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PRODUCTION AND CHARACTERIZATION OF SAND-PLASTIC COMPOSITE FLOOR TILES

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The amount of plastic waste generated in developing nations like Nigeria is increasing day by day, which is non-biodegradable and causes environmental pollution. Among the plastics used, low-density polyethylene is abundant. These plastics can be removed from the environment and recycled into useful products. In this study, low-density polyethylene plastic waste was utilized in the manufacture of floor tiles to curb its generation. The tiles were produced by mixing fine sand with molten plastic waste in different proportions. The physical and mechanical properties of the floor tiles such as water absorption, density, tensile and compressive tests, modulus of elasticity as well as impact strength and friction tests were investigated. The water absorption ranged from $0.02 - 0.38$ %(m/m), while the density varied between 998.5 and 1289 kg/m^3. The tensile strength and modulus of elasticity fell within the range of 0.050 to 0.232 MPa and 0.924 to 2.806 MPa, respectively. This result proved the applicability of recycled plastic waste in the formulation of floor tiles.

Keywords: plastic waste, floor tiles, low-density polyethylene, pollution, properties

1. Introduction

Plastic waste is now a global problem and one that must be addressed in order to solve worldwide problems concerning resources and energy. Plastics are a generic group of synthetic or natural materials consisting of high-molecular-weight chains composed predominantly if not entirely of carbon. They are classified into two categories, namely thermoplastics and thermosetting plastics, moreover, are found in different forms, e.g. as bags, furniture, cups, basins, drinking and food containers, etc. [1].

The increasing consumption of plastic products in various fields generates a significant amount of waste products, equating to more than 12% of municipal solid waste. Since plastics are non-biodegradable, that is, cannot easily reenter the natural carbon cycle, the life cycle of plastic materials ends at solid waste disposal facilities and in water bodies. However, the full extent of plastic pollution goes far beyond macroplastic litter. Microplastics can contain additives, which have the potential to leach into the surrounding environment, resulting in toxicity to organisms, including carcinogenesis and disruption of the endocrine system in humans [2].

There are several methods for disposing of municipal and industrial plastic waste such as landfill, incineration, true material recycling and chemical recovery. Treating plastic waste suitably is crucial to waste management and important in terms of energetic, environmental, economic and political viewpoints. Some plastics can safely be recycled, while others cannot so litter the environment [3].

A large and increasing amount of household plastic waste is being produced. The composition of waste varies from country to country, since it is affected by socioeconomic characteristics, consumption patterns and waste management programmes. Nevertheless, generally speaking, the proportion of plastics concerning the composition of waste is high. The largest component of plastic waste is polyethylene, followed by polypropylene, polyethylene terephthalate and polystyrene [4].

Polyethylene is the most common plastic and can be classified into several different categories based mainly on its density and branching. Important grades pf polyethylene are high-density polyethylene (HDPE), linear low-density polyethylene (LLDPE) and low-density polyethylene (LDPE). Plastic is recycled worldwide since it reduces environmental impacts associated with the improper disposal of plastic waste. Therefore, this study focused on the production of floor tiles by mixing sand and plastic waste in different proportions. The characterization of the tiles will provide some insight into the suitability of applying sand-plastic composites in building constructions.

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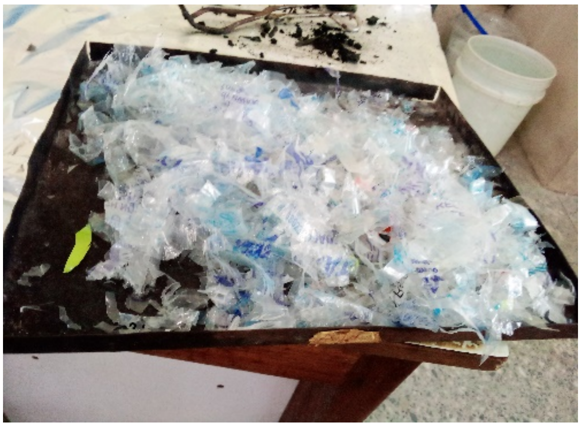
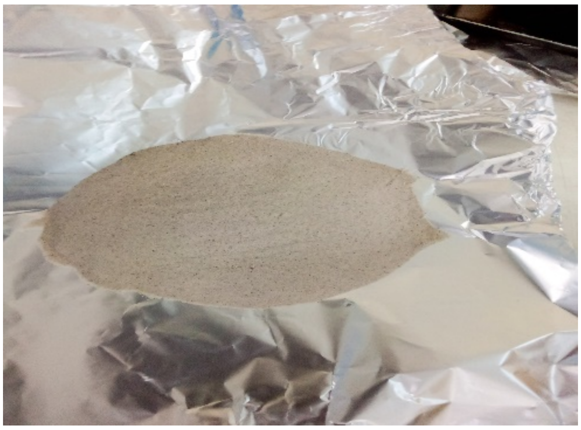


(a) Shredded LDPE



(b) Fine sand

Figure 1: Formulation samples

2. Materials and Methods

2.1 Sample collection and preparation

The plastic waste was collected from the University of Uyo Water Company landfill site in Uyo, South-South Nigeria. The LDPE plastic waste was washed with water to remove dust and other impurities. The washed sample was sun dried for 48 h and shredded into smaller pieces (Fig. 1a). A clay-free sample of fine sand (Fig. 1b) was obtained from Ifiayoung stream in Uyo, sun dried for 24 h, then oven dried at 105 °C for 4 h before being sieved through a 125 μm mesh.

2.2 Formulation and Production of Floor Tiles

35 g of plastic waste was continuously introduced into a fabricated melting pot made of stainless steel and heated to a temperature of 160 °C , whilst being stirred continuously to ensure homogeneous melting. 105 g of fine sand was then added to the melted plastic waste before being well mixed. The mixture was transferred into a stainless-steel mould with the dimensions of $10.0 \times 10.0 \times 1.5$ cm coated with a lubricating oil to facilitate demoulding. The mixture in the mould was compressed by applying a force before being cooled in a water bath for 5 mins. The resulting tile was then removed from the mould. The production process was repeated by varying the proportions of plastic waste and fine sand. The samples of tiles produced using different formulations are shown in Fig. 2.

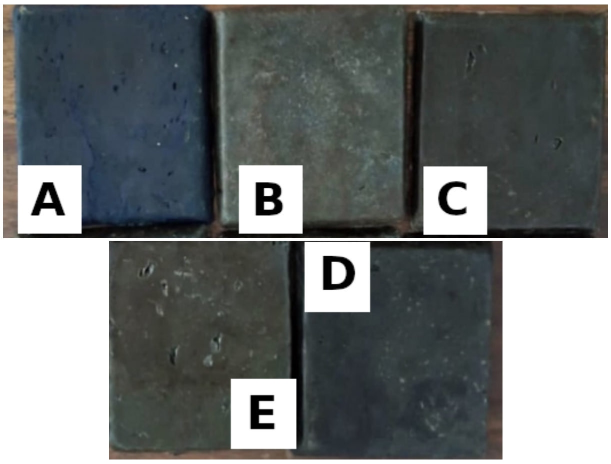


Figure 2: Samples of Floor Tiles

2.3 Characterization of Floor Tiles

Water absorption

Water absorption tests were carried out in accordance with the ASTM-C373 standard test method. Each sample was oven dried at 110 °C to constant weight (W_o) before being immersed in distilled water at room temperature (25 °C) for 24 h. The samples were removed from the distilled water, cleaned with a cotton fabric and weighed (W_t). The amount of water absorbed (W_a) by each sample was calculated using

$$\%W_\mathrm{a} = \frac{(W_\mathrm{t} - W_\mathrm{o})}{W_\mathrm{o}} \times 100 \tag{1}$$

Density

The density of each sample was calculated using

$$\text{Density} = \frac{\text{mass of sample}}{\text{sample volume}} \tag{2}$$

Impact strength

Impact strength was measured using a JBS-300N model Charpy impact testing machine and determined according to the ASTM D6110-18 standard test method. A standard sample was prepared with the dimensions 1×8 cm while maintaining the original thickness before being placed on the plate of the impact testing machine, wherein the jack handle was carefully released to allow the load to strike the sample of the ceiling board. The energy of the impact was recorded and the impact strength calculated by

$$\text{Impact Strength} = \frac{\text{Absorbed Energy}}{\text{Cross-sectional Area}} \tag{3}$$

Tensile strength

This was determined using the Mohan Brothers Tensile testing machine CAP, 500KGF ISO9001 model. The samples were prepared for this test according to the ASTM C1185 standard test method (Type II). Each sample was carefully placed in the tensile testing machine and clamped at both ends. The machine was turned on and the load at which each sample fractured recorded. The tensile strength was calculated by

$$\text{Tensile Strength} = \frac{\text{Maximum Load}}{\text{Original Cross-sectional Area}} \tag{4}$$

Young's Modulus of Elasticity

Young's Modulus of Elasticity (Y) is a measure of stress per unit strain and was calculated using

$$Y = \frac{\text{stress}}{\text{strain}} \tag{5}$$

Friction Test

A friction test was conducted using the Cussons friction test device graduated from $0 - 90°$ and was performed based on the ASTM D1037-94 standard test method. The sample was placed on an inclined plane of the piece of equipment and the angle at which the specimen slid freely down the surface was recorded. The coefficient of friction was calculated by:

$$\text{Coefficient of Friction} = \tan\theta \tag{6}$$

where θ denotes the angle of repose.

Compressive Strength

A compressive strength test was carried out using a universal testing machine and performed based on the ASTM D790 standard test method. The specimens with dimensions of 20 by 20 mm were prepared and tested on a support span of 130 mm in length as per the standard test method. The load at which each sample was compressed as a result of the force applied on it by the machine was recorded. The compressive strength was calculated using

$$\text{Compressive Strength} = \frac{\text{Maximum Load}}{\text{Cross-sectional Area}} \tag{7}$$

Table 1: Composition and Physical Properties of Floor Tiles

Sample	Composition (%(m/m))		Water Absorption (%(m/m))	Density (kg/m^3)
	LDPE	Fine Sand		
A	25	75	0.38	1289.6
B	35	65	0.04	1269.5
C	50	50	0.02	1168.2
D	65	35	0.24	1015.6
E	75	25	0.3	998.5

3. Results and Discussion

3.1 Physical Properties of Floor Tiles

The physical properties of floor tiles are presented in Table 1. Water absorption is the ability of a bisque tile to absorb water or moisture. The calculated water absorption of the floor tiles was between 0.02 and 0.38%(m/m). The lowest water absorption (0.02%(m/m)) was obtained in Batch C with a composition of 50%(m/m) LDPE and 50%(m/m) fine sand. The amount of water absorbed closely resembled that of ceramic tiles of 0.03%(m/m). Generally, tiles with a high level of water absorption have a low resistance to chloride and sulphate as well as to water penetration [5].

The density of the tiles ranged from 998.5 kg/m^3 to 1289.6 kg/m^3 as is shown in Table 1. The lowest density, calculated in Batch E, was due to the large quantity of LDPE in the formulation. The density decreased as the proportion of LDPE increased. A rise in the density resulted in an increase in the compressive strength and a decrease in water absorption by the tile [6].

3.2 Mechanical properties of the formulated tiles

The mechanical properties of the batches are shown in Table 2. The tensile strength of the floor tiles was between 0.050 and 0.232 MPa. The tensile strength of a material is a measure of the force required to pull a material to the point where it breaks. Batches A and E exhibited the lowest and highest tensile strengths, respectively, possibly due to the amount of LDPE used as a binding agent in their formulations.

The Young's modulus of elasticity with regard to the batches of tiles ranged from 0.924 to 2.810 MPa as depicted in Table 2. The Young's modulus of elasticity is a measure of the stiffness of an elastic material and it is an important parameter in evaluating the deformation of materials subjected to a working load. The lowest Young's modulus of elasticity that was calculated in Batch A may result in a lower stiffness compared to that of Batch E that yielded the highest.

The compressive strength of the tiles presented in Table 2 was between 91.7 and 133.0 MPa. Batches D and B

Table 2: Mechanical properties of Floor Tiles

Sample	Tensile strength (MPa)	Young's modulus of elasticity (MPa)	Compressive strength (MPa)	Impact strength (kJ/m^2)	Coefficient of friction
A	0.05	0.924	116.7	1912	0.6
B	0.067	0.975	91.7	1883	0.53
C	0.083	2.666	118	1955	0.51
D	0.082	2.653	133	2346	0.58
E	0.232	2.806	115	1933	0.58

exhibited the highest and lowest compressive strengths, that is, 133.0 MPa and 91.7 MPa, respectively. This implies that the impact strength of Batch D to compressive loading will be greater than that of Batch B.

Impact strength is the resistance of a material to fracture by being hit, expressed in terms of the amount of energy absorbed before the fracture. The impact strength of the batches ranged from 819.05 to 1720 KJ/m^2. Since Batches D and B exhibited the highest and lowest impact strengths, respectively, Batch B will easily be fractured.

Table 2 shows that the coefficient of friction of the floor tiles is between 0.51 and 0.60. However, given that these values are similar, all the floor tiles responded similarly to sliding freely over the same surface. The coefficient of friction depends on the surface finish of the floor tiles and the values obtained are in good agreement with the acceptable value of 0.5 outlined by the ASTM standard test method [7].

4. Conclusion

Floor tiles were successfully developed from plastic waste and fine sand. Although the physical and mechanical properties of Batch D yielded the best results, this recycled plastic waste can be used to produce some industrial products like floor tiles which are resistant to highly corrosive environments like offshore platforms.

Competing interests

The authors declare that there are no competing interests.

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