, 2005). WA values were least for boards made with the combined pre - treatment methods for 24 hours cold soak and 1hour hot water (80^{o}C) soak than those made at the either of the two levels. This means in effect that boards made from 4% additive content were more dimensionally stable than those made from 3%.

Furthermore, cement bonded particle boards made with $FeCl_3$ as chemical additive exhibited lower WA values than those made with calcium chloride ($CaCl_2$). Based on this finding, cement – boards made with $FeCl_3$ as additive were more dimensionally stable than those made with $CaCl_2$

Conclusion and recommendation

Sawdust of *Afzelia africana* (APA) can conveniently be converted into cement board of adequate strength and stiffness if appropriate pre – treatment method is applied. From the result achieved, it is apparent that the degree of efficacy varies from one method to another. It is also apparent that the chemical substances present in APA which may inhibit settings of cement if not removed to a large extent soluble in both cold and hot water soak treatment. In order to ensure production of cement – boards of adequate strength, stiffness and moisture resistance properties from Nigerian hardwood species, more research studies on the use of different pre – treatment methods is recommended. Other methods which can be studied include use of sodium hydroxide NaOH and its combination with other methods (cold water

and hot water soak). The essence of the pre – treatment is to extract from the wood, chemical substances such as sugars, oils and extractives which may inhibit cement setting. Since the solubility of these substances is likely to vary from one solvent medium to the other, the need to screen other available pre – treatment methods may become very desirable.

TABLE 1: Showing 12 treatment combinations used for the experiment

TREATMENT NUMBER	TREATRMENT CODE
1	PC_1 CAT_1 PT_1
2	PC_1 CAT_1 PT_2
3	PC_1 CAT_1 PT_3
4	PC_1 CAT_2 PT_1
5	PC_1 CAT_2 PT_2
6	PC_1 CAT_2 PT_3
7	PC_2 CAT_1 PT_1
8	PC_2 CAT_1 PT_2
9	PC_2 CAT_1 PT_3
10	PC_2 CAT_2 PT_1
11	PC_2 CAT_2 PT_2
12	PC_2 CAT_2 PT_3

NOTE: PC = Percentage concentration
CAT =Chemical additives type
PT = Pre – treatment type

TABLE 2: SHOWING THE RAW MATERIALS APPLIED IN EACH TREATMENT

TREATMENT LEVEL	WEIGHT OF CEMENT REQUIRED/g	WEIGHT OF SAWDUST REQUIRED/g	WEIGHT OF WATER REQUIRED/g	WEIGHT OF CHEMICAL REQUIRED/g
PC_1 CAT_1 PT_2	662	247	437	19
PC_1 CAT_1 PT_2	662	247	437	19
PC_1 CAT_1 PT_2	662	247	437	19
PC_1 CAT_2 PT_1	662	247	437	19
PC_1 CAT_2 PT_2	662	247	437	19
PC_1 CAT_2 PT_3	662	247	437	19
PC_2 CAT_1 PT_1	662	247	437	26
PC_2 CAT_1 PT_2	662	247	437	26
PC_2 CAT_1 PT_3	662	247	437	26
PC_2 CAT_2 PT_1	662	247	437	26
PC_2 CAT_2 PT_2	662	247	437	26
PC_2 CAT_2 PT_1	662	247	437	26

NOTE: PC = Percentage concentration
CAT =Chemical additives type
PT = Pre – treatment type
Density = mass/volume
Board size = 35cm x 35cm x 6mm
Board volume = 35 cm x 35 cm x 0.60 cm
= 735 cm^3
Density = 1200kg/m^3

TABLE 3: Average MOR values of cement-bonded particle board made from *Afzelia africana* (APA) at each of the treatment combination applied in the study

Treatment combination

Pre – treatment type	Chemical additive type	Chemical additive concentration%	MOR Value (N/mm^2)
24hours cold soak	$CaCl_2$	3.0	4.44
24hours cold soak	$CaCl_2$	4.0	5.02
24hours cold soak	$FeCl_3$	3.0	4.30
24hours cold soak	$FeCl_3$	4.0	4.77
1hour hot water (80^0c)	$CaCl_2$	3.0	7.31
1hour hot water (80^0c)	$CaCl_2$	4.0	7.99
1hour hot water (80^0c)	$FeCl_3$	3.0	7.01
1hour hot water (80^0c)	$FeCl_3$	4.0	8.21
24hours cold water + 1hour hot water	$CaCl_2$	3.0	8.02
24hours cold water + 1hour hot water	$CaCl_2$	4.0	8.78
24hours cold water + 1hour hot water	$FeCl_3$	3.0	7.88
24hours cold water + 1hour hot water	$FeCl_3$	4.0	8.52

Average for 2 observations

TABLE 4: Average MOE values of cement – bonded particle board made from *Afzelia africana* (APA) at each of the treatment combination applied in the study.

Treatment combination

Pre – treatment type	Chemical additive type	Chemical additive concentration%	MOE Value (N/mm^3)
24hours cold soak	$CaCl_2$	3.0	2200
24hours cold soak	$CaCl_2$	4.0	2430
24hours cold soak	$FeCl_3$	3.0	2160
24hours cold soak	$FeCl_3$	4.0	2340
1hour hot water (80^0c)	$CaCl_2$	3.0	2620
1hour hot water (80^0c)	$CaCl_2$	4.0	2710
1hour hot water (80^0c)	$FeCl_3$	3.0	2600
1hour hot water (80^0c)	$FeCl_3$	4.0	2750
24hours cold water + 1hour hot water	$CaCl_2$	3.0	2810
24hours cold water + 1hour hot water	$CaCl_2$	4.0	2990
24hours cold water + 1hour hot water	$FeCl_3$	3.0	2770
24hours cold water + 1hour hot water	$FeCl_3$	4.0	2840

Avearage for 2 observations

TABLE 5: Average water absorption (WA) values of cement –bonded particle board made from *Afzelia africana* (Apa) at each of the treatment combination applied in the study.

Treatment combination

Pre – treatment type	Chemical additive type	Chemical additive concentration%	WA Value (%)
24hours cold soak	$CaCl_2$	3.0	15.32
24hours cold soak	$CaCl_2$	4.0	14.88
24hours cold soak	$FeCl_3$	3.0	15.11
24hours cold soak	$FeCl_3$	4.0	14.72
1hour hot water (80^0c)	$CaCl_2$	3.0	14.76
1hour hot water (80^0c)	$Cacl_2$	4.0	13.84
1hour hot water (80^0c)	$FeCl_3$	3.0	14.66
1hour hot water (80^0c)	$FeCl_3$	4.0	13.77
24hours cold water + 1hour hot water	$CaCl_2$	3.0	14.11
24hours cold water + 1hour hot water	$CaCl_2$	4.0	13.00
24hours cold water + 1hour hot water	$FeCl_3$	3.0	14.00
24hours cold water + 1hour hot water	$FeCl_3$	4.0	12.96

Average for 2 observations

TABLE 6: Average thickness swelling (TS) values of cement-bonded particle board made from *Afzelia africana* (Apa) at each of the treatment combination applied in the study.

Treatment combination

Pre – treatment type	Chemical additive type	Chemical additive concentration%	TS Value (%)
24hours cold soak	$Cacl_2$	3.0	4.31
24hours cold soak	$Cacl_2$	4.0	4.00
24hours cold soak	$Fecl_3$	3.0	4.12
24hours cold soak	$Fecl_3$	4.0	3.96
1hour hot water (80^0c)	$Cacl_2$	3.0	2.99
1hour hot water (80^0c)	$Cacl_2$	4.0	2.31
1hour hot water (80^0c)	$Fecl_3$	3.0	2.76
1hour hot water (80^0c)	$Fecl_3$	4.0	2.12
24hours cold water + 1hour hot water	$Cacl_2$	3.0	1.14
24hours cold water + 1hour hot water	$Cacl_2$	4.0	0.84
24hours cold water + 1hour hot water	$Fecl_3$	3.0	1.02
24hours cold water + 1hour hot water	$Fecl_3$	4.0	0.68

Average for 2 observations

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