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REINFORCEMENT OF CEMENT TILES WITH PALM KERNEL SHELL PARTICLES AS NATURAL FIBRE

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Abstract
This study focused on the experimental investigation of the effect of palm kernel shell particulate reinforcement on the mechanical properties of cement-based tiles. Five samples of cement tiles reinforced with different compositions of kernel shell of 1440 µm particle size at predetermined moisture content were produced against a control sample to ascertain the composition that offered the best suitable properties for the functional requirements of cement tiles at reduced cost. For all the samples produced, evaluations for bulk density, apparent porosity, water absorption capacity, and flexural strength were investigated. The results showed that porosity, water absorption capacity, and apparent density decreased with an increase in the palm kernel shell compositions while bulked density increased. The variation with 80 % cement and 20 % palm kernel shell fibre reinforcement (Sample B) demonstrated optimal tile quality with apparent porosity of 10.35 %, a water absorption capacity of 5.47 %, bulk density of 1.89 g/cm^{3}, and flexural strength of 37.21 kgF/cm^{2}. It was evident that the flexural strength of sample B met the ASTM-C293 standard cement tiles requirement of 35 kgF/cm^{2} to 40 kgF/cm^{2} thus the optimal volume fraction with improved surface characteristics and recommended for applications where hard and heavy materials are used on tiles.

1.0 INTRODUCTION
Tiles are made from hard materials like stone, ceramic, baked clay, metal, or even glass and are usually used in roofs, floors, walls, and often objects such as tabletop coverings. Other units made of lightweight perlite, wood, and mineral wool materials used typically in wall and ceiling applications have been regarded as tiles [1]. These tiles come in diverse shapes (square, rectangular, hexagonal, and custom) and designs. The use of tiles could be traced back in history to about 875 BC when the Assyrians used glazed tiles to create wall relief decorations in their palaces. These reliefs in today's Iraq reflect the then military exploits and kings' hunting expeditions some twenty-eight hundred years ago [2]. Nigerians have started to appreciate the aesthetic and functional values as most modern houses are now embellished with tiles of various types, sizes, and colors [3].

Cement tiles or hydraulic tiles, basically made from cement material are beginning to dominate the tiles market across the country. Homeowners are now showing a greater preference for tiles as decorative materials for both the floors and the walls of their

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homes. The durability of cement tiles was drawn from their composition of a coarser layer of sand and cement, and a finely dehydrated ground cement layer. The pigment layer becomes a part of the tile by being hydraulically pressed into the surface. The cost of tile constituents such as cement, and fine and coarse aggregates is increasing by the day, thus throwing up the quest for viable alternatives [4].

Oil palm kernel shell, an important product of oil palm fruit (*Elaeis guineensis* of the tribe *Ceoxylimae* and the family *Palmaceae*) are used on floors as tiles [5][6][7][8][9][10]. Nigeria is blessed with an abundant supply of these palm kernel shell (PKS) deposits with about 1.5 million tons produced annually; most of which are often dumped as residues [11]. Thus, the shells have little commercial value, but create disposal and waste problems instead. However, studies are ongoing on the conversion of these supposed waste materials to useful products when properly harnessed such as in the production of indigenous tiles for floor/wall decoration.

PKS has been successfully utilized in the production of concrete [12 – 21]. The mechanical strength of PKS in epoxy composites encouraged the use of agro-waste materials as reinforcement to create new composite materials with reasonably good mechanical properties thereby helping to reduce environmental pollution [22 - 23].

However, cement tiles develop issues regarding weight, physical appearance, level of maintenance, and water absorption in addition to high cost. Meanwhile, a good tile is also expected to have an acceptable flexural strength (shear strength that measures the maximum strength a material or component can withstand before it yields or suffers structural failure in shear) between 35 kgF/cm^2 to 40 kgF/cm^2 [24]. About 80% of tiles used in Nigeria today are imported from abroad; since the few tile-producing industries cannot satisfy the huge demand for the product [3]. This is a very serious observation that poses a challenge to Nigerian contemporary ceramists/engineers and stakeholders who no doubt are in a better position to assist. The cost of the existing cement tiles is high and unaffordable because materials for production are inorganic and non-renewable which necessitates the urgent need for renewable substitutes to pull down the prizes. The PKS is a waste, locally available and renewable which has been successfully utilized as a non-binding component and partial replacement for granite in concrete formulation and reinforcement of cement tiles for ultimate cost and weight reduction without undermining the functional requirement [4].

Although the use of other biomaterials like corn comb, sawdust, rice husk, and coconut shell as a composite substitute or admixture in construction materials has been investigated, PKS has exhibited more promising features of structural stability and versatility in addition to economic viability for its renewable and sustainable potentials [4] [25] [26]. This study, therefore, seeks to investigate the suitability and effectiveness of the use of palm kernel shell (PKS) as natural fibre in reinforcing cement tiles for improved properties.

2.0 MATERIALS AND METHOD

2.1 Materials

The raw materials used for this study were white Portland cement and palm kernel shells which were obtained from the Umuahia building material market and the Palm oil factory in Amaoba, Ikwuano, both in Abia State, Nigeria respectively. The other materials were marble powder, fine sand, water, and natural mineral color pigments sourced locally from the markets in Umuahia. Equipment used included a digital weighing balance (A2ZC DWM of 0.1 g accuracy), hydraulic press (Model HBP020), tiles mold of (400 x 400) mm, and flexural testing machine (ASTM-C293) during the evaluation.

Figure 1: Sharp fine sand

Figure 2: Washed palm kernel shells

2.2 Sample Preparation

Then palm kernel shells were sorted to remove impurities, soaked in water, and washed with Klin detergent to remove every trace of oil. The washed sample was rinsed in a plentiful supply of water, dried at ambient conditions for 10 days, and then oven-dried at 70 ^{o}C to constant weight for 48 hrs in accordance ASTM standard method. The sharp sand was also soaked in water and washed similarly before drying at 110 ^{o}C to constant weight. Figures 1 and 2 show portions of the processed samples of sand and PKS respectively. The palm kernel shells were ground to the particle size of 1700 µm. A mesh of sieve size 1440 µm was used to get uniform particle size of palm kernel shells.

2.3 Design of Mold and Tile Samples Development

Metal mold of dimension (208 x 208 x 20) mm as shown in Figure 3 was used for the tiles mold. The ground samples of the shells were measured with the digital weighing scale of 5kg capacity to get the desired weight, and with other constituents, they were put in five (5) different containers labeled A, B, C, D, E, and F samples. The reinforced cement tile formulations were as shown in the design matrix (Table 1).

Figure 3: The mold

Table 1: Design matrix of sample formulation.

Sample	Fixed ratio (Marble powder, water, and Sharp sand) %	Variable ratio	
		Cement (%)	PKS (%)
A	100	100	0
B	100	80	20
C	100	60	40
D	100	50	50
E	100	40	60
F	100	20	80

Each sample produced has a fixed ratio of marble powder, water, and sharp fine sand, and a varying ratio of cement and palm kernel shells. The total net weight of the constants (marble powder, water, and sharp sand) is 2kg, while the total net weight of each selected variation of cement and PKS is also 2kg, making the total net weight of the reinforced samples 4kg each based on composition ratio as shown in Table 1.

2.4 Evaluation Procedures

2.4.1 Determination of water absorption capacity

Water absorption capacity evaluates the quantity of water the sample can retain within its body matrix [27]. It was calculated as the ratio of the absorbed water weight by the sample to the dry weight of the sample (Equation 1). The test pieces after drying using the oven dry method were weighed and recorded as M_1(g). The dry samples were then immersed in water for 24 hours; thereafter removed, cleaned, and immediately reweighed and recorded as soaked (wet) weight, M_2(g) following the ASTM method. The water absorption (W.A, %) was then calculated using Equation 1 [4].

$$W.A(\%) = \frac{M_2 - M_1}{M_1} \text{ x } 100 \quad (1)$$

Where; M_1 is weight of the sample before soaking (Dry mass), g; M_2 is weight of samples after soaking (Wet mass), g.

2.4.2 Porosity and density determination

Porosity and density are among the determining factors upon which the compressive strength of cement-based tiles are accessed for quality and applications [28 - 30]. Apparent Porosity (A.P), Apparent Density (A.D), and Bulk Density (B.D) of cement tile composite were thus determined using Equations 2, 3, and 4 respectively:

$$A.P(\%) = \frac{100[M_2 - M_1]}{M_2 - M_3} \quad (2)$$

$$A.D\left({}^{g}/{}_{cm^3}\right) = \frac{M_1}{M_2 - M_3} \quad (3)$$

$$B.D\left({}^{g}/{}_{cm^3}\right) = \frac{M_1}{M_1 - V_3} \quad (4)$$

Where; M_3 is the suspended weight of the test pieces, g (determined by the use of a lever balance).

2.4.3 Flexural strength determination

Flexural strength was performed using the electrical transversal strength testing machine. Flexural strength (or the modulus of rupture) determines the shear strength of a formulation. This test was carried out as described by [23]. The flexural strength σ was determined from Equation 5:

$$\sigma = 3FL/2wd^2 \quad (5)$$

Where; F is maximum force applied, L is length of the sample, w is width of the sample, and d is depth of the sample.

3.0 RESULT AND DISCUSSION

3.1 Result of Mechanical Tests

The physical and mechanical properties of the reinforced cement tile test pieces produced are as follows:

3.1.1 Apparent porosity

The porosity decreased with an increase in the composition of PKS as shown in Figure 4. The decrease in porosity indicates the closure of pores associated with the replacement of cementitious materials with non-porous PKS. This closure of pores also indicates the reduction in apparent solid volume as the bulk volume increases [30]

The 80 % PKS which corresponded to sample F was less porous which suggests an appreciable interlock of binder and PKS particles [31]. The apparent porosity reduced till sample C where it was almost the same with samples D and sample E (Figure 4). And the value of apparent porosity falls on sample F and further samples upon increase in palm kernel shell composition.

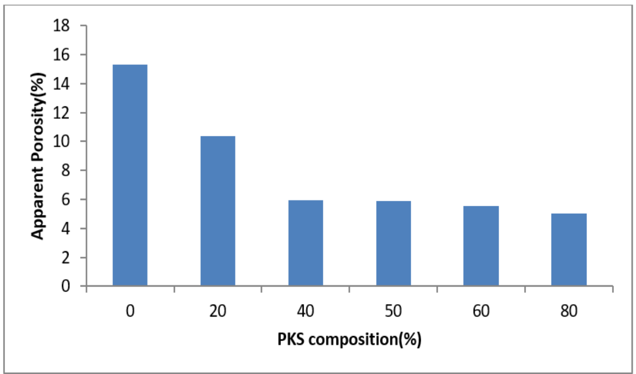

Figure 4: Response of apparent porosity variation in PKS

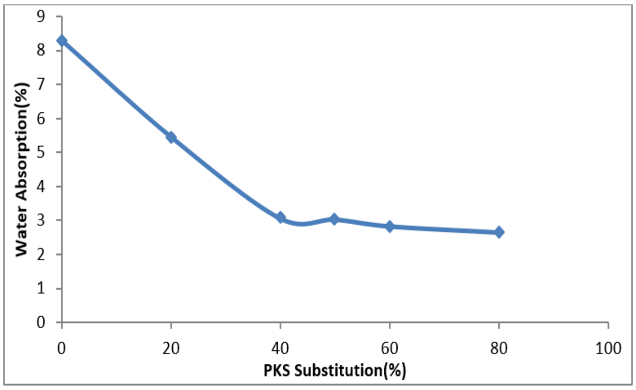

Figure 5: Effect of PKS on Water absorption capacity

3.1.2 Water absorption

The observed decrease in water absorption with an increase in PKS is due to an increase in the introduction of non-expansive impervious material and a reduction in the cementitious binder as shown in Figure 4. The high resistance to water penetration with an increase in relatively impervious PKS besides indicating the closure of pores also suggests suitability for usage in a waterlogged environment.

Sample B (PKS 20%) with less value of apparent porosity makes it have better resiliency, high physical strength, and light weight in addition to improved surface properties. Its value of lower water absorption makes it have a lower whole life cost, improved dimensional stability, self-lubricating properties, limiting the need for manual attention, and corrosion-resistant according to [32].

3.1.3 Apparent and bulk density

Figure 6 shows the relationship between density and PKS composition of samples. A decrease in the apparent density and an increase in bulk density with increasing PKS composition were observed. An increase in bulk density generally means an increase in the closure of pores and an increase in compaction [31] [33] [34].

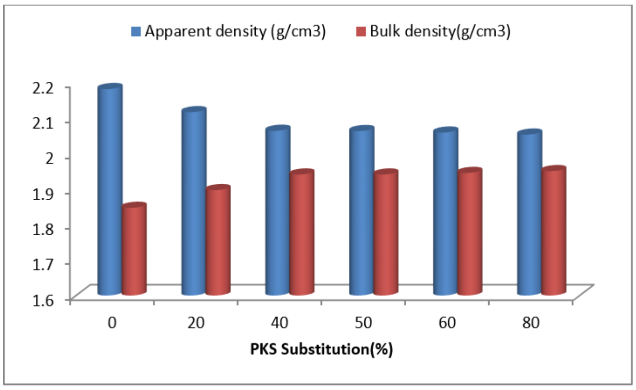

Figure 6: PKS Effect on Apparent density and Bulk density

The apparent density accounts for closed pores as well as open pores. With the increase in impervious PKS, the volume of open pores is reduced leaving little space for air and water entrapment [34 -35]. This closure of open pores reduces the apparent density with an increase in PKS as shown in Figure 6.

3.1.5 Flexural Strength

The Flexural strength which was tested on a tri-axial flexural strength testing machine shows that the 100 % cement tile has the highest shear strength value and can withstand more heavy materials. But notwithstanding, the 20% PKS reinforced cement tile has a flexural strength value of about 37.21kgF/cm^2 which also falls in the range of standard cement tile which is 35kgF/cm^2 to 40kgF/cm^2 as described by [36]. The behavior of the cement tiles with PKS partial substitution of the cement binder is shown in Figure 7.

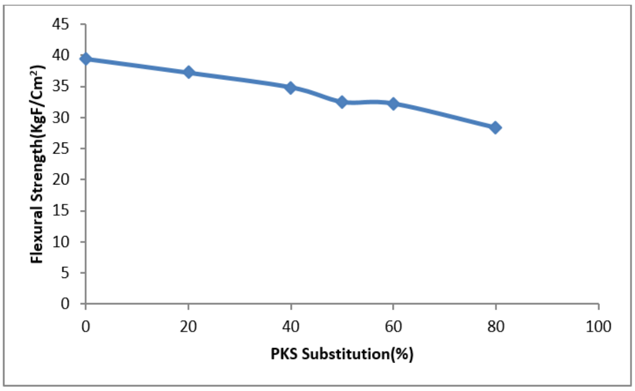

Figure 7: Effect of PKS on Flexural Strength

Sample A being the control sample (the 100% cement tile and 0% PKS) shows a strong flexural strength of about 39.43kg/cm^2, and that is the reason why it is chosen in an environment where hard and heavy materials will be used. On the other hand, a closely matching sample B (80% cement and 20% PKS) has a high flexural strength of 37.21kgF/cm^2 with desirable lower porosity and higher bulk density, making the sample more preferable to use in environments of hard and heavy materials as it also falls in the range of standard cement tile which is 35kgF/cm^2 to 40kgF/cm^2 [6].

3.2 Face Value Evaluation

It was observed by visual inspection that as the PKS composition increased from sample B to F, the samples exhibited a coarse and rough surface outlook. This property favored the surface characteristics for floor tiles and therefore made palm kernel shell reinforced cement tiles suitable in floor applications where friction is exploited in addition to its load-carrying capacity (justified by flexural strength) and this is consistent with the assertion of [4].

Figure 8: PKS/Cement ratio A (0:100), B (20:80), C (40:60), D (50:50), E (60:40) and F (80:20)

4.0 CONCLUSIONS

The following conclusions were drawn from the study:

i. Palm kernel shell can suitably be utilized in cement tile reinforcement for property improvement due to low water absorption capacity, improved dimensional stability (low porosity and high bulk density), good flexural strength, and enhanced surface characteristics exhibited by its tile composite

ii. The reinforcement of cement tiles with 20 % PKS can suitably replace the normal cement tiles in the market without undermining the functional requirements of the cement tiles thus, recommended for mass production to ease construction inadequacies.

5.0 CONFLICT OF INTERESTS

The authors declare that they have no competing interests

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