

PAPER 152 – A REVIEW OF WATER ABSORPTION IN WATER HYACINTH REINFORCED HIGH DENSITY POLYPROPYLENE (HDPP) COMPOSITE

Ojomu, G.O., Adegbuyi, P.A.O., Adefuye, A.O., Raji, N.A., Adedeji, K.A

Lagos State University, Department of Mechanical Engineering, Lagos, Nigeria.

ABSTRACT

Natural plant fibre-reinforced composites have been in use as engineering materials in recent times. They are advantageous because of their light weights, biodegradability, cost and are environmentally friendly. In this paper, a composite of size 75mm x 3.77mm x 20.65mm was developed from 55 grammes of high-density polypropylene (HDPP), 35 grammes of water hyacinth, and 10 grammes of aluminium powder used as a binder. A second sample was produced in the same quantity but was coated with 0.05 micron-film of zinc primer (which weight is negligible). The weights of the composites were initially weighed in the dry forms and recorded. Each of the samples was immersed in same quantity of distilled water for 35 days while the differences in weight percentage in their dried forms and wet forms were noted at intervals of five (5) days by a weighing/timing sensor attached to immersion apparatus for the period. It was noted that the sample with zinc primer weighed less at each measuring interval than the one without; this suggested that water absorption can be minimized with the application of zinc primer or other materials that are waterproofed. Fibre loading was also varied in the composites at 10, 15, 20, 25, 30, 35 and 40 weight percentage (Wt. %) to investigate water absorption as the loading was increasing; water absorption increased as the load increased but less in the sample with zinc primer.

KEYWORDS: Fibre-Reinforcement, Water Hyacinth, Water Absorption, High-Density Polypropylene (HDPP), Composites, Zinc Primer.

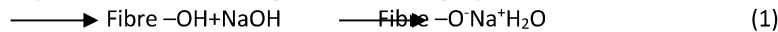
1. INTRODUCTION

Plant fibres and their polymer composites have been found to possess mechanical properties comparable to some engineering materials. In this group of plants is water hyacinth (*Eichhornia Crassifolia*). Water hyacinth is found abundantly on waterways. It has high specific stiffness than other plant fibres like kenaf, jute, sisal, coir, pine apple leaf, cotton, etc, Dhakai, Zhang and Richardson, (2006). The plant constitutes nuisance to fishing expeditions and marine transport. Composites from the plants are lighter in weight; this is a major advantage to other composites. Reinforced plastics and fibre reinforced plastics consists of the fibre, which is the discontinuous or dispersed phase in a polymer matrix (the composition phase). The fibres are the reinforcement and the main source of strength while the matrix transfers stresses between the reinforcing fibres; the fibres carry the loads along their longitudinal direction, Ekundayo and Adejuyigbe, (2019). Sometimes, fillers are added to smooth the production process and impact special mechanical properties to the composites. In this type of composite materials, the low modulus and temperature limitations of the plastics are overcome by reinforcement with fibres of high modulus. Therefore, harvesting this plant and using it as components in fibre-reinforced composites is of more advantage; however, composites from natural plant fibres are hydrophilic as they age in use (Chikol, Teshapa and Bharath 2012); this reduces their service durability.

2. THEORETICAL ANALYSIS

Investigation into the behavior of water hyacinth fibre-reinforced composites was reviewed by Rahman and Afsar (2011); in their research, they developed fibre-reinforced polyethylene composites using water hyacinth, varying the weights of the fibre at 15, 20, 25, 30 and 35 grammes. The fibre was initially treated with sodium hydroxide; another part was not treated with the alkali. Water absorption on the composites was conducted by immersion method on both treated and untreated fibre-reinforced composites. Results of their findings showed that the treated fibre-reinforced samples absorbed less water than the untreated samples; this suggested the treatment with alkali helped in more interfacial bonding between the fibre and matrix than in the untreated one; also, traces of cellulose in the fibre might have added to the bonding, (Begun et al; 2021). The treatment reduced voids and porosity in the treated composites, thereby allowing less water molecules into it; this improved performance in the mechanical properties in the treated than the untreated samples. However, water absorption increased in the composite as the fibre loading increased in the composites. It is therefore necessary to look into this gap and reduce it to a certain degree. Meenalochani and Reddy (2017) also worked on the

principle that water absorption behavior of natural fibre-reinforced composites can be reduced through the removal of OH groups from fibres according to the following equation:



The authors worked on jute-hemp reinforced hybrid polymer composites. This enhanced inter-bonding between the matrix and fibre. The hybrid material act as skin protection, slowing down water intake from 21% to 6%. Fick's law of diffusion plays a major role in the process; it shows that the diffusion coefficient is an important factor. Therefore for diffusion that obeys Fick's law, diffusion coefficient (or moisture intake) can be expressed as the following equation:

$$M = \frac{4Mm}{h} \left(\frac{t}{\pi}\right)^{0.5} * D_x^{0.5} \quad (2)$$

Where M_m =equilibrium moisture content of the sample

h =thickness of the composite sample

t =time of immersion/diffusivity and

D_x = mass diffusivity in the composite.

3. MATERIALS AND METHODS

3.1 Materials

1. Water Hyacinth plant. Source: Lagos lagoon, Nigeria.
2. High density polypropylene (HDPP). Source: Exxon Mobil, Lagos, Nigeria
3. Aluminium powder. Source: ALLUMACCO, Agege, Lagos, Nigeria
4. Zinc primer. Source: Berger Paints. Lagos, Nigeria.
5. Clean basin
6. Distilled water

3.2 Equipment

1. Grinding machine
2. Digital weighing balance
3. Sensory weighing/timing machine

3.3 Method

Water hyacinth was harvested from Lagos lagoon and washed with clean water to remove dirt; the bulk of the fibre was treated with dilute sodium hydroxide (NaOH) to improve adhesion between the fibre and high-density polypropylene matrix. It was thereafter dried in the sun for fifteen (15) days. After this process, the fibre was grinded into powder by a grinding machine. A composite was developed from the fibre and matrix using a 2-Roll mill and compounding moulding machines with a mould size designed to a rectangular size of 75mm x 22mm x 7mm; the high-density polypropylene (HDPP) was first charged into the mill at a temperature of 167 degree centigrade which melted it into liquid form. After this, mixture of the dried water hyacinth and aluminium powder was sprinkled into the melted HDPP and rolled along the mill until the mixture formed homogenous solid mixture. The solid composite was then transferred to the compression moulding machine where it was moulded into the required rectangular shape; this was labeled sample A. Another composite was developed in the same process but was dipped into 2 micron-film of zinc primer and labeled as sample B (the weight of the micron-film zinc primer was assumed negligible). All samples are shown in figures 1 and 2. The samples were first weighed in their dried forms and the weights recorded; they were then immersed in distilled water for thirty five (35) days during which time they were weighed separately again at intervals of five (5) days with a

weighing/timing sensor; the differences in weight were noted at each of the five (5) day intervals with the process of weighing performed three (3) times and the mean values recorded; this was done in order to use the parameters calculate the equilibrium moistures in the composites. Water hyacinth fibre loading was varied in the composites at 10, 15, 20, 25, 30, 35 and 40 weight percentage (Wt. %) to investigate water absorption as the loading was increasing. Since water absorption is measured by measuring the increase in mass as a percentage of dry mass, then it is equivalent to the increase in weight percent as specified in equation 3 below:

$$\text{Increase in weight} = \frac{W_f - W_i}{W_i} \times 100\% \quad (3)$$

Where W_f = weight of sampled in distilled water after specific (determined) days and W_i = initial weight of sample before immersion in distilled water in the specific (determined) days; this is predetermined by the porosity, P:

$$\text{Porosity (P)} = \frac{\Delta W}{T} \quad (4)$$

$$\Delta W = W_2 - W_1$$

W_2 = weight of composite at time t

W_1 = initial weight of composite at time t

Composites Developed

Sample A



Sample B



Figure 1: Composite without zinc primer

Figure 2: Composite with zinc primer

Data from experiment

Weight (Wt) of sample A in dried form= 100 gms

Weight (Wt.) of sample B in dried form= 100 gms

Using equation 1, the water intake per cent (water absorption) was calculated for samples A and B as shown in table 1 below:

SAMPLE A (without zinc primer) SAMPLE B (zinc primer)

Table 1: Water absorption values for samples A and B/days of immersion

DAYS	Wt in wet form	Water Absorption	Wt. in wet form	Water Absorption
5 Days	100.23	0.23	100.21	0.21
10 Days	100.60	0.60	100.43	0.43
15 Days	100.82	0.82	100.62	0.62
20 Days	101.10	1.10	100.81	0.81
25 Days	100.45	1.45	101.15	1.15
30 Days	101.74	1.74	101.48	1.48
35 Days	101.83	1.83	101.63	1.63

Table 2: Fibre loading/water absorption for samples A and B

Fibre Loading (Wt. %)	Sample A Water Absorption	Sample B Water Absorption
10	0.25	0.23
15	0.40	0.38
20	0.68	0.60
25	1.25	0.80
30	1.31	1.11
35	1.40	1.25
40	1.48	1.35

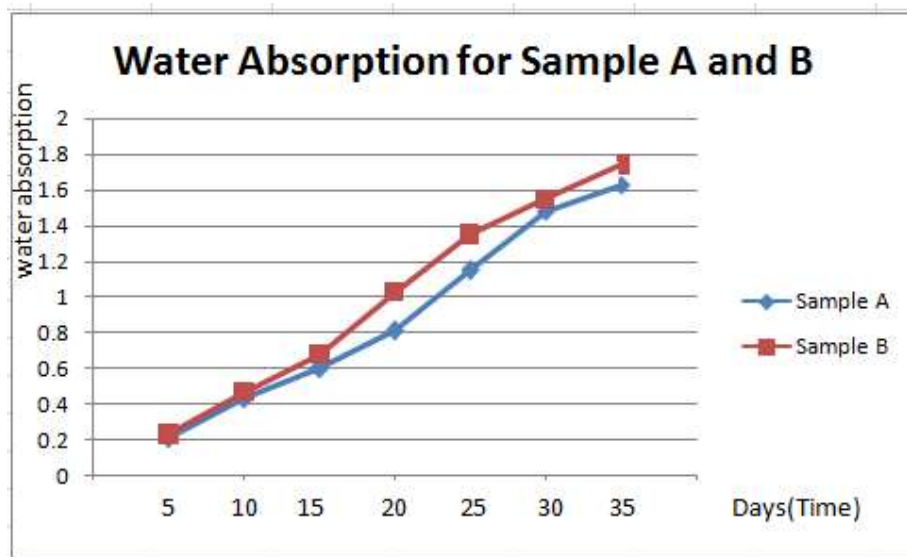


Figure 3: Graph of Water Absorption/Days of Immersion

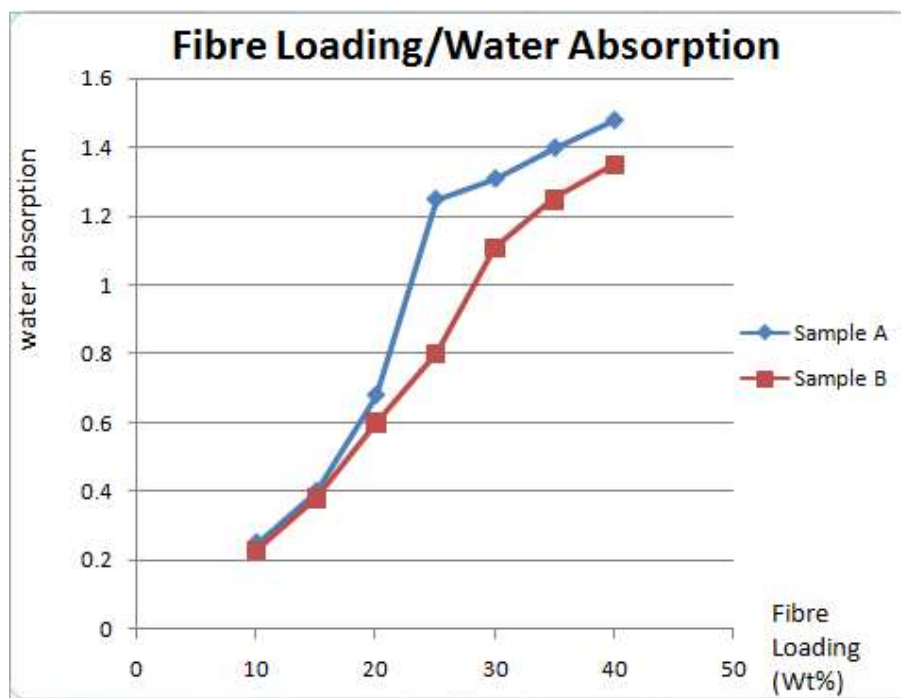


Figure 4: Graph of fibre loading/water absorption

RESULTS AND DISCUSSION

From the results in Table 1, all the samples absorbed water molecules; however, water absorption was less in the sample with the zinc primer because it was less porous because of the 'skin' protection of zinc film; this suggests that coating natural fibre-reinforced composites with zinc primer can reduce water intake, thus reducing the hydrophilic nature of the composites. From 20th to 25th day of immersion in figure 3, there is significant difference between the samples; this significance decreased between day 30 and 35, suggesting saturation was beginning to set in. For fibre loading: in Figure 4, as the fibre loading in the composite samples increased, water absorption increased. When natural fibre is exposed to water molecule (or a humid condition), the cellulose in it is attracted by the humid environment. Between 25 and 40% fibre loading, water absorption increased; this weakens the adhesion in fibre-matrix surface, resulting in brittleness of the composites. However, the sample with the zinc primer (sample B) absorbed less water as shown in the figure (Figure 4).

5.0 CONCLUSION

The research showed that coating fibre reinforced polymer composites reduced moisture intake.

6.0 ACKNOWLEDGEMENT

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