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Experimental Study on the Use of Waste Polyethylene Terephthalate (PET) and River Sand in Roof Tile Production

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Abstract –

This study deals with the effects of using Polyethylene Terephthalate (PET) and river sand in roof tile production. This work is based on experimental study of roof tiles produced with river sand and recycled PET in varying proportion of 10%, 20%, 30%, 40%, 50%, 60% and 100% of PET combined with the corresponding fine aggregate percentage. The PET plastics used were derived from waste plastic bottles for soft drinks. The shredded plastic was subjected to heat and ensured that it does not lose it's plasticity. The tests which were performed to evaluate the physical and mechanical performance of this material were sieve analysis, specific gravity, water absorption, density and compressive strength. The results show that recycled PET replacement gives better results for 40 and 50% of plastic composite tile than Ordinary Portland Cement (OPC) at 28 days. In conclusion, the plastic composite tiles have both good strength and absorptive property for roof tiling.

Key Words: Polyethylene Terephthalate, river sand, Ordinary Portland Cement, compressive strength, roof tiles

1. Introduction

Building materials have experienced a considerable measure of change from old circumstances till this present innovation time [1]. The importance of habitation to man cannot be completely dealt with as it is next in significance to air, water and sustenance [2]. A building as a structure consists of several interconnected elements coming together to satisfy needs [3]. These needs usually vary in accordance with design and specifications as presented by relevant parties in the construction industry. With people looking for agreeable houses to live in, each researcher is endeavoring to create new building materials that would be sturdy and financially savvy [4]. Building materials includes: clay, fine aggregates (sand), wood, coarse aggregates (rock), concrete, reinforcement (steel), roofing tiles among several others [5, 6]. Amidst several elements, a worthy element to recognize in any building structure is the roof as it is the crown of such structure. There is high value and importance placed on the roofing of any structures. The roof basically is the covering provided on the topmost part of any building that gives protection from elements such as weather conditions like rain, snow, wind, heat and sunlight to mention a few [7]. In order to obtain proper covering with roof, the right material must be used. Agbede et al [8] showed that roof tiles (concrete roof tiles) can be produced using Rice Husk Ash (Rha) in partial replacement of cement. Kolawole et al [9] carried out research on developing coco-nut fibre cement composite roof tiles and concluded that with optimum 10% coco-nut fibre an economical composite roof tile was achieved. According to a recent study, a million plastic bottles are bought every minute across the

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world and only 7% are recycled, the rest end up in landfills or in water bodies [10, 11]. Discovery has shown that fibers from recycled PET can be used in the construction sector especially as insulation and roofing material [12]. Due to the peculiar qualities of plastic for example, simple assembling and forming, less expensive, and low thickness. It is one of the most man used materials in the world [13]. The main methods for satisfactorily dealing with tons of plastic waste being arranged are through the appropriation of reusing and recycling processes [8,10]. Cement as the significant established binder in development industry is extremely costly [14]. This is a direct result of extraordinary populace development and urbanization which have activated appeal of cement for a few development purposes to get together with the need to grow a vast number of structures [15]. In this manner the need to interface the void amongst request and high cost has justified the reason to research the utilization of less expensive elective sources such as Polyethylene Terephthalate (PET) [16,17]. Mehdi et al., [18] demonstrated the possibility of making a composite material (roof tiles) using high density polythene (HDPEr) plastics combined with sand as roofing material. From their work the polymer tile with 70% plastic was selected because of the high quality derived after testing. A check out in the earth uncovers colossal generation of waste, some of which can be changed over into utilization in the business development in order to give elective quality however more affordable rooftop tiles. This research aims to explore the viability of using waste PET bottles from municipal solid waste in the place of cement to produce roofing tiles. This research is strictly geared towards developing and producing valid and reliable roof covers from recycled PET bottles.

2. Materials and Methods

The plastic waste was obtained from bottles utilized for soda pops with a premise of polyethylene terephthalate. Plastics were collected from the waste to wealth gathering centers inside Covenant University premises in Ota, Ogun State, Nigeria. PET Shredded bagged are as shown in Figure 1 below. The sand utilized was sourced from the neighborhood waterway Ogun and was washed from each type of silty material. Figure 2 shows the fine aggregate utilized.

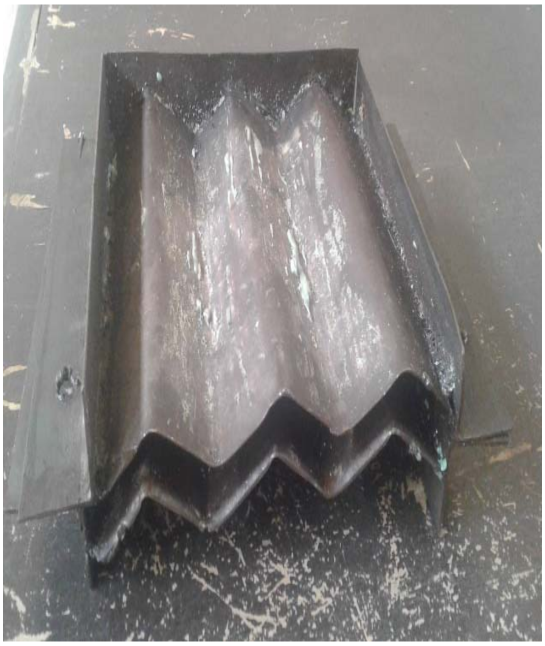
Figure 1: Bags containing 50kg waste plastic of the PET

Figure 2: Fine aggregates utilized for research work

The apparatus used for this study were metal mold, gas cylinder, burner, head pans, weighing balance, measuring bowl, lubricating oil, binding wire, plier, metal bowl, screwdriver, brush, matches, stirrer, and personal protective wears. The physical properties of PET and fine aggregates were determined using particle size distribution and specific gravity tests in line with [19, 20]. The plastic and sand were mixed together while stirring both in order to obtain a homogeneous mixture at 230°C as shown in Figures 3a and 3b. The percentage by weight of plastic to sand include: 10:90, 20:80, 30:70, 40:60, 50:50, 60:40 and 100:0 percent respectively. After pouring of the mixture in the mould, the mould was covered properly in order to bring about smooth surface finish. Covering is left for few minute before withdrawal. The mix was allowed to cool under normal temperature conditions which help to obtain a rigid tile with plastic as a binding material. After their withdrawal from the mould, the tiles are cured under in ambient air until the day of testing. The composite roof tiles using waste plastic bottles (PET) and fine aggregates utilizing several compositions of plastic were produced as shown in Figure 3d. While compressive strength, density and water absorption tests were carried out on roof tiles produced in line with [20-23] standards.

(a) Melting of the plastic

(b) Addition of sand



(c) Molding of the tile

(d) Recycled roof tile

Figure 3: Operating mode of the production of waste plastic roof tile. **a.** Melting of the plastic. **b.** Addition of sand. **c.** Molding of the tile. **d.** Plastic binder roof tiles

3. Result and discussions

3.1 Particle size distribution test results

The sieve analysis was determined to know the aggregate gradation of fine sand. Figure 4 shows that the fine sand sample is well graded. Also, 2.670, 0.960, 2.7 values of coefficient of uniformity, Coefficient of gradation, and Fineness Modulus obtained from the study show that the aggregate is as well graded and is suitable for construction work. The grading of the sample conforms to [24].

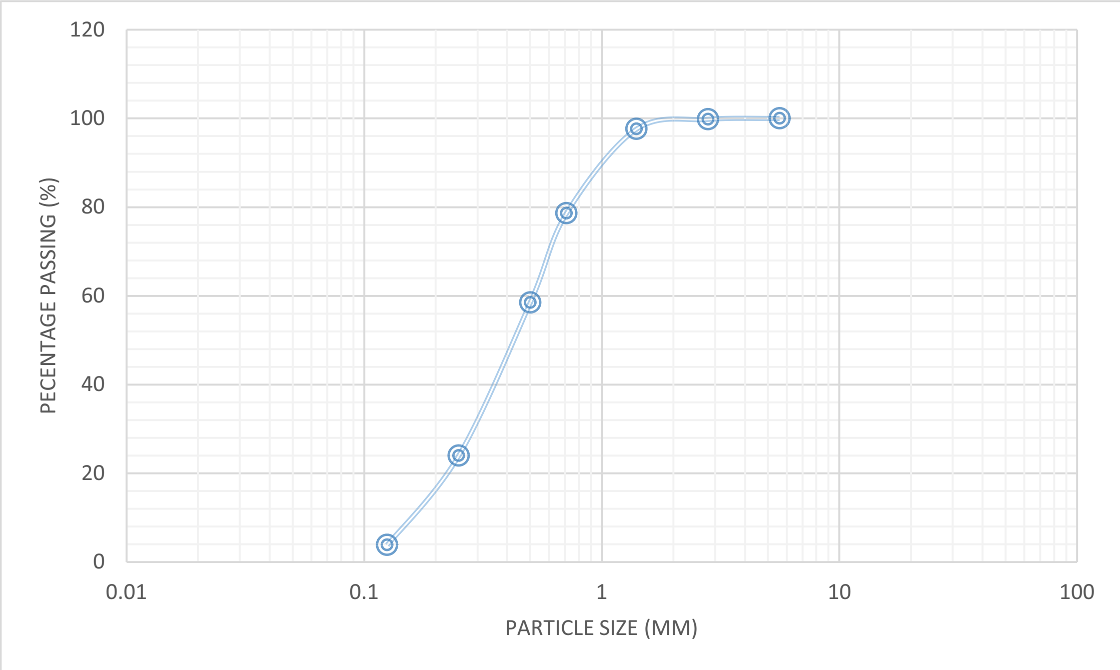


Figure 4: Particle size distribution of sharp sand

3.2 Specific Gravity Test Results

The average specific gravity of 2.68 obtained from the study as shown in Table 1 is within the range specified by [20] for fine aggregates. Kosmatka et al [25] reported that the relative densities of natural aggregates ranges between 2.4-2.9, while [24] specifies specific gravity range of 2.4 - 3.0 for normal weight aggregates.

Table 1: Specific gravity values for fine aggregates

Process	Sample 1	Sample 2	Sample 3
Weight of sand (g) B	550	550	550
Weight of density bottle	595	595	595
Weight of bottle + water (g) P	1595	1595	1595
Weight of bottle + Sand (g)	1145	1145	1145
Weight of bottle + water + sand (g) PS	1940	1938	1942
Specific gravity Gs	2.68	2.66	2.71

Average specific gravity Gs = 2.68

3.3 Water Absorption

Water absorption controls the roof quality. Figure 5 showcases a graph which highlights the differences between saturated and dry weights. For this study, the highest levels of water absorption amongst the composites were 10% PET (2.94%) while the lowest was at 30% PET (0.15%). This implies that 30% PET has the least affinity for water with absorption rate of 0.15% and relatively the soundest while 0% PET with 6.02% is the least on the soundness scale. Composite values were all lower than that of the reference tile 0% PET (6.02%). Amongst the plastic binder compositions, water absorption values decreased steadily down to 100% PET of which 20-100% of PET fell between the range of 2% specified by the standard. This simply showed that increase in plastic content led to corresponding decrease in water absorption up to 100% PET which is in line with [23].

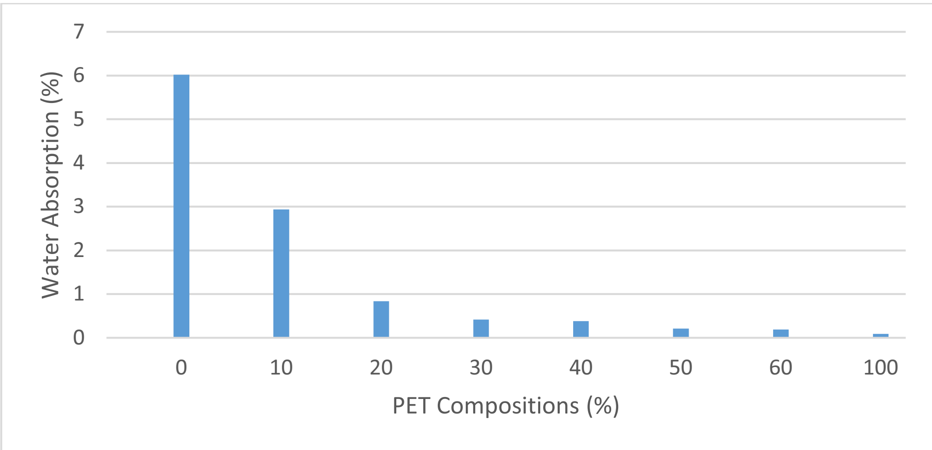


Figure 5: Water absorption values in % for different tile compositions

3.4 Density

From experiment conducted, the average densities of the tile specimens with lowest recorded density was at 100% PET (852.07 kg/m^3) and the highest for PET was 10% PET (1899.56 kg/m^3). From Figure 6, the graph indicates a steady rise in average densities up to 10% PET before a sudden decrease down to 100%. When compared with control tiles, the composite tile density decreases as the percentage of PET increases.

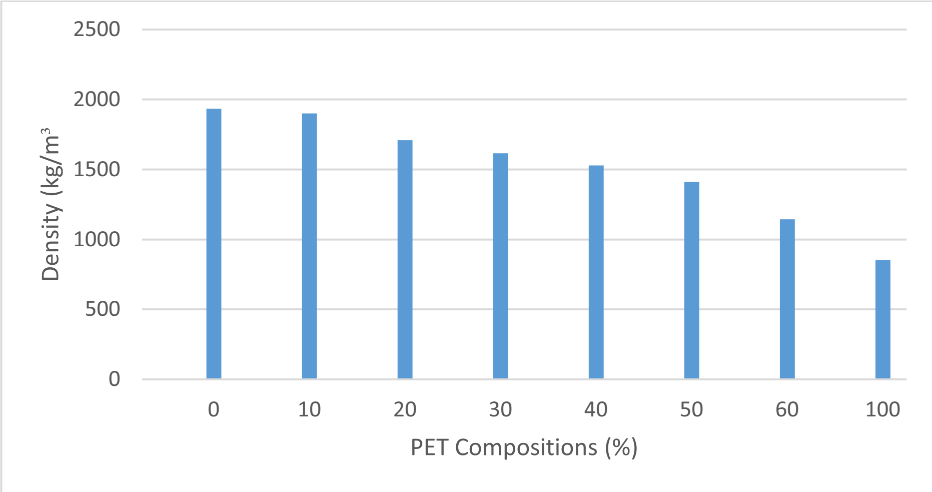


Figure 6: Average density values of the respective samples

3.5 Compressive Strength

To derive the accurate results here, tiles were properly leveled before placing into the UTM. From Figure 7 values for composite roof tiles steadily rose from 10% up to 50% PET before a noticeable decrease at 60% PET. The highest compressive values for composite tiles were that of 40 and 50% PET (1.5868 and 1.4869 N/mm^2) respectively. This value was higher than the control tiles at 28 days (1.4869N/mm^2). Comparing the results obtained with Konin [14] that used polypropylene, this study produced better results.

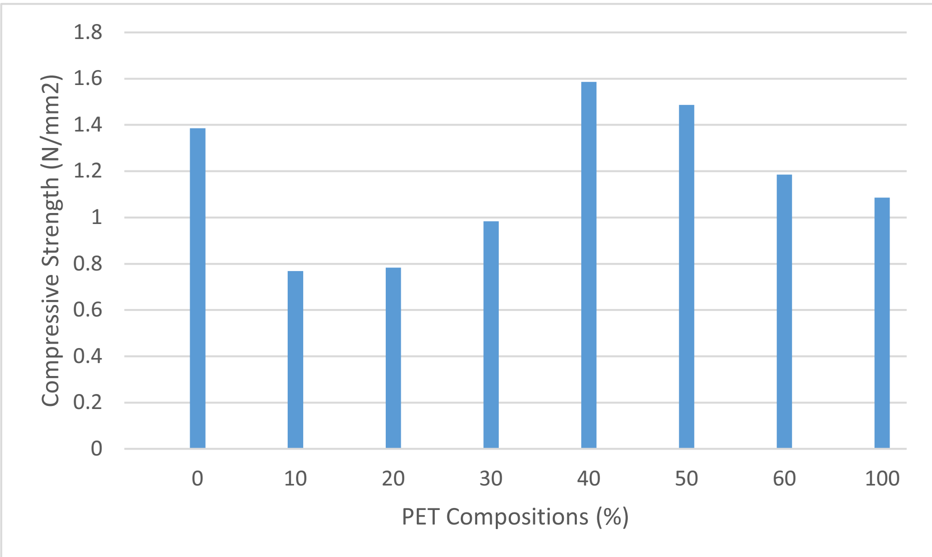


Figure **7:** Average compressive strength values of the respective samples

4. Conclusion

The utilization of plastic waste rather than cement in the production of tiles can be viewed as taking into account this investigation. From the series of tests carried out on materials and roofing tiles, the following conclusions were made: The recycled PET tiles have estimations of water absorption that are generally low, which makes them for all intents and purposes impenetrable contrary to micro-concrete tiles. Also the composition with 40 and 50% of the recycled PET tile give the best outcomes both physically and mechanically. Which implies that recycled PET tiles can be utilized rather than the control micro-concrete tiles. The qualities acquired are moderately better and as a result of these qualities the PET roof tiles can be produced utilizing the waste PET and fine aggregates as a total replacement for Ordinary Portland Cement (OPC). In addition, when this roof tile is found to be useful, more effort will be made in adopting the product within the country, thereby reducing the amount of the country's importation of roof covers. The work is patented in Nigeria. A further study of the microstructural analysis of the material produced and the environmental impact of the production process is desired.

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