Physico-Mechanical Properties of Wood and Non-Wood Plaster of Paris Bonded Composite Ceiling Boards

Temidayo Emmanuel Omoniyi¹, Kenny Ajobiewe¹

¹ University of Ibadan

Ibadan, Oyo State, 900001, Nigeria

DOI: [10.22178/pos.58-9](https://doi.org/10.22178/pos.58-9)

LCC Subject Category: [TH6014-6081](#)

Received 23.04.2020

Accepted 28.05.2020

Published online 31.05.2020

Corresponding Author:

Temidayo Emmanuel Omoniyi

temidayoomoniyi@gmail.com

© 2020 The Authors. This article is licensed under a [Creative Commons Attribution 4.0 License](#)

Abstract. Woody (*Alzibia zygia*) and Non-woody (rattan and yarn strands) fibres were used comparatively to improve the physicomachanical properties of Plaster of Paris bonded composite which is used as ceiling boards. The addition of fibre reinforcement in a discrete form improves the engineering properties of the Plaster of Paris. The woody and nonwoody residues were varied in 10, 20, 30, 40, and 50% of the whole mix while the Plaster of Paris used were in the ratio 100 (control), 90, 80, 70, 60, and 50 %. The mean density of the composite produced is 3250 kg/m³. The mean thickness swelling after 2 and 24 hours is 0.84 % and 0.88 % respectively with the mean water absorption at 13.8% after 2 hours and 16.2 % after 24 hours. The MOR and MOE of the composites produced ranged from 1.21-1.22 N/mm², 2431-51488N/mm² for sawdust, 1.17-1.22 N/mm², 10027-49940 N/mm² for yarn strands and 1.20-1.22 N/mm², 23566-86210 N/mm² for the rattan strands. The results showed physicomachanical properties of POP-bonded fibre reinforced composites were increased for both wood and non-wood fibres and rattan strands compared best.

Keywords: Wood composites; Physico-machanical; Fibre reinforcement; Plaster of Paris; Ceiling board.

INTRODUCTION

Reinforced Plaster of Paris Composite ceiling boards is a new decorative and finishing material that is gaining increasing importance and usage. Plaster of Paris or gypsum is a very soft sulfate mineral of chemical formulae $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ which presents itself often as monoclinic, massive, flat, or elongated and generally prismatic crystals with its colour ranging from colorless to white [1]. In recent years, asbestos materials for making ceiling boards have been banned in many advanced countries due to its carcinogenic nature, with agencies in construction industries having identified its real and potentially adverse effect on humans [2]. Locally sourced building materials that would facilitate sustainable development remain underdeveloped to a socially and economically acceptable level, owing to the low level of development of the economy [3].

Authors [4] reported that composite is designed to take advantage of the desirable characteristics of constituent materials by choosing an appropriate combination of matrix and reinforcement

material, thus producing a new material that meets the exact requirements of a particular application. Yarn is a long continuous length of interlocked fibres suitable for use in the production of textiles, sewing, crocheting, knitting weaving, embroidery, and rope making, while rattan is a stick made from the stem of the rattan palms. Rattan canes are numbered among the important commercial non-timber forest products employed in the furniture industry in the tropics, however, over 30% of rattan harvested at any time particular for furniture manufacture are wastes [5]. *Alzibia zygia* is a deciduous tree nine to thirty meters tall with a spreading crown and a graceful architectural form and its bole tall and clear, around 240 cm in diameter. It has a dark grey and smooth surface [6]. These materials experimented as reinforcement to improve the properties of Plaster of Paris to produce durable, affordable, and environmentally friendly (non-carcinogenic substances) material suitable structurally as ceiling boards.

METHODOLOGY

Materials Collection. Sawdust of *Alzibia zygia* collected from the Bodija plank market in Ibadan was graded and sieved to remove impurities, then oven-dried to around 101 °C to reduce the moisture content of the fibre. Rattan, yarn fibres and Plaster of Paris were purchased from a retail outlet also in Ibadan.

Procedure. The materials were then weighed and batched in accordance to the research methods (Tables 1, 2, and 3). The mixing was done manually with potable water and added into a prepared wooden mold. The mixture was allowed to sit for some minutes before curing take place. The produced composite materials were then subjected to the test to investigate their physical and mechanical properties (Table 1–3).

Table 1 – Plaster of Paris and *Alzibia zygia* (Ayunre)

Samples	POP (%)	Wood fibre (%)	Samples produced
PWF1	100	0	3
PWF2	90	10	3
PWF3	80	20	3
PWF4	70	30	3
PWF5	60	40	3
PWF6	50	50	3

$$PWF = POP + woof \text{ fibre}$$

Table 2 – Plaster of Paris and Rattan fibre

Samples	POP (%)	Rattan fibre (%)	Samples produced
PRF1	100	0	3
PRF2	90	10	3
PRF3	80	20	3
PRF4	70	30	3
PRF5	60	40	3
PRF6	50	50	3

$$PRF = POP + rattan \text{ fibre}$$

Table 3 – Plaster of Paris and yarn fibre

Samples	POP (%)	Rattan fibre (%)	Samples produced
PYF1	100	0	3
PYF2	90	10	3
PYF3	80	20	3
PYF4	70	30	3
PYF5	60	40	3
PYF6	50	50	3

$$PYF = POP + yarn \text{ fibre}$$

The following tests were carried out on the specimens.

Density. After curing, the samples were weighed on a digital weighing scale and their corresponding weight in kilograms was recorded. The density of the materials was calculated with the following equation (1):

$$\partial = \frac{w}{v}, \quad (1)$$

where ∂ is the density in (kg/m³);
 w is the weight of the composite produced;
 v is the volume of the produced composite.

Specific gravity. The specific gravity was calculated using this equation (2):

$$SG = \frac{\partial c}{\partial w}, \quad (2)$$

where SG is the specific gravity of samples;
 ∂c is the density of composites produced (kg/m³);
 ∂w is the density of water in (1000 kg/m³).

Water Absorption and Thickness swelling. The specimen from each specimen was submerged horizontally under 50 mm of distilled water maintained at a room temperature of about 27 °C. The amount of water absorbed after 2 hours and 24 hours were recorded.

$$\% \text{ water} = \frac{w_2 - w_1}{w_1} \times 100, \quad (3)$$

w_1 and w_2 is the initial and final weight before and after soaking respectively.

$$\% \text{ thickness swelling} = \frac{t_2 - t_1}{t_1} \times 100, \quad (4)$$

t_1 and t_2 is the initial and final thickness before and after soaking.

Modulus of Rupture (MOR). This was conducted to approximate the bending strength of the produced composite materials. The samples were tested using the universal test machine (UTM) of the Department of Agricultural and Environmental Engineering, University of Ibadan.

$$MOR = \frac{3PL}{2BH^2}, \quad (5)$$

where P is the maximum force/ load in (N);
 L – span of the board (mm);
 B – width of the test specimen (mm);
 H – thickness of the test specimen (mm).

Modulus of Elasticity (MOE):

$$MOE = \frac{PL^3}{4DBH^3}, \quad (6)$$

where P is the maximum force / load in (N);
 L – span of the board (mm);
 B – width of the test specimen (mm);
 H – thickness of the test specimen (mm);
 D – deflection at mid-point.

RESULTS AND DISCUSSION

Density and specific gravity. Figure 1–2 shows the produced composite materials.

Figure 1 – Producing samples with Vibrating table

Figure 2 – Samples of the fibre composites

Table 4 shows the densities and specific gravity of the material produced. The densities varies from 3200 kg/m³ to 3900 kg/m³ (wood fibre), 2700 kg/m³ to 4500 kg/m³ (rattan fibre), 2000 kg/m³ to 4500 kg/m³ (yarn fibre) and 4700 kg/m³ (POP only). Samples produced with POP alone have higher densities due to the presence of reinforced fibres (which tends to be lighter) in other samples. Increase in the fibre content of the composite produced decreases the density and specific gravity of the material which is in accordance to the report on wood composite by [5].

Thickness Swelling and Water Absorption. Table 5 and 6 shows the water absorption and thickness swelling percentage of the composite materials respectively. Cumulatively, the higher the fibre content in the composite, the higher the water absorption, which may be due to the hydrophilic nature of the wood and the other fibres.

Table 4 – Density and specific gravity of composites

Sample, Pop/fibre	ρ_{PWF} (kg/m ³)	ρ_{PRF} (kg/m ³)	ρ_{PYF} (kg/m ³)	SG _{PWF}	SG _{PRF}	SG _{PYF}
100/0	4700	4700	4700	4.7	4.7	4.7
90/10	3900	4500	4500	3.9	4.5	4.5
80/20	3500	4000	3500	3.5	4	3.5
70/30	3480	3000	3200	3.48	3	3.2
60/40	3320	3100	2700	3.32	3.1	2.7
50/50	3200	2700	2000	3.2	2.7	2

The behaviour of the produced composites was similarly reported by [8], that the presence of hydroxyl groups inside the cellulose and hemicelluloses attract the water molecules and form hydrogen bonding. Moreover, due to the porous

structure of wood fibres, the composites with higher wood content absorb more water which penetrates into the pores according to the principle of capillary flow. The yarn fibre absorbed the lowest amount of water content.

Table 5 – Water absorption (%) of composites produced

Sample	%WA _{PWF} (2 hrs)	%WA _{PWF} (24 hrs)	%WA _{PRF} (2 hrs)	%WA _{PRF} (24 hrs)	%WA _{PYF} (2 hrs)	%WA _{PYF} (24 hrs)
100/0	11.53	15.2	11.55	15.23	11.63	11.24
90/10	14.87	15.75	13.98	14.24	12.32	12.94
80/20	15.06	16.98	14.28	14.93	12.72	13.19
70/30	15.47	18.78	14.72	15.34	13.01	13.89
60/40	15.90	19.22	14.84	15.45	13.59	14.14
50/50	15.98	20.02	15.77	16.32	14.34	15.21

Table 6 – Thickness swelling (%) of composites

Sample	%TSPWF (2 hrs)	%TSPWF (24 hrs)	%TSPRF (2 hrs)	%TSPRF (24 hrs)	%TSPYF (2 hrs)	%TSPYF (24 hrs)
100/0	0.39	0.59	0.39	0.59	0.39	0.59
90/10	0.58	0.78	0.48	0.69	0.40	0.58
80/20	0.77	0.88	0.51	0.78	0.58	0.59
70/30	0.96	1.18	0.76	0.98	0.58	0.67
60/40	1.28	1.57	0.98	1.13	0.77	0.98
50/50	1.35	1.96	1.17	1.23	0.79	0.99

Table 6 shows the results of the thickness swelling test. Generally, the change in thickness of the produced composites is very minimal after 2 and 24 hours. The yarn fibre has the best performance under the thickness swelling test. As reported by [2] increase in the fibre ratio of the composites increases the thickness swelling after water immersion.

Modulus of Elasticity (MOE) and Modulus of Rupture (MOR). The strength properties of the composites were shown in table 7. The introduction of fibre tends to increase the Modulus of Elasticity of the composites as the primary objective of fibres as filler is to increase the stiffness of WPC. The results tally with [9] report, in which the ten-

sile and flexural strength slightly increased with an increasing wood fibre content of a WPC. The rattan fibre reinforced composites has the highest range of MOE values of 40167 KN/mm² to 50982 KN/mm², wood filler composites has a range of 39310 KN/mm² to 43477 KN/mm², and the yarn filler composites range from 39567 KN/mm² to 43270 KN/mm². The composites exhibit the same behaviour for the MOE and MOR test. The rattan performs best with MOR values of 1.221 KN/mm² to 1.229 KN/mm², wood fibre ranges from 1.221 KN/mm² to 1.229 KN/mm², and yarn fibre ranges from 1.219 KN/mm² to 1.211 KN/mm².

Table 7 – Results of MOE and MOR

Sample	MOE _{PWF} (KN/mm ²)	MOE _{PRF} (KN/mm ²)	MOE _{PYF} (KN/mm ²)	MOR _{PWF} (KN/mm ²)	MOR _{PRF} (KN/mm ²)	MOR _{PYF} (KN/mm ²)
100/0	32142.9	32142.9	32142.9	1.210	1.210	1.210
90/10	39310.1	40167.38	39567.39	1.221	1.284	1.219
80/20	41488.0	45235.11	41678.78	1.224	1.297	1.219
70/30	42757.9	56567.76	41997.98	1.237	1.307	1.227
60/40	43038.9	51709.78	43018.78	1.228	1.375	1.211
50/50	43477.7	50982.77	43270.77	1.229	1.376	1.228

CONCLUSION

Fibre-POP composites was produced from wood (*Alzibia zygia*), rattan (*Laccosperma secundiflorum*), and yarn. The composites were tested for strength and physical properties. The results derived implied that:

1. The mechanical properties of Rattan reinforced composite in terms of Modulus of Rupture and Modulus of Elasticity has the highest value meaning that bending strength of rattan reinforced composite is high.

2. The use of fibre to reinforce Plaster of Paris considerably increased the strength properties of the material.
3. There is reduction in environmental pollution through the use of waste fibres to yield a material suitable in ceiling board production.

REFERENCES

1. Migneault, S., Koubaa, A., Erchiqui, F., Chaala, A., Englund, K., & Wolcott, M. P. (2009). Effects of processing method and fiber size on the structure and properties of wood–plastic composites. *Composites Part A: Applied Science and Manufacturing*, 40(1), 80–85. doi: [10.1016/j.compositesa.2008.10.004](https://doi.org/10.1016/j.compositesa.2008.10.004)
2. Ajayi, B. (2006). Properties of maize-stalk-based cement bonded composite. *Forest Product Journal*, 56(6), 51–56.
3. Popovic, F., Filipovic, J., & Bozanic, V. (2013). Paradigm shift needed - municipal solid waste management in Belgrade, Serbia. *Hemijaska Industrija*, 67(3), 547–557. doi: [10.2298/hemind120620087p](https://doi.org/10.2298/hemind120620087p)
4. Omoniyi, T. E. , Alabi, O. J. (2017). *Performance evaluation of a single screw extruder for the production of WPC*. Forestry Association of Nigeria: n. d.
5. Olorunnisola, A. O., & Agrawal, S. (2015). *Effect of NaOH concentration and fibre content on the physic mechanical properties of cement bonded rattan fibre composite*. Retrieved from https://pdfs.semanticscholar.org/a5d0/e1606e3b994e65576cccf991b59f864dc29b.pdf?_ga=2.137225392.1488894276.1591557453-1042230176.1581878685
6. Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., & Anthony, S. (2009). *Agroforestry Database: a tree reference and selection guide version 4.0*. Retrieved from <https://www.feedipedia.org/node/1650>
7. Forest Products Laboratory. (2010). *Wood Handbook*. Retrieved from https://www.fpl.fs.fed.us/documnts/fplgtr/fpl_gtr190.pdf
8. Bledzki, A. K., Reihmane, S., & Gassan, J. (1998). Thermoplastics Reinforced with Wood Fillers: A Literature Review. *Polymer-Plastics Technology and Engineering*, 37(4), 451–468. doi: [10.1080/03602559808001373](https://doi.org/10.1080/03602559808001373)
9. Stark, N., & Rowland, R. (2003). [Effects of wood fiber characteristics on mechanical properties of wood/propylene composites](#). *Wood and Fibre Science*, 35(2), 167–174.