

PHYSICO-MECHANICAL PROPERTIES OF WOOD AND NON-WOOD PLASTER OF PARIS BONDED COMPOSITE CEILING BOARDS

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Abstract: The effects of wood and non-wood fibres reinforcement on the properties of Plaster of Paris were evaluated. The woody and non woody residues were varied in 10, 20, 30, 40, and 50 % of the whole mix while the Plaster of Paris used was 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 and water absorption after 2 and 24 hours were 0.84 % and 0.88 %, and 13.8 % and 16.2 % respectively. The MOR and MOE increased with increase in fibre content hence the composite is suitable for indoor applications.

Keywords: wood composites, physico-mechanical, fibre reinforcement, plaster of Paris, ceiling board.

1. INTRODUCTION

Reinforced Plaster of Paris (POP) 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 sulphate mineral of chemical formulae CaSO₄2H₂O which present itself often as monoclinic, massive, flat or elongated and generally prismatic crystals with its color 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 potential adverse effect on humans [2]. As a result, POP is gaining stand among builders and house owners who are practically interested in the alternative it provides to asbestos. Locally sourced building materials which would facilitate sustainable development remain underdeveloped to a socially and economically acceptable level, owing to the low level of development of the economy [3]. It was reported by [4] 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.

Among the natural fibres that have been used for reinforcement in composite boards include; bagasse fibre [5], Rattan [6], oil palm [7], sisal fibres [8], coconut coir [9], pineapple leaves [10] etc. Each of the researchers reported significant improvement to the properties of the composites formed. However, this may depend on the percentage of the natural fibres present in the matrix as well as the type of pre-treatment performed on the fibre before mixing. These natural fibres have been used mostly with cement as the binder and some of them can serve as potential reinforcement materials for POP in order to make it affordable and can in some ways increase the mechanical properties.

Yarn, a natural non-woody fibre is a long continuous length of interlocked fibres suitable for use in the production of textiles, sewing, crocheting, knitting weaving, embroidery, and roe making, while rattan, also one of the natural

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non-woody fibres, 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 furniture industry in the tropics, however over 30% of rattan harvested at any time particular for furniture manufacture are wastes [6]. *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 [11]. These materials could be experimented as reinforcement to improve the properties of Plaster of Paris in order to produce a durable, affordable, and environmentally friendly (non-carcinogenic substances) material suitable structurally as ceiling boards. The objective of this study, therefore, was to investigate the effects of some woody and non-woody natural fibres contents on the strength and sorption properties of POP.

2. METHODOLOGY

2.1. Materials Collection

Saw dust of *Alzibia zygia* collected from 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.

2.2. Procedure

The fibrous materials were sun dried then hammer milled and weighed accordingly. The fibre-POP composites were produced by manual dry-mixing of the *Alzibia zygia* fibres and the POP in a plastic bowl at different fibre contents (0%, 10%, 20%, 30%, 40%, and 50% respectively). This continued until a homogeneous mixture was formed. An estimated volume of water from preliminary was added to the contents and mixed continually until a desirable level of uniformity was achieved. The wet mixture was poured into a unit of 500 mm by 300 mm by 6mm plastic sheet placed in a mould on a table vibrator as shown in Figure 1. The content was spread over the mould until it properly covered the whole area. The table was then vibrated for 60 seconds. The specimen was left to moist cure for 24 hours and later left in water for 28 days, from preliminary, for proper curing. Three replicates of the samples were produced for each of the specimen designation presented in Table 1. The process was repeated for rattan and yarn fibre-POP composites production as presented in Table 2 and 3 respectively. The produced composite materials were then subjected to test to investigate their physical and mechanical properties.

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

Specimens	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 = Plaster Of Paris (POP) + wood fibre

Table 2. Plaster of Paris and Rattan fibre.

Specimen	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 =Plaster of Paris (POP) + rattan fibre

Table 3. Plaster of Paris and Yarn fibre.

Samples	POP (%)	Yarn 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 = Plaster of Paris (POP) + Yarn fibre

2.3. Composite Property Tests

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 from equation (1) as given by [1]:

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

where ∂_c is the density in (Kg/m³) of the composite produced, w is the weight of the composite produced and v is the volume of the produced composite.

Specific gravity (SG): The specific gravity was calculated using equation (2) as given by [1]:

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

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

Water Absorption and Thickness swelling: The specimen from each specimen were submerged horizontally under 50mm 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. The % water absorption and % thickness swelling were calculated using equation (2) and equation (3) respectively:

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

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

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

where 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 OKH-600 digital display universal test machine (UTM) of the Department of Agricultural and Environmental Engineering, University of Ibadan in accordance with [12]. The test was carried out on the sample specimens shown in Figure 2.

Modulus of Elasticity (MOE):

The MOE of the samples was determined using the OKH-600 digital display Universal Testing Machine in accordance with [12]. The test was carried out on the samples displayed in Figure 2.



Fig. 1. Producing samples with Vibrating table.



Fig. 2. Samples of the fibre composites.

3. RESULTS AND DISCUSSIONS

3.1. Density and specific gravity

Figure 2 shows the produced composite materials. Table 4 shows the densities and specific gravity of the material produced. The densities vary 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 compared to samples reinforced with fibre this may be due to the lighter weight of the fibres. Increase in the fibre content of the composite produced decreases the density and specific gravity of the material which is in accordance with the report on wood composite by [6].

Table 4. Density and specific gravity of composites.

Sample POP/fibre	³ $\hat{\rho}_{PWF}$ (kg/m ³)	³ $\hat{\rho}_{PRF}$ (kg/m ³)	³ $\hat{\rho}_{PYF}$ (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

POP/fibre = percentage of POP/percentage of fibre, $\hat{\rho}_{PWF}$ = density of POP and wood fibre composite, $\hat{\rho}_{PRF}$ = density of POP and rattan fibre composites, $\hat{\rho}_{PYF}$ = density of POP and Yarn fibre composites, ³Average of three values

3.2. Thickness Swelling and water absorption (WA)

Table 5 shows the water absorption percentage of the composite materials. 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. The behaviour of the produced composites was similarly reported by [13], 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. The WA property also increased with the time of immersion as expected, and that explains the disparity in value after 2hrs and 24hrs immersion.

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.

Table 5. Water absorption (%) of composites produced.

Sample POP/Fibre	³ W _{APWF} (%) (2hrs)	³ W _{APWF} (%) (24hrs)	³ W _{APRF} (%) (2hrs)	³ W _{APRF} (%) (24hrs)	³ W _{APYF} (%) (2hrs)	³ W _{APYF} (%) (24hrs)
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

W_{APWF} = Water Absorption for POP-wood fibre composites, W_{APRF} = Water Absorption for POP-rattan fibre composites, W_{APYF} = Water Absorption for POP-Yarn fibre composites, ³Average of three values.

Table 6. Thickness swelling (%) of composites.

Sample POP/Fibre	³ TS _{PWF} (%) (2hrs)	³ TS _{PWF} (%) (24hrs)	³ TS _{PRF} (%) (2hrs)	³ TS _{PRF} (%) (24hrs)	³ TS _{PYF} (%) (2hrs)	³ TS _{PYF} (%) (24hrs)
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

TS_{PWF} = thickness swelling of POP-wood fibre composites, TS_{PRF} = thickness swelling of POP-Rattan fibre composites, TS_{PYF} = thickness swelling of POP-Yarn fibre composites, ³Average of three values

3.3. 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 composites. The results tally with the report of [14], in which the tensile and flexural strength slightly increased with increasing wood fibre content of a Wood Plastic Composites. The rattan fibre reinforced composites has the highest range of MOE values of 4.02 GPa to 5.66 GPa at 90/10 and 70/30 respectively; for wood filler composites, MOE ranged from 3.93GPa to 4.35GPa at 90/10 and 50/50 respectively; and for the yarn filler composites' MOE ranged from 3.96GPa to 4.33GPa at 90/10 and 50/50 respectively. The composites exhibit same behaviour for the MOE and MOR test. The rattan performs best with MOR values of 1.28 MPa to 1.38 MPa at 90/10 and 50/50 respectively; wood fibre ranges from 1.22 MPa to 1.24 MPa at 90/10 and 70/30 respectively; and yarn fibre ranges from 1.21 MPa to 1.23MPa respectively at 60/40 and 50/50. The results compared well with standard value as reported in [15].

Table 7. Results of MOE and MOR.

Sample POP/Fibre	³ MOE _{PWF} (GPa)	³ MOE _{PRF} (GPa)	³ MOE _{PYF} (GPa)	³ MOR _{PWF} (MPa)	³ MOR _{PRF} (MPa)	³ MOR _{PYF} (MPa)
100/0	3.21	3.21	3.21	1.21	1.21	1.21
90/10	3.93	4.02	3.96	1.22	1.28	1.22
80/20	4.15	4.52	4.17	1.22	1.30	1.22
70/30	4.28	5.66	4.20	1.24	1.31	1.23
60/40	4.30	5.17	4.30	1.23	1.38	1.21
50/50	4.35	5.10	4.33	1.23	1.38	1.23

MOE_{PWF} = MOE of POP-Wood fibre composite, MOE_{PRF} = MOE of POP-Rattan fibre composite, MOE_{PYF} = MOE of POP-Yarn fibre composite, MOR_{PWF} = MOR of POP-Wood fibre composite, MOR_{PRF} = MOR of POP-Rattan fibre composite, MOR_{PYF} = MOR of POP-Yarn fibre composite, ³Average of three values.

CONCLUSIONS

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:

- The mechanical properties of all reinforced composite in terms of modulus of rupture (MOR) and modulus of elasticity (MOE) increased with increase fibre contents. However, rattan fibre reinforced composites have the highest value (MOE: 5.66 GPa and MOR: 1.38 MPa respectively at 70/30 and 50/50) meaning that bending strength of rattan reinforced composite is high. Generally, the use of fibre to reinforce Plaster of Paris considerably increased the strength properties of the material.
- The WA and TS properties increased as the fibre contents increased, this implies the composites produced will be more suitable for the internal applications such as ceiling boards.
- The fibre reinforced composites had no significant effect on the surface of the samples produced, as no new shrinkage was formed that may relate to the presence of the fibres in the composites.

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