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[1]Isiaka OLADELE, [2]Henry Kayode TALABI, [3]Akeem Damilola AKINWEKOMI

DEVELOPMENT OF CHEMICALLY TREATED OIL PALM FIBER/ARABA (seiba pentandra) WOOD DUST PARTICULATE REINFORCED CEMENTITIOUS COMPOSITES

[1-3] Department of Metallurgical and Materials Engineering, School of Engineering, Federal University of Technology P.M.B. 704, Akure, Ondo State, NIGERIA

Abstract: This work was carried out to investigate the effects of chemical treatment on the mechanical and water absorption properties of wood sawdust reinforced cementitious composites. Araba (*seiba pentandra*) wood, a specie of softwood sawdust was selected and treated with KOH solution at an elevated temperature of 50 °C for 4 hours followed by washing with distilled water and sun drying for 5 days. The dried sawdust was further pulverized and sieve to obtained particle size of 150 μ and oven dried at 65 °C for 1 hour. The composites were developed by mixing the particulate wood dusts with oil palm fiber and the cementitious matrix in predetermined proportions. Mechanical and physical properties tests were carried out on the cured samples to determine properties such as compressive, flexural and water absorption properties respectively. From the analysis, it was found that both chemically treated and untreated fiber and filler serves as good reinforcement materials where chemically treated samples gave the best results in compressive properties while untreated samples gave the best results in bending and water absorption properties.
Keywords: sawdust; oil palm fiber, cementitious, particulate, chemical treatment, composites

INTRODUCTION

A composite is composed of two or more individual materials which come from either metal, ceramics or polymer. A composite material is formed when two or more materials are combined so that the properties of the composite are better than those of individual constituents. The design goal of a composite is to achieve a combination of properties that is not displayed by any single material and also to incorporate the best characteristics of each of the component materials. The properties of composite are a function of the properties of the constituent phases, relative amount and the geometry of the reinforcing phase. Reinforcing phase geometry in this context means the shape of the reinforcement, the size, distribution and orientation of the reinforcing phase [1, 2]. It is by this principle that most composites have been designed to achieve a combination of mechanical characteristics such as stiffness, toughness, ambient and high temperature strength. Composite materials are classified on the basis of the matrix component into three broad types; Metal Matrix Composite (MMC), Ceramics Matrix Composite (CMC), and Polymer Matrix Composite (PMC) [3]. The fracture toughness of ceramics have been improved significantly by the development of a new generation of ceramics matrix composites (CMC)- particulates, fibers, or whiskers of one ceramics material that have been embedded into a matrix of another ceramics. The tremendous interest in composites exists because they can be used to make things that are better and cheaper than those made from traditional in recent times.

The innovative development of high temperature damage-tolerant composite materials with lower cost of processing and fabrication has become imperative as a result of increasing demand for improved materials to replace traditional stocks such as metals in a wide range of application. Cement is an adhesive or glue, which when set binds particles of fine aggregate together to produce mortar. When mixed with water, cement forms a paste which is called the fine matrix and when coarse aggregate is added as in concrete production, the matrix is described as fine and coarse matrix. Cements are hydraulic materials, this means that they depend upon a reaction with water rather than air for strength development. When water is added to cement a chemical reaction called hydration commences immediately and continues while water is still present.

Research directed towards the development of composite materials for both structural and non-structural applications has increased considerably in current years. It is also applicable in areas like aircraft frames, automobile parts, engine components, rocket, satellite and structural buildings. The spur to this rapid expansion over the last few decades was the development in United Kingdom of fibers and in United State of America of boron fibers in the early 1960s. These fibers which have high elastic constants, a significant stiffness, gave very high strength-to-weight and stiffness-to-weight ratios to the composite materials manufactured with them [4]. These synthetic fibers are expensive because of the difficulties in their processing thereby leading to the thought of replacing them with readily available natural organic materials which can almost serve the same purpose of reinforcement. Despite the fact that natural fibres generally have poor mechanical properties as compared with synthetic fibres [5], their use as reinforcement material has been adopted by mankind [6]. The rapid growth has been achieved mainly by the replacement of traditional materials. In the continuing quest for improved performance of materials, this research is being carried out.

Wood fibre (WF) is an attractive reinforcement material because of its low density, low cost, high specific strength and modulus, renewable and biodegradable character due to low degradation when recycled and reasonable process-ability. Wood is natural three-dimensional polymeric composites and consists primarily of cellulose, hemi-cellulose and lignin. In addition, wood is an original and natural composite. Cellulose is the main component. The trees used as raw material by the forest industry are often classified as either softwoods or hardwoods. Softwoods or conifers belong to the group of plants known as gymnosperms (flowerless seed-bearing plants). These include pines, cedars larches, araba and firs. On the other hand, hardwoods belong to the group of plants called angiosperms (flowering plants). They include broad-leaved tree species such as oak, maple, beech, walnut, mahogany, teak and balsa [7].

The name softwood does not imply that wood of such a tree is softer than that from a hardwood. Indeed, the wood of some softwood trees can be harder than that of some hardwood trees. All trees are formed mostly of cells whose length runs parallel to the stem. A smaller number of cells run perpendicular to the stem. However, this work seeks to look into the effect of the selected soft wood dust on the reinforcement potential in cementitious composites. This was with the aim of benefitting from the numerous advantages that are embedded in using agro fibers which are; high mechanical performance, significant processing advantages, low cost and abundance of natural fibre [8]. Natural fibres are relatively cheap, pose no health hazards and finally, provide a solution to environmental pollution by finding new uses for waste materials. Fibres obtained from the various parts of the plants are known as vegetable fibres. Many of the plant fibres find application as a resource for industrial materials [9]. The aim of the work is to add value to some agro wastes that are readily available around us in Nigeria. Wood dust for example, are being produced, dumped and later burnt on daily basis in the Country without any conservation for their use as engineering materials. This work therefore seeks to use them so as to create the awareness for scientists and producers to really adopt their use.

MATERIALS AND METHODS

The materials used in carrying out this research were softwood sawdust from Araba (*seiba pentandra*) wood, Oil palm fiber, Cement, Potassium hydroxide (KOH) and Distilled water.

Processing of Sawdust and Oil Palm Fiber

The wood sawdust used for this research was obtained from sawmill during milling operation in Akure, Ondo State, Nigeria. Also, the oil palm fiber was obtained from Aponmu in Ondo State, Nigeria. Both the wood saw dust and the oil palm fiber were sun dried for 3 days before chemical treatments were carried on them.

Mass of wood sawdust prepared- 1200 g which was divided into two equal mass of 600 g.

Mass of wood oil palm prepared- 500 g which was divided into two equal mass of 250 g.

Chemical treatments were carried out using a solution of 2 M KOH maintained at 50 ^{o}C for 4 hours. This was used to treat the wood sawdust and oil palm fiber which are all lignocellulose materials so as to reduce the lignin and hemicellulose contents that are present for effective binding at the fibre/matrix interface and as well preserved them from fungi attack. Some other parts of the sawdust and oil palm fiber were left untreated.

Pulverizing of the Sawdust

The dry sample of the sawdust was pulverized using ball mill and sieved with mesh of grain size 150 μm.

Composites Formulation

The process employed in mixing the various constituents: cement, sawdust and oil palm fibers reinforced cementitious composites were as shown in Table 1 for treated wood saw dust and oil palm fiber. The same compositions were also used for the untreated wood saw dust and oil palm fiber composites. Where; TS - Treated Soft, US - Untreated Soft, CS - Control Samples.

Table 1. Experimental Composition

Sample	Cement (g)	Treated Wood sawdust (g)	Treated Fiber (g)
TS_1	1485	15	10
TS_2	1455	45	10
TS_3	1425	75	10
TS_4	1395	105	10
TS_5	1365	135	10
TS_6	1335	165	10
CS	1500	-	10

Production of Composites

The composites were developed by mixing the wood saw dust which serves as filler with oil palm fiber that serves as reinforcement and the cement as binder in predetermined proportions. After thorough stirring to obtain homogeneous paste, the mixture was poured into the mould of the flexural and compressive test samples. The filled moulds were compacted with laboratory compression machine maintained at constant load 20 KN for 10 minutes before being removed. The compacted samples were removed from the moulds and were allow to further cured and solidified for 30 days in the laboratory at ambient temperature.

Testing for the Mechanical and Physical Properties

Following the moulding of the composites, samples were prepared and subject to flexural, compressive and water absorption tests.

Determination of the flexural property of the materials

Flexural test was carried out by using Testometric Universal Testing Machine in accordance with ASTM D790. To carry out the test, the grip for the test was fixed on the machine and the sample that has been cut into the test piece dimension of 150 mm x 50 mm x 3 mm, was hooked on the grip and the test commenced. As the specimen is stretched the computer generates the required data and graphs. The Flexural Test was performed at the speed of 100 mm/min.

Determination of the compressive property of the materials

Compressive test was carried out using universal testing machine machine. The compressive strength is usually obtained experimentally by means of a compressive test. The machine used for this test is the same as that used in a tensile test. However, rather than applying a uniaxial tensile load, a uniaxial compressive load is applied. As can be imagined, the specimen (usually cylindrical) is shortened as well as spread laterally. A stress-strain curve is plotted by the instrument.

Determination of the water absorption property of the materials

Water absorption test was carried out in accordance with International Organisation for Standardisation, ISO 175-1981 (E). To carry out the test, clean plastic containers were procured into which 250 cm^3 of water media were measured using measuring cylinder. The initial weight of each of the sample is taken using chemical weighing balance; FA2104A Model which is of high precision ± 0.0001 g accuracy before dropping inside distilled water medium used and readings are taken at an hour interval for 7 hours. To take the readings, the samples were brought out, clean with white cloth and weighed. The data collected was used to determine the % water absorption using the formula in equation 1 below.

$$\text{Water Absorbility (\%)} = \frac{\text{Final Weight} - \text{Initial Weight}}{\text{Initial Weight}} \times 100 \quad (1)$$

RESULTS AND DISCUSSION

Bending Test Results

Figure 1 revealed the results of the flexural test at peak performed on the developed composites. From the results, it was observed that both treated and untreated fiber reinforced cementitious composites developed exhibit similar trend in the values of the bending strength at peak. Also, noticed was that, all composites developed with the addition of filler material possess better strength than the one without the filler material that was used as the control. This shows that the addition of this filler material has actually aid the enhancement of the strength at reduced cement content which justified the reason why the composites were developed.

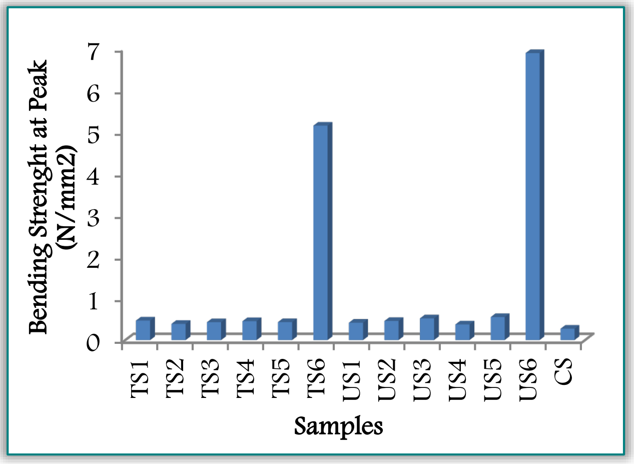

Figure 1. Graph of Bending Strength at Peak against Samples

Best performance was obtained at 1335:165 g of cement to wood dust in both cases which implies that, the best strength at peak was attainable at the maximum filler content since the fiber was kept constant. However, sample denoted as US_6 has the optimum value of 6.98 N/mm^2 followed by sample denoted as TS_6 which has a value of about 5.15

N/mm² compared to the control sample with a value of 0.27 N/mm². Considering the % increase that this amounted to, it was > 1000 from the best result.

The result of the bending modulus was as shown in Figure 2 from where it was observed that the two sets of the developed composites respond to the property differently. While the samples from the untreated fiber/filler reinforced cementitious composites tend to increases as the weight content increases, the treated fiber/filler reinforced cementitious composites did not show any trend. It can be seen from the results of the untreated fiber/filler reinforced cementitious composites that from US_3-US_6, the bending modulus was better enhanced compared to the control. Nevertheless, the best two samples happened to be those that were the best from Figure 1 above but unlike the results, the control sample was able to perform more than some of the composites with filler. The response of the composites was better in modulus than strength at peak as can be seen from Figures 1-2. These results demonstrated that, some materials may be weak in some properties and be strong in another and, therefore can be tailored towards their areas of strength. Best performance was obtained at 1335:165 g of cement to wood dust in both cases which implies that, the best bending modulus was attainable at the maximum filler content. Sample denoted as US_6 has the peak value of 1.66 N/mm² which marginally exceed sample denoted as TS_6 which has a value of about 1.64 N/mm² compared to the control sample with a value of 1.00 N/mm². This amounts to about 66 % increase from the best result.

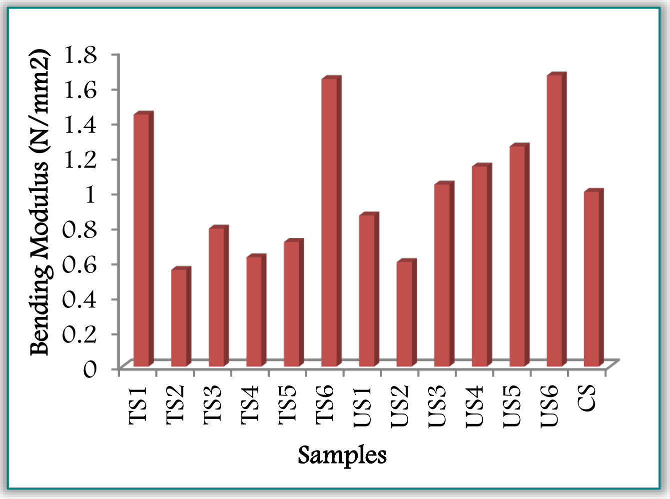

Figure 2. Graph of Bending Modulus against Samples

Compressive Test Results

The response of the materials to compression test was as shown in Figure 3 for compressive strength at peak. It was noticed that the treated fiber/filler reinforced cementitious composites performed better than the untreated fiber/filler reinforced cementitious composites. Composite sample denoted as TS_2 which has a composition of 1455: 45 g of cement to wood dust has the optimum value of about 12962 N/mm² followed by sample denoted as US_4 which has a composition of 1395: 105 of cement to wood dust with a value of 10368 N/mm² compared to the control with a value of 9634 N/mm². By this performance, the addition of the filler material to the composite has aid 35 % increase in the compressive strength at peak from the treated sample.

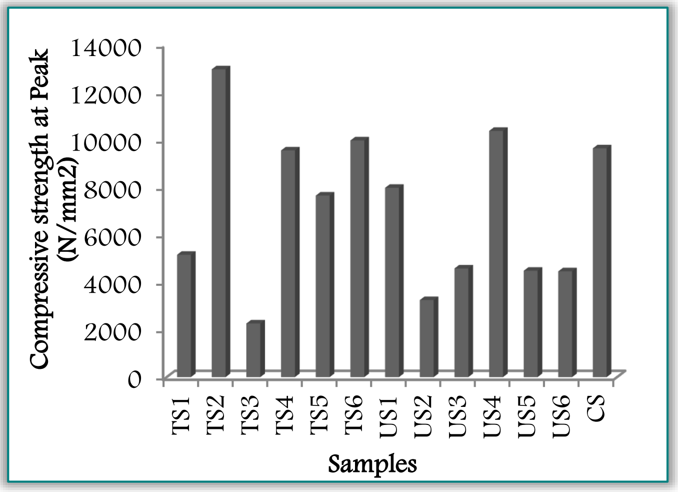

Figure 3. Graph of Compressive Strength at Peak

The response of the materials to compressive modulus was as shown in Figure 4. The modulus of the treated fiber/filler reinforced cementitious composites performed better than the untreated fiber/filler reinforced cementitious composites where they reflect weak behavour compared to the compressive strength at peak.

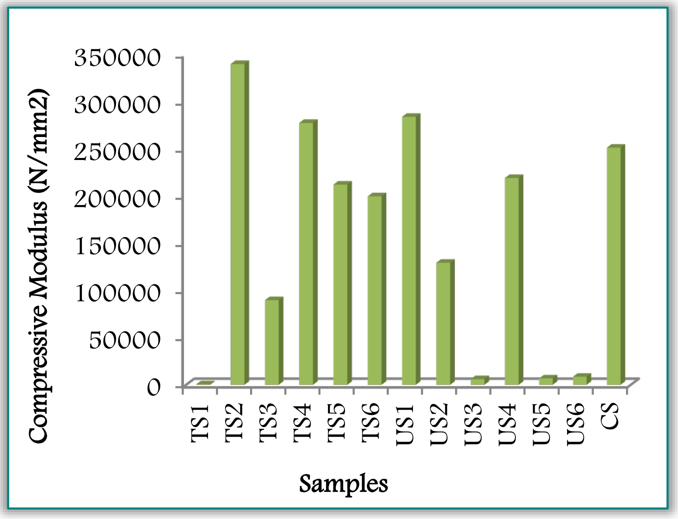

Figure 4. Graph of Young Modulus against Samples.

From the results, composite sample denoted as TS_2 which has a composition of 1455: 45 g of cement to wood dust has the optimum value of about 339985 N/mm² followed by sample denoted as US_1 which has a composition of 1485: 15 of cement to wood dust with a value of 284160 N/mm² compared to the control with a value of 251607 N/mm². By this performance, the addition of the filler material to the composite has aid 35% increase in the compressive modulus from the treated sample.

Water Absorption Property Response

The results from the water absorption test were shown in Figure 5 from where it was observed that the materials respond in a similar manner to the test. All the samples were noticed to absorbed more water as the time increases. However, the untreated fiber/filler reinforced cementitious composites performed better than the treated fiber/filler reinforced cementitious composites by absorbing less amount of water within the time limit examined. This good performance was highly noticed within the range of US_4-US_6. The control sample was observed to absorb the highest amount of water being majorly dominated by cement.

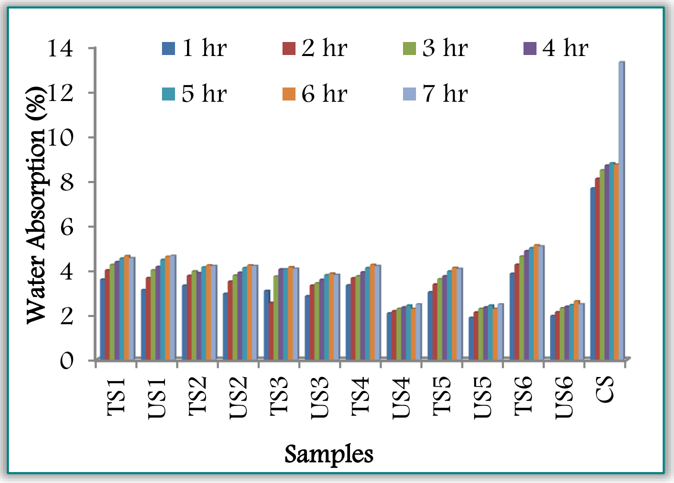

Figure 5. Graph showing the Response of Samples to Water Absorption in Hours.

CONCLUSION

Investigations of the mechanical and physical properties of the developed composites from this research have shown that the use of wood dust as fillers in cementitious composites is a promising technological advancement. This was possible since the outcome of the research have shown that;

Both chemically treated and untreated fiber and filler serves as good reinforcement materials where chemically treated samples gave the best results in compressive properties while untreated samples gave the best results in bending and water absorption properties. As a result of this, the use of these agro-wastes makes the research and the developed composites environmental friendly and economical.

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