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Mechanical and Water Absorption Analysis of Polyester Hybrid Matrix Composite Reinforced with Clay and Carbon Black

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Abstract: ***This research examines the influence of carbon black (CB) and clay (CL) addition on the mechanical and water absorption behaviour of polyester matrix composite. The aim is to enhance the properties of the polyester matrix for increase service application. The clay was beneficiated to remove impurities of dead decay organic matters and thereafter dried before screening to obtain particle sizes of 660µm while the carbon black was obtained from a petroleum refining company as industrial waste. The carbon black composites (CBC), clay composites (CLC) and hybrid composites (HYC) were fabricated using 2, 4, 6, 8 and 10% wt reinforcement of the particulates. After curing, the samples were tested to determine their tensile, flexural and water absorption potentials. The result shows that the tensile strength of the composites improved when 2% and 4% wt reinforcement of Carbon black (CB) and clay particles (CL) were used and as the percentage reinforcement increased their strength values reduces while the flexural test also shows a decrease in strength value as the percentage particle reinforcements increased. The water absorption results shows a similar trend pattern and from the test it was found that, composites having 8% clay, 2% carbon black and 2% hybrid has the lowest affinity for water.***

Keywords: polyester, clay, carbon black, hybrid, composite, particles

1. Introduction

Polymer composites are materials whose application cuts across various fields of science and technology such as in aircrafts, automobiles, structural application, sports, and household components. [1-2]. Polymer composite has been tagged among the promising field with potentials to yield novel materials and as such have been greatly studied by researchers. Over the years various research works had been carried out to replace synthetic fillers with natural fillers for the reinforcement of polymers. Such natural fillers include egg shells, palm kernel shell, rice husk ash, and coconut shell. These attempts were carried out to enhance the mechanical performance, improve productivity and reduce cost of the polymer [3]. The use of agricultural and industrial by-products as fillers in composites had in recent time been applauded by researchers because they are economical and reasonable methods of developing novel property enhanced engineering materials with edge cutting applications and also helps to create a cleaner and safer environment [4-5].

The need for a cost effective, friendly and environmentally safe material had led various researches to work on reinforcement of resins, with natural particulates fillers or fibers to produce a low cost, eco-friendly and high performance polymer composite. For instance [6] investigated and reported that the development of polymer matrix composite reinforced with snail shell particles recorded an increase in thermal properties of the material with the addition of snail shell particles. [7] Also reported an improvement in the mechanical properties, abrasion resistance and water absorption of polyester composite when reinforced with coconut shell ash and charcoal. [8] Also investigated and revealed that the use of varying particles sizes of snail shells in the reinforcement of polypropylene composite caused an increase in the mechanical properties of the composite. Oladele et al., [9] reported likewise that an increase in the tensile strength and fracture was recorded when polyethylene composites were reinforced with keratin-based biofibre.

Polyester resins are polymeric materials and are limited in their ability to resist temperature, low mechanical strength, weak abrasion resistance and high coefficient of expansion. Although polyesters also possesses good engineering properties and wide range of application but the shortcomings has limited their use for major engineering applications. This limitation can however be addresses by reinforcing the polymer to improve its inherent properties for robust service application [10]. Convectional materials like carbon, kevlar fibre and graphite had been used as fillers in polyester matrix by researchers [11]. But however the high cost of these materials has reduced their use as fillers most especially in developing nations and therefore the need for a low cost alternative replacement like clay and carbon black [12]. Clay is an inorganic filler and is used in this work due to its combined properties of high surface area (>750m^2/g) and high aspect ratio (>100). They exist in different geological settings around the world (13) and are readily available in high volumes at little or no cost. Carbon black is a material produced by the incomplete combustion of heavy petroleum products such as FCC tar, coal tar, ethylene cracking tar, and a small amount from vegetable oil. Based on how they are produced, average primary particle diameters of commercially produced carbon blacks range from10-500 nm, while diameter of average primary aggregate range from 100-800 nm [14]

In this research work clay and carbon black were use as replacement for the rather expensive convectional fillers to produce a low cost properties improved polyester reinforced composite. The aim of the research is to enhance the inherent properties of the polyester matrix to increase its scope for structural and engineering application. The influence of this filler on the polyester matrix was then evaluated by carrying out the mechanical and water absorption analysis on the fabricated composites.

2. Material and Methods

2.1 Materials

The materials used in this research are unsaturated polyester resin, clay, carbon black, 2% Cobalt solution as accelerator, Methyl ethyl ketone peroxide (catalyst), Ethanol and polyvinyl acetate (mould releasing agent).

2.2 Methods

2.2.1 Sourcing and preparation of Clay particulates

The clay was bought from clay miners in Ikere-Ekiti in Ekiti, South-Western Nigeria. The clay was soaked in water for three days and thereafter sieved with a 700µm sieve size. It was thereafter allowed to coagulate for 3days before decantation of surface water was carried out. The slurry clay formed was poured inside a clay drying pit to evaporate the excess water in the clay and then sun dried for 3weeks to remove all free water in the clay before screening with a metallurgical sieve to obtain 660µm clay particle sizes. The carbon black was bought from a petroleum refining company in Efunrun, Warri Delta state.

2.2.2 Composite preparation

The composite samples were fabricated by cold forming method using the samples designation shown in table 1. The polyester resin, particulates and accelerators were first mixed at different weight ratios before the catalyst was added which helps to speed the rate at which the polymer composites were formed. Hybrid samples were also developed using clay and carbon black particles as combined reinforcement of the polymer. The samples were mixed for 10 minutes with a stirrer to obtain a homogenously blended mixture of the resin and particulates before feeding into the mould.

Table 1: Designation for fabricated polyester composites

Materials	Samples Composition
Polyester resin (php-parts per hundreds)	100
Carbon black and clay particles (php)	2, 4, 6, 8, 10
Cobalt solution	2 % of measures polymer
Methyl ethyl ketone peroxide	2 % of measured polymer

Property Test

2.2.3 Measurement of Flexural Strength

The flexural test was carried out according to ASTM D 790 M using a three point bending test. The dimensions of the samples were 150 x 50 x 3mm and the test was conducted using an Instron universal Testing machine. A minimum of three samples were tested for each percentage weight particle reinforcement and the average value was taken as the representative values. The tests were carried out 21 days after the samples had properly cured.

2.2.4 Measurement of Tensile Strength

The tensile tests were measures using an Instron universal testing machine according to ASTM D412 1983 laid down produce. The composites were fabricated to dimensions of 3mm thickness and 150mm gauge length. The tensile value for each reinforcement was determined by finding the average values of each identical samples representation. This process is done to minimize errors in results

2.2.5 Measurement of Water Absorption

The properly cured samples were allowed to dry in open air and then dipped in water under room temperature. The rate of absorbed water was measured at different time intervals. The weights of samples were measures by first drying off water from the polymer surface using a drying cloth before weighing on an electronic weighing balance. Percentage of water absorptivity was evaluated using the expression in equation 1.

$$\%\,Wt = \frac{Wt - W_0}{W_0} \times 100 \qquad (I)$$

From the equation *Wt* is the sample weight at t time while the initial sample weight is Wo

3. Results and Discussion

Figures 1-3 presents the results of the ultimate tensile strength, tensile strain at maximum load and flexural strength of the developed composites. From Figure 1, the ultimate tensile strength of the fabricated composites were observed to show improved results for the 2% and 4% carbon black and clay particles reinforced polymer composites. The UTS was afterwards observed to decrease with increase in particles reinforcement of the matrix. The increase in UTS observed may be attributed to the strong interaction between the particles and matrix which hinders the deformation of the matrix under load. The decrease in UTS as the percentage reinforcement increased may also be due to the increased discontinuity within the matrix and reinforcing particles surface. The ultimate tensile strength however recorded the highest value at 2% and 4% weight reinforcement of carbon black and clay particles reinforcement with values of 1083.7 and 1116.2 N/mm2 recorded when compared to the control sample with a value of 959N/mm2. The hybrid samples were also observed to show a decrease in UTS with increase in particle reinforcement of the composites. This could be attributed to poor interfacial bonding between the carbon black and clay particles within the matrix phase of the developed composite. The rise in tensile values recorded in the 2% and 4% reinforcement can be due to the effective load transfer synergy between the matrix and reinforcement.

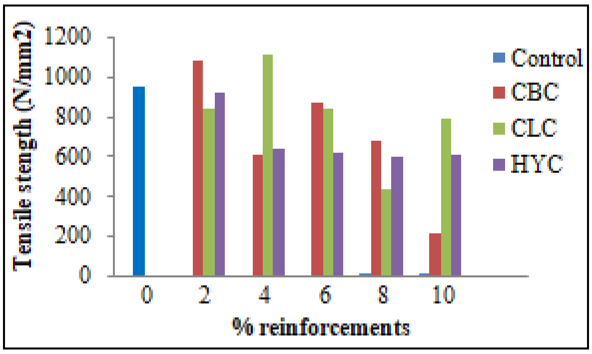

Figure 1: Graph of ultimate tensile strength of developed composites

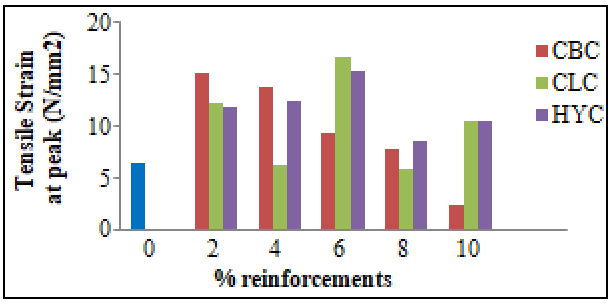

Figure 2: Graph of tensile strain at maximum load of developed composite

Figure 2 shows a gradual decrease in tensile strain at maximum load as the percentage weight reinforcement of the carbon black increased while a fluctuation strain behaviour was observed in the composites reinforced with clay particles with the 6% wt reinforced clay particles showing the highest strain rate. The hybrid samples also shows similar strain pattern to the clay reinforced particles with samples with 6% wt particles having the highest strain rate of 15.43 N/mm2. From the result it was observed that increase in the percentage reinforcement tends to reduce the elasticity of the matrix. This rigidness in the polymer matrix composite causes a reduction in the tensile behaviour and ductility of the material. as reported by salmeh et al., [15] that composites materials decrease in ductility upon addition of fillers and that as the fillers increases, the filler-matrix interactions becomes substituted for a filler-filler interaction which reduces the ductility of the material.

Figure 3 shows the flexural behaviour of the produces composites. The results show that there were no improvements on the produced composites. The flexural behaviour of a material depends on the microstructure and bonding that exist between the particles and the matrix phase which aids in load transfer. [16]. This result may be due to a weak particle-matrix bonding that exist in the developed composites and particle sedimentation at the matrix base without adhesion to the matrix structure. The result also shows that, as the percentage particle reinforcement increased the flexural strength decreases

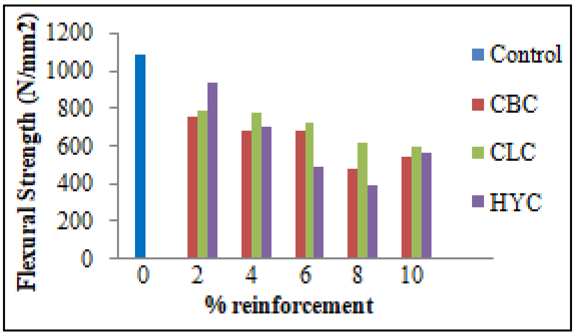

Figure 3: Graph of Flexural strength of developed composites

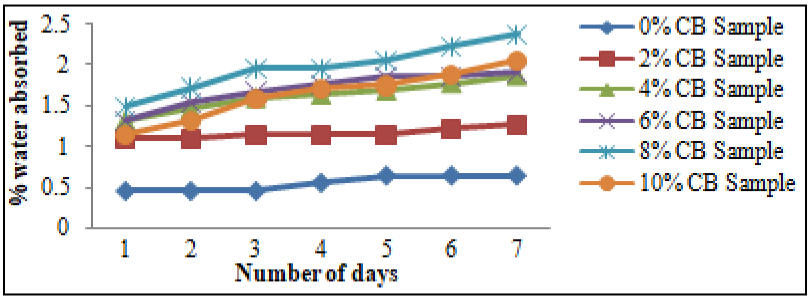

Figure 4: Graph of percentage water absorbed in carbon black reinforced composition

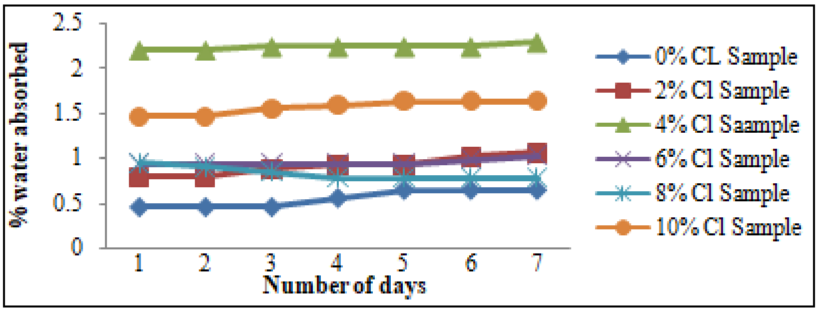

Figure 5: Graph of percentage water absorbed in clay reinforced composition

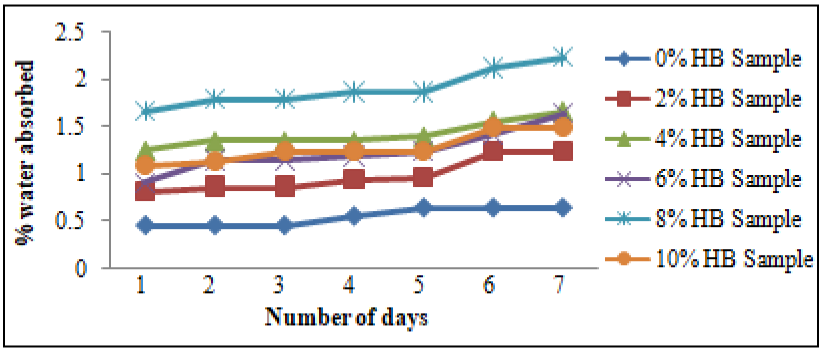

Figure 6: Graph of percentage water absorbed in hybrid reinforced composition

Figure 4 – 6 shows the water absorption relationship between the produced composites in a span of 7 days. The result shows that the affinity of samples for water varied with samples having 2% reinforcements showing the lowest water absorption. The composites show a close water absorption trend with the rate of absorption increasing with increase in particle sizes. It was also observed that all the composites showed water absorption potential higher than the control which may be attributed to the presence of reinforcing particles in the matrix. Samples with 8% carbon black, 4% clay and 7% hybrid reinforced composites were observed to show the highest affinity for water.

4. Conclusion

The following conclusions were drawn within this research:
1) The results of the study showed that tensile strength of the composites were highest when 2% carbon black and 4% clay particle were used as reinforcement in the developed composites.
2) The flexural strength of the polyester reinforced composite were observed to decreased with an increase in clay and carbon black reinforcement which may be attributed to a low particle-matrix interaction.
3) From the water absorption test it was found that, composition having 8% clay, 2% carbon black and 2% hybrid has the lowest affinity for water and thus can may be suitable for use in an area were low water absorption is required.

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