DIMENSIONAL STABILITY OF GYPSUM-BONDED BOARDS REINFORCED WITH NATURAL FIBRES

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Abstract

The increase in cost of building materials has pushed scientists and engineers to search for composites boards reinforced with cheap and eco-friendly materials. The dimensional stability of ceiling boards produced from gypsum reinforced with natural fibres was assessed. Twenty-seven (27) medium density boards of 600kg/m^3 having dimension 200 x 200 x 10mm were produced from Plaster of Paris (POP) in combination with Cocos nucifera, Thaumatococcus danielli and yarns at four different mixing proportion of 100%, 75%, 50% and 25%. Water absorption (WA) and thickness swelling (TS) properties of the experimental boards were assessed after 24 and 48 hours using standard methods. Data obtained were analyzed using descriptive statistics and analysis of variance at $p<0.05$ level of significance. Boards obtained from different mixing proportion of gypsum, natural and synthetic fibres displayed water absorption values which ranged from 4.18 to 26.01% and thickness swelling values of 1.11 to 3.6%. The percentage of WA and TS reduces as the percentage of natural fibres to synthetic fibres increases. Hence, it is concluded that gypsum reinforced with natural fibres are reliable materials which could be used to produce ceiling boards for low-cost housing constructions.

Introduction

The promotion of sustainable development has put pressure on all industries, including the construction industry to adopt and implement proper methods to protect the environment. Due to current global concerns for sustainable development that have risen from extensive environmental problems such as climate change and the impoverishment of resources coupled with the rapid pace of technological advancement within the building sector, interest in alternative building materials have been developed (Ashous *et al*., 2015; Doukas *et al.,* 2006).

Plaster of Paris is a white powder obtained by heating Gypsum (CaSO4.2H20), a naturally occurring stone (a metallic salt of calcium stone) to about 300°F (150°C). When the dry plaster powder is mixed with water, it re-forms into gypsum (Coditz, 2002). Due to its availability in subsoil, relative low cost, ease of high usage and mechanical characteristics suitable for many uses, plaster is widely used as construction material, which can compete with cement. Where the latter is not eliminated completely but used rationally, structure like foundations and chaining must be strengthened. However, plaster appears to be heavy, permeable and too brittle (Gunasekaran *et al*., 2008). Heaviness and brittleness may be appreciably reduced by combining plaster with natural fibers (Dalmay *et al*., 2010)

There is great deal of interest in developing the technology of using natural fiber material as reinforcement in gypsum composites. Natural fibers exist in reasonably large quantities all over the world in different forms. There is a wide range of natural fibers, namely sisal, bamboo, coir (coconut fiber), jute, wood cellulose fiber, leaf stalk fibers and many others (Zain *et al*., 2011; Mulinari, 2011). Natural fibers are abundantly available and are comparatively cheap. Natural fiber composites are also claimed to offer environmental advantage such as lower pollutant emissions lower greenhouse emission, enhanced energy recovery and end of life biodegradability, inexpensive, environmentally friendly and easily available as reported by Xie *et al.,* (2010). Hence, the demands to utilize natural fibers for making good quality and low-cost materials sustainable for housing and others uses are increasing.

Fibers of *Cocos nucifera* and *Thaumatococcus danielli* are used in place of synthetic fibers to produce plaster board and this is to encourage the use of these "seemingly" waste products as construction materials in low-cost housing. This study was limited to the production of ceiling board from Plaster of Paris (POP) and natural fibers from *Cocos nucifera* and *Thaumatococcus danielli*. The ceiling board was produced at the department of Wood and Paper Technology, Federal College of Forestry, Ibadan. The boards were produced using POP, natural fibers with board density of 600g/m^3. Physical properties such as density, water absorption, moisture content, thickness swelling, and mechanical properties such as MOR and MOE, compressive strength, impact test were examined.

Materials and Methods

Collection and Preparation of Natural Fibers and Plaster of Paris (POP)

The coconut husks were collected from Ibode area, Ibadan. The husks were washed properly and air dried for five days under ambient temperature in accordance with the ASTM C33(2009). The coconut husks were chopped with sharp scissors maintaining a length from 15 to 35mm. The coconut fibers were pre-treated in hot water at 80°C for one hour to remove water soluble sugars and other chemicals that can affect the setting and curing of the plaster. Then, the fiber was washed thoroughly in cold water and air dried to 12% moisture content and was stored in polythene bag prior to use (Plate 1 and 2). *Thaumatococchus danielli* stalks used for this study were harvested from Ikeji-Ile (Lat. 7° 41' 04" N, Long. 4° 49' 01" E) in Osun State. The stalks were cut to short lengths of 50mm, and the fibres were removed with a sharp knife and dried at 20 h at 60°C to constant moisture content (plate 1 and 2).C BAA 80kg of Plaster of Paris (POP) and Synthetic Fibre (Yarn) were purchased from Supreme Interior Decoration (NIG) LTD, Iwo road Ibadan, Oyo State Nigeria.

Plate1: Natural and Synthetic fibres (A – Yarn; B - *Cocos nucifera;* C - *Thaumatococcus danielli)*

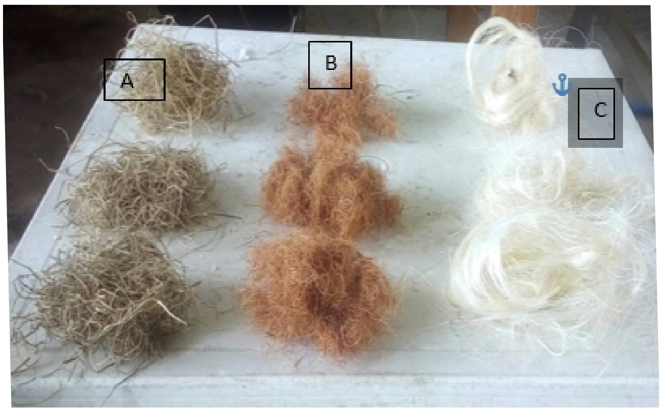

Plate 2: The Shredded Fibres (A – *Thaumatococcus danielli*; B - *Cocos nucifera;* C - Yarn*)*

Mixing Proportion of the Board

Medium density board of 600kg/m^3 having dimensions 200 mm x 200mm x 10mm were produced for both synthetic and natural fibres based on the volume and mass of the board as follows: 5g of fibres + 235g of Plaster of Paris (POP) + 300ml of water

Level 1: (Yarn/POP)

Level 2: (*Thaumatococcus danielli* / POP)

Level 3*: (Cocos nucifera* / POP)

Table 1: Mixing Proportion of the Plaster of Paris and the Natural Fibres and Synthetic Fibres

FIBRES	MIXING PROPORTION
100%	POP_{235g}: Coconut $_{5g}$
	POP_{235g}: Thamatococcus $_{5g}$
	POP_{235g}: Yarn $_{5g}$
75%	P_{235g}: $C_{3.5}$: $Y_{1.5}$
	P_{235}: $T_{3.5}$: $Y_{1.5}$
50%	P_{235}: $C_{2.5}$: $Y_{2.5}$
	P_{235}: $T_{2.5}$: $Y_{2.5}$
25%	P_{235}: $C_{1.5}$: $Y_{3.5}$
	P_{235}: $T_{1.5}$: $Y_{3.5}$

Note: P- POP; C- coconut husk; T- Thamautococcus danielli; Y- Yarn

Board Formation and Setting

Mould of 200mm × 200mm × 10mm was placed on flat metal and was lubricated to prevent the sticking of the formed boards on the plates. The POP, yarn and natural fibres were measured using the sensitive scale accordingly; the measured water was poured gradually into the bowl containing the gypsum and stirred gradually. The POP mixture was turned gradually into the mould and the fibers were spread equally onto it; another mixture of POP was added to the surface thereby making the fibers to be in between the plaster. The casting was done quickly because it is the nature of POP to harden quickly. After all the procedure, the board was allowed to set for five (5) minutes and was removed gently from the mould and kept in a well-ventilated place to dry. The image of the produced is shown on plate 3. The board was further cut into various test specimens for evaluation in accordance with BS 5669: (1979). The parameters tested for are water absorption and thickness swelling.

Plate 3: Samples of the board produced

Water Absorption and Thickness Swelling

The board samples were soaked in distilled water and maintained for 24 hours and 48 hours in order to condition the board samples to moisture contents above fibre saturation point (FSP). Afterwards, the samples were weighed, and their dimensions also taken. Water absorption values (WA) and Thickness swelling was calculated using equations (1) and (2) respectively, according to ASTM- 1037 (2003).

$$WA\ (\%) = \frac{W_2 - W_1}{W_2} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

Where:
WA (%) = Water absorption
W_2 = wet weight of the specimen after soaking in water (g)
W_1 = weight before soaking (g)

$$TS\ (\%) = \frac{T_2 - T_1}{T_2} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 2$$

Where
TS = thickness swelling (%)
T_1 = initial thickness before soaking
T_2= final thickness after soaking

Statistical Analysis

The data obtained from the experiment were analyzed using descriptive statistical analysis, which gave summaries of the raw data and analysis of variance. For each data, significantly different groupings were obtained using Duncan Multiple Range Test (DMRT).

Results and Discussion

Water Absorption

The mean values for percentage water absorption (WA) after 24 h and 48 h is presented in Figure 1. The results for WA range from 1.01 – 16.1% and 4. 18 -26.01% for 24 h and 48 h respectively. The board with 100% (P_{235g}: Y_{5g}) had the lowest value while board of 25% ($P_{235g:}$ $C_{1.5g:}$ $Y_{3.5g}$) has the highest value. Moreover, ANOVA results (Table 2) shows that there is no significant difference in the WA for 100% (P_{235g}: Y_{5g}) and 100 % (P_{235g}: C_{5g}). Likewise, there is no significant difference in water absorption for mixing proportion 75% (P_{235g}: $C_{3.5g:}$ $Y_{1.5g}$) and 75% ($P_{235g:}$ $T_{3.5g:}$ $Y_{1.5g}$). It was observed clearly from the result that water absorption increases with increase in synthetic fibre mix ratio but there was a decrease in percentage water absorption of gypsum bonded with natural fibres in all the 100% mixing proportion. The values obtained for WA in the present study compared favorably with those reported in literature for natural fibres,55-6.6% (Amoo *et. al*, 2016); 3.69-22.22% (Ajayi, 2003); woods and rattan, 2.2-28.6% (Olorunisola *et al,* 2005).

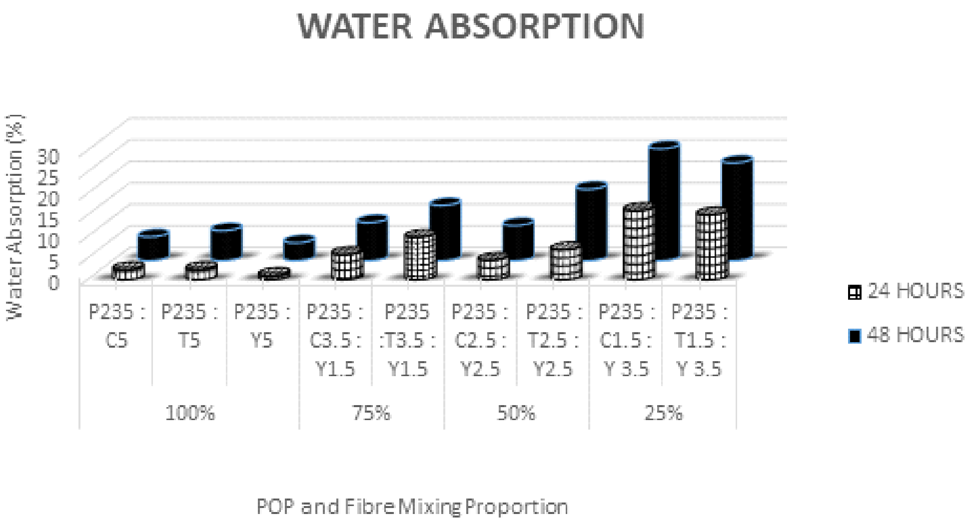

Figure 1: Water Absorption of Gypsum-Bonded Boards from Natural and Synthetic Fibers.

The observed decrease in water absorption with increase percentage of natural fibre (coconut) to synthetic fibre is probably due to good bond formation, less voids spaces and this leads to reduction in the rate of water absorption. The mixing proportion of natural fibers to synthetic fibre could also have contributed to increase water absorption which created spaces for penetration of water, thus increasing the final board's weight after soaking (Kaplon, 1995).

Thickness Swelling

The mean values of thickness swelling (TS) of boards produced from POP bonded with natural fibers and synthetic fibers at different mixing ratio are presented in Figure 2. The result of the TS ranged between 0.69-2.77% and 1.11- 3.6% for 24 h and 48 h respectively. It is seen from the result that at 24 h immersion of board with 100% fibers at mixing ration P_{235g}: C_{5g} has the lowest value while board with 25% fibers with mixing ratio P_{235g}: $T_{1.5g}$: $Y_{3.5g}$ has the highest value. After 48 h immersion, board with 100% fibers with mixing ratio P_{235g}: C_{5g} still maintained the lowest TS (1.11%) while board of 25% fibers with mixing ratio P_{235}: $T_{3.5g}$: $Y_{1.5g}$ has the highest TS (3.6%). ANOVA results (Table 2) showed that there is no significant difference between 100% (P_{235g}: C_{5g}) and 100% (P_{235g}: Y_{5g}) after 24 h immersion in water. However, there is significant different in TS of 100% mixing proportion when compared to other mixing ratio after 24 h immersion. The TS after 48 h immersion did not follow same trend, there was significant differences between each mixing proportion at different levels. This result shows that as the proportion of natural fibre to synthetic fibre increases, there is reduction in the TS of the boards. The values obtained for TS compared favorably with those reported for natural fibres 0.7-2.5% (Amoo *et al*., 2016); cement- bonded with banana stem, 0.27- 6.5% (Ajayi, 2003).

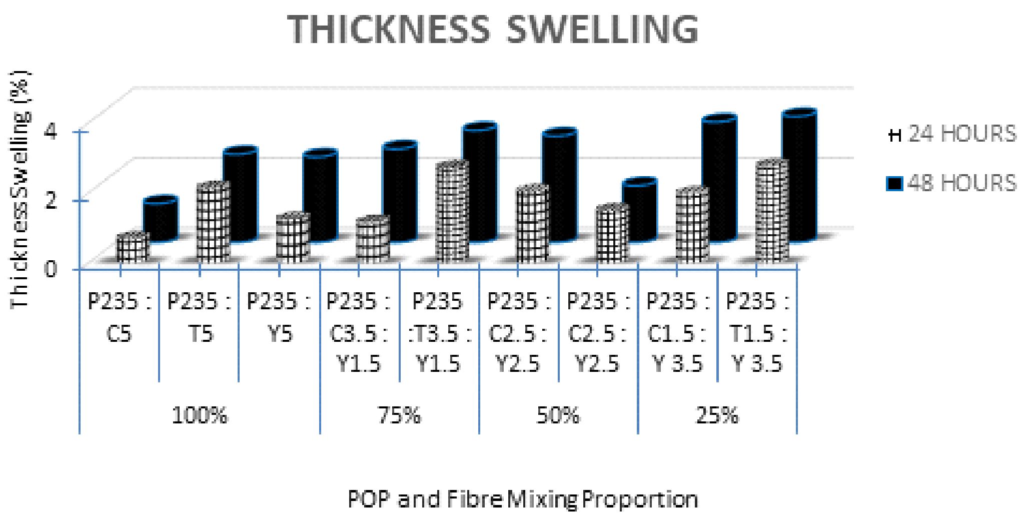

Figure 2: Thickness Swelling of Gypsum-Bonded Boards from Natural and Synthetic Fibers.

The reduction in TS of the boards made from gypsum-bonded with natural fibers could also be attributed to greater compression and better gypsum-fibre interaction resulting to little or no void spaces to accommodate water. This improvement in gypsum-bonded with natural fibers has also been reported by Kaplon (1995), Terry (2000) and Ajayi (2003).

Table 2: Follow up test for water absorption and thickness swelling produced from Gypsum, natural and synthetic fibers.

MIXING RATIO OF FIBERS		WATER ABSORPTION 24 HOURS	WATER ABSORPTION 48 HOURS	THICKNESS SWELLING 24 HOURS	THICKNESS SWELLING 48 HOURS
100%	$P_{235:}$ C_5	2.37±0.6^a	5.54±1.3^a	0.69±0.1^a	1.11±0.1^a
	$P_{235:}$ T_5	2.41±0.8^a	7.01±0.7^{ba}	2.140.5^b	2.52±0.5^b
	$P_{235:}$ Y_5	1.01±0.3^a	4.18±0.1^a	1.25±0.1^a	2.44±1.6^b
75%	$P_{235:}$ $C_{3.5:}$ $Y_{1.5}$	5.89±1.7^b	8.88±0.6^b	1.16±0.3^a	2.67±0.13^b
	$P_{235:\ T3.5}$: $Y_{1.5}$	9.84±3.5^c	12.83±1.1^c	2.73±0.6^b	3.2±1.1^c
50%	$P_{235:}$ $C_{2.5}$: $Y_{2.5}$	4.54±0.95^b	8.19±1.4^b	2.04±1.6^b	3.04±2.4^c
	$P_{235:}$ $T_{2.5}$: $Y_{2.5}$	6.99±1.6^b	16.63±0.2^c	1.5±0.9^{ab}	1.62±0.9^{ab}
25%	$P_{235:}$ $C_{1.5:}$ $Y_{3.5}$	16.1±1.9^d	26.01±1.7^d	1.98±0.5^{ab}	3.44±1.01^c
	$P_{235:}$ $T_{1.5:}$ $Y_{3.5}$	15.08±2.4^d	22.70±2.3^d	2.77±1.0^b	3.6±1.0^c

Mean of the with different alphabets in same column are significantly different at ($p \leq 0.05$)

Moreover, it is observed that the gypsum-bonded boards have low water absorption and thickness swelling rates which could make it not only suitable for indoor applications but also outdoors.

Conclusion

The results obtained from this study showed that production of boards reinforced with natural fibres is possible from *Cocos nucifera* and *Thaumatoccocus daniellii* fibres. The study however revealed that mixing proportion of natural fibres with synthetic fibres influences the dimensional stability. The values obtained for water absorption and thickness swelling after 48-hour water soak cycle ranged from 4.18 to 26.01% and 1.11 - 3.60% respectively. These results show that increase in percentage of natural fibres to synthetic fibres in mixing proportion resulted in the improvement of the dimensional stability of the boards. The result obtained from this study also shows that there is no significant different in the values for WA and TS of the boards produced from 100% synthetic and natural fibres. Therefore, fibres from *Cocos nucifera* and *Thaumatococcus danielli* could be used successfully for reinforcement of gypsum-bonded boards.

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