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Investigation of the properties and production of sawdust ceiling tile using polystyrene as a binder

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In this research, a production and properties investigation of wood sawdust ceiling tile using polystyrene as a binder was carried out. The content by weight of the wood sawdust was 5, 10, 15, 20, 25 and 30% consisting of three composite samples for each of the six filler content percentages. The samples were prepared in accordance with the American Standard for Testing and Material (ASTM) for wear resistance, flexural and tensile properties as well as water resistance. From the results, it was observed that with the exception of the wear loss, 5% sample gave the best values next to the control sample in almost all the properties. For wear resistance, the value was 0.4568 g and was the sample with the best wear resistance. The result revealed that curing rate is highly influenced by the filler since it decreases as the filler content increases. Higher resistivity was recorded as the filler content increased and this may not be unconnected to the fact that air, being a poor conductor, is more in the composite where we have more filler content.

Keywords: composites, hydrophilic, mechanical properties, polymers, reinforcement, resilience

Introduction

The research on using natural fibres to reinforce composite materials has increased markedly during the last few decades. Fibre-reinforced composites consist of reinforcing a polymer matrix, which acts as a binder for the fibres (Srinivasababu, Murali Mohan Rao, and Kumar 2010, 34). The use of natural fibres as reinforcement of polymeric materials for automobile, structural and packaging applications has, therefore, become of increasing interest to researchers (Oladele, Omotoyinbo, and Borisade 2013, 2). The significant aspect of this commonly employed composite material is to ensure that stresses on the composites materials are transmitted via the fibre/polymer matrix interface to the reinforcing fibres, which enhances the stiffness and strength of the material. Sawdust or wood dust is a by-product of cutting, grinding, drilling, sanding, or otherwise pulverizing wood with a saw or other tool; it is composed of fine particles of wood.

Wood sawdust is the main component of particleboard. Wood sawdust has a variety of other practical uses like wood pulp, mulch and as an alternative to fuel. It has been used in artistic displays and as scatter. It is also sometimes used to soak up liquid spills which allow the spill to be easily collected or swept aside. As such, it was formerly common on bathroom floors. It is used to make Cutler's resin (Chaharmahali, Tajvidi, and Najafi 2008, 606).

There is a growing interest in the use of natural fibres as reinforcing components for both thermoplastic and thermoset matrices because of the ideal benefits offered by natural fibres such as convenient renewability, biodegradability and environmental friendliness (Srinivasababu, Murali Mohan Rao, and Kumar 2009, 34)

Polystyrene is a synthetic aromatic polymer made from the monomer styrene, a liquid petrochemical. Polystyrene can be rigid or foamed. General purpose polystyrene is clear, hard and brittle. It is a very inexpensive resin per unit weight. It is a rather poor barrier to oxygen and water vapour and has a relatively low melting point. It is used to make napalm-B, where it makes up about 46% of the formulation (Clemons 2002, 123). As a thermoplastic polymer, polystyrene is in a solid (glassy) state at room temperature but flows if heated above about 100°C, its glass transition temperature, and becomes rigid again when cooled. This temperature behaviour is exploited for extrusion, and also for moulding and vacuum forming, since it can be cast into moulds with fine detail. In chemical terms, polystyrene is a long chain hydrocarbon wherein alternating carbon centres are attached to a phenyl group (the name given to the aromatic ring benzene). It does not biodegrade easily and, therefore, in Nigeria, it is usually regarded as waste and litters the environment, particularly along shores and waterways, especially in its foam form (Bledzki, Reihmane, and Gassan 1998, 451).

Thermoplastic polymers reinforced with natural fibres present mechanical properties similar to the properties obtained by adding other inorganic fillers like talcum, calcium carbonate and glass fibre or synthetic fibres like polyester and polyamide but with low density (Kim and Pal 2011; 59; Oladele, Omotoyinbo, and Borisade 2013, 2). Natural fibre reinforced thermoplastics, in comparison with their competitors, have a lower part energetic content that, in manufacturing, does not have any harmful effect on consumers and they are biodegradable, though at different degrees (Oladele, Omotoyinbo, and Borisade 2013, 2; Sanadi et al. 2001, 15). This work assesses the viability of the use of these materials, commonly regarded as wastes, as engineering materials for structural applications.

Material and method

The wood sawdust ceiling tile was prepared using polystyrene as a binder. The materials used for the specimen preparation were wood sawdust (cedar wood), polystyrene and gasoline. The dry sample of the sawdust was pulverized using a ball mill BM-540 (1.5 hp) and sieved with mesh with a grain size of 106 μm. Three test samples were prepared for wear, flexural and tensile tests for each of

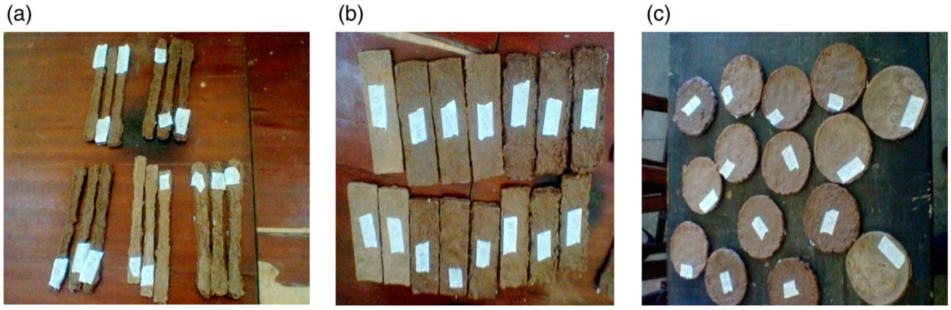

Figure 1: Developed samples for tensile, flexural and wear tests.

predetermined proportions as well as the control sample. The samples were subjected to tests in accordance with the procedures stipulated in ASTM standards: ASTM 1044, ASTM D790 and ASTM D412 for wear, flexural and tensile tests, respectively. The metal moulds were cleansed and coupled together to form the required wear, flexural and tensile shapes. The polystyrene particle was dissolved in gasoline to form aqueous solution. The fibre (cedar wood) particles were then introduced into the known quantity of aqueous polystyrene and stirred thoroughly in order to obtain a homogeneous mix and to allow for the proper dispersion of the fibre within the matrix. The dimension of the flexural mould used was 150 × 50 × 3 mm while the tensile and wear moulds were prepared according to ASTM D412 and ASTM 1044, respectively. The prepared formulation of the polystyrene and cedar wood dust was poured to fill the moulds and clamped to allow the sample composites to solidify. Control samples made of polystyrene were also formed for each test. When fully cured, they were stripped off the moulds and allowed to solidify naturally for 21 days to prevent internal micro cracking of the composite resulting from induced stresses. Samples of the test pieces are shown in Figure 1.

Mechanical testing of cast samples

(a) *Determination of the tensile properties of the materials*.
Tensile tests of the samples were performed on INSTRON 3369 at a fixed Crosshead speed of 10 mm min-1. Samples were prepared according to ASTM D412 (ASTM D412 1983) and tensile properties were determined in line with those put forward by Oladele, Omotoyinbo, and Borisade (2013, 6).

(b) *Determination of the flexural property of the materials*.
Flexural test was carried out by using a 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 had dimensions of 150 × 50 × 3 mm was hooked on the grip and the test commenced. As the specimen is stretched the computer generates the required data. The flexural test was performed at the speed of 100 mm/min in agreement with Oladele, Omotoyinbo, and Borisade (2013, 6).

(c) *Determination of the wear property of the materials*.
Abrasive wear occurs when a hard, rough surface slides across a softer surface. ASTM International (formerly American Society for Testing and Materials) defines it as the loss of material due to hard particles or hard protuberances that are forced against and move along a solid surface. The wear is calculated using the weight loss from the sample. The Taber Abraser, ASTM 1044, was used to measure the low-stress abrasive wear resistance of materials.

Water repellent test

Water repellent test of samples were carried out in the laboratory at room temperature. The dry samples were first

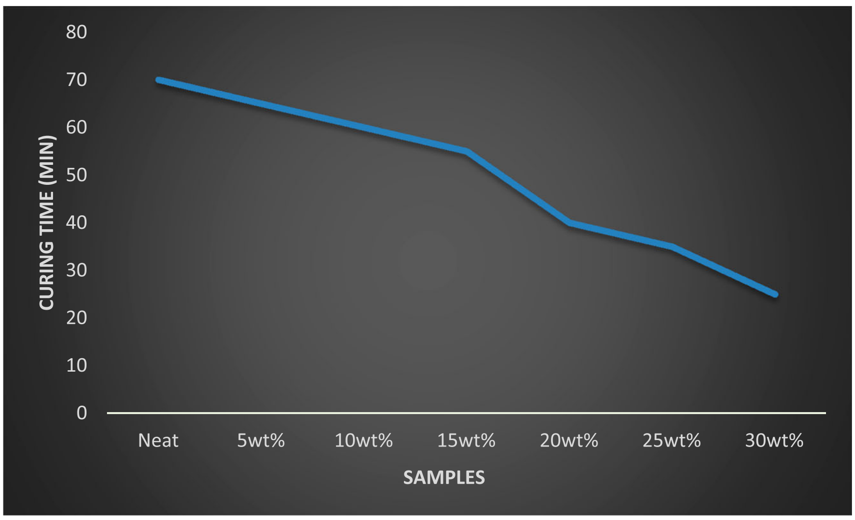

Figure 2: Plots of curing time for the developed samples.

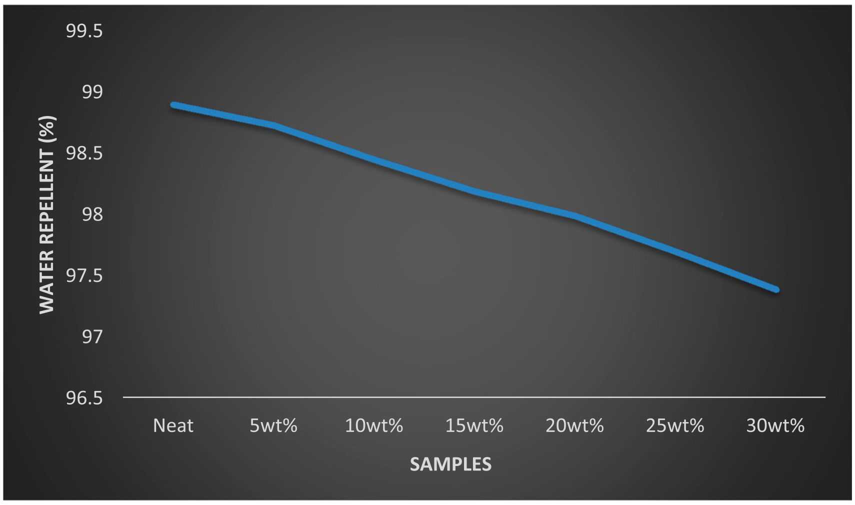

Figure 3: Water repellent properties of the developed samples.

measured on the weighing balance and, thereafter, they were soaked in a bowl of water for seven days, with the weights of the specimens taken at 24-hour interval. This was observed until there was no significant increase in the weight of the specimen. Then, the final weight, when there was no increase in the weight of the samples, was recorded. The difference in the dry sample weight and the saturated weight of the sample was recorded. The percentage weight of the specimen sample was calculated and recorded as shown in Equation (1).

$$\% \, W_t = \frac{W_t - W_o}{W_o} \times 100 \qquad (1)$$

where W_t is the weight of sample at time t and W_o is the initial weight of the sample.

Results and discussion

Composite curing time test results

As Figure 2 shows, the composite curing time decreases as the fibre content increases, resulting in the 5 wt% filler content composite having the longest curing time. This result further shows that increasing filler content aids curing time of the composites. The sample with 30% by weight of wood dust cured the fastest of all samples with a value of 25 minutes compared to the neat sample that had a curing time of 65 minutes. This implies that by adding this filler to the matrix, the production time can be reduced, thereby improving the rate of production.

Water repellent test results

Figure 3 shows the results of the water repellent capability of the developed samples. It can be seen from the results that the sample with 5% by weight has the highest water repellent value of 98.73%. This result, when compared with the control sample, has relatively the same value. This shows that there was little void and good miscibility between the low wood dust particle addition and the polystyrene. From the analysis, it was noticed that an increase in the filler content increases its water absorption, thereby reducing its water repellent properties. This could be explained by wood composition because wood sawdust contains high hydrophilic content (cellulose and hemicelluloses). The larger the amount of filler content, the higher

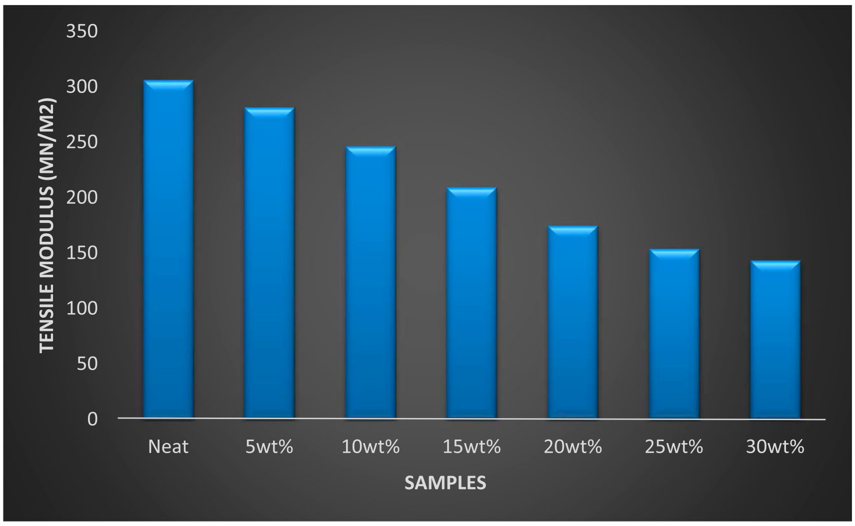

Figure 4: Plots of tensile modulus for the developed samples.

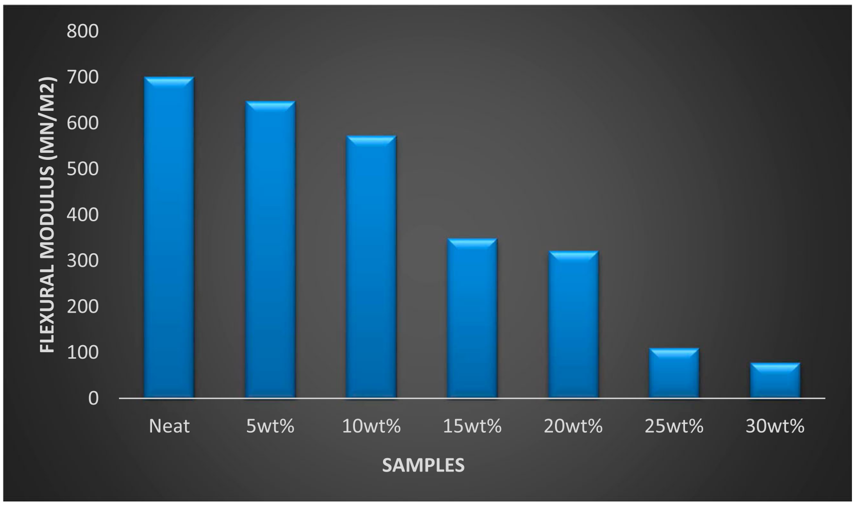

Figure 5: Plots of flexural modulus of the developed samples.

the water absorption value, subsequently decreasing the water resistance of the composites.

Modulus of elasticity test results

The modulus of elasticity test results are shown in Figure 4 where the neat sample was observed to possess the best modulus with a value of 305.82 MN/m^2 followed by sample made with 5% by weight filler content with a value of 281.13 MN/m^2. This value is relatively closer to that of the control sample. Also from this result, it is evident that the modulus of elasticity decreases as the filler content increases. This is not unconnected to the fact that polymer has a higher tensile strength and the adhesive properties between the two constituents of the composite may be contributing to the decrease in the modulus of elasticity as the filler content increases.

Flexural test results

Figure 5 shows the results of the flexural test conducted on the various samples. From the plots, it was observed that the flexural modulus decreases as the filler content increases. However, the sample developed with filler content of 5% by weight showed a comparatively higher modulus of elasticity when compared with the control sample. From the analysis, it shows that 5% by weight filler content displays a very good property in terms of tensile and flexural properties compared with other composites. This result is in agreement with the findings of Mohd, Mohd, and Mohd (2010, 87) who reported that for oil palm reinforced epoxy composites flexural strength showed a decreasing trend as the volume fraction of the fibre increased.

Wear test results

Figure 6 shows the results from the wear test. From the results it was observed that the wear resistance of the developed composites tends to decrease as the filler content tends to increase. However, the sample developed with 5% by weight filler content had the best wear resistance with a value of 0.4568 g. This value shows that the composite has a higher resistance to wear than the control sample which had a value 0.4802 g.

Thermal conductivity test results

The thermal conductivity of a material is the quantity of heat transmitted through a unit thickness in a direction perpendicular to a surface of a unit area due to a unit temperature gradient under given conditions (Sengul et al. 2011, 671). The thermal conductivity of the composites was

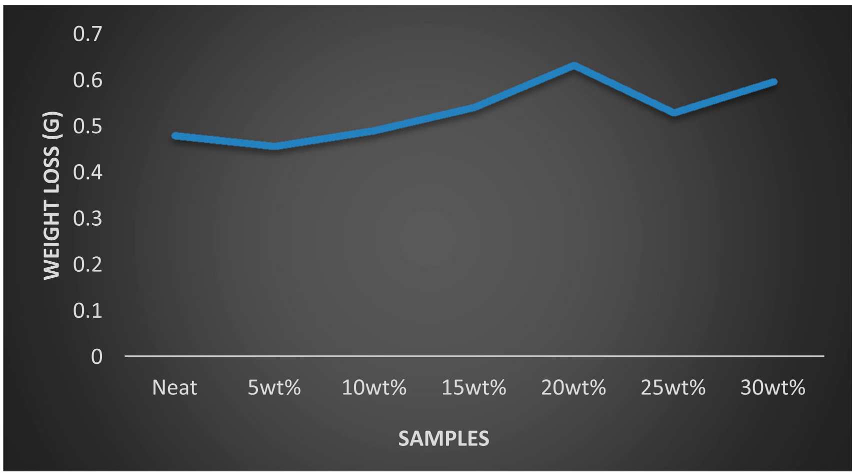

Figure 6: Wear properties of the developed samples.

Table 1: Thermal conductivity result.

Samples (%)	Thermal conductivity (W/mk)	Thermal resistivity (%)
5	0.0250	40
10	0.0215	47
15	0.0185	54
20	0.0155	65
25	0.0135	74
30	0.0115	87
Neat (Control)	0.0285	35

investigated and the results compared with that of the control sample. The results prove that the composite samples are superior in thermal resistivity. However, higher resistivity was recorded as the filler content increased and this may not be unconnected to the fact that air being a poor conductor is more in the composite where we have more filler content; molecular structure which is in consonant with (Low and Ng 2010, 2452). Lower thermal conductivity is observed in porous samples containing high levels of wood dust, as shown in Table 1.

Conclusions

From the obtained results, it was evident that the wear resistance as well as the thermal resistivity of the composites were enhanced by the addition of this wood sawdust filler. In most of the properties examined, the sample developed with 5% filler content emerged as the best, except for thermal resistivity in which the sample with 30% filler content happened to be the best.

The work suggests the possibility of using these waste materials as engineering material for structural applications.

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