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The Effect of Varying Sand and Plastic Additives on The Mechanical Properties of Cement Matrix Tiles

The Effect of Varying Sand and Plastic Additives on The Mechanical Properties of Cement Matrix Tiles

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Abstract-
The global efforts regarding polymer waste and pollution reduction in the environment through waste recycling is essential to forestall its deleterious effect on the environment. This work focused on utilizing used plastic and sand as additive in cement matrix tile production while cement and laterite quantities were kept constant. Tile specimens having a uniform thickness of 15 ± 1 mm and facial dimensions of 150 mm x 150 mm were produced in the laboratory utilizing varying quantities of sand (30, 20, 10, 0 %) and plastic (35, 45, 55, 65 %), with constant quantities of laterite (30%) and cement (5%) additives. Laterite was thoroughly mixed with sand, plastic and cement with a known volume of water in a clean bowl. The resulting mixture was then subjected to a compaction load of 25 KN in a mould to obtain cohesive material. Two sets of samples were prepared; unfired and fired sample. The unfired sample was allowed to cure after wetting for 7 days. Thereafter, the sample to be fired was heat treated in an oven at a temperature of 2200C for 35 minutes. The fired tile specimen was removed from the oven and allowed to cool down at room temperature. The specimen was then subjected to water absorption, water shrinkage, flexural and compression tests. The results obtained showed that the tile with plastic: sand ratio of 65:0 had the best water absorption and water shrinkage values of 11.4 and 5.3 % respectively. Furthermore, the mechanical tests showed that the flexural and compression tests data of 39.08 and 158.06 MPa respectively were the best when compared to other samples for the tile with plastic: sand ratio of 65:0. It was also noted that a direct relationship existed between the quantity of plastic used and the strength of tile produced. The unfired sample could not be subjected to mechanical tests as the bonds formed between the additives were weak. It is recommended that cement quantity used be slightly increased to investigate its effect on the strength of the cement matrix tile. Based on the result, it is suggested to increase the plastic content and decrease the sand content of the sand:plastic ratio to achieve a better physico-mechanical properties of tile samples

Key words: Sand, laterite, plastic, tiles and properties

1. Introduction

Over the past decade, man has manufactured more plastic than was done in the previous century. Plastics production worldwide increased from 322 million tons in 2015 to 335 million tons in 2016 alone [1]. Kehinde et al, [2] stated that one of the major factors leading to poor waste management in Nigeria is its high population density. Half of all plastics produced are considered as disposable due to being single-use plastic products and packaging materials. After their service life is exhausted and the plastic product becomes waste, most of these plastic wastes are not dropped off in garbage cans for consequent removal to incinerators, recycling centers, or landfills. Rather, they are indiscriminately discarded in proximity to where their useful life ends abruptly. Discarded on the ground, tossed out of a moving vehicle, piled up on a gorged garbage bin, or stolen away by a current of wind, they immediately become an aesthetic problem and pollute the local ecosystem. Increasing accumulation of these plastics in the environment has become a worldwide problem and severe threat to the planet. Almost 10 percent by weight of municipal garbage content are plastics [3]. Abioye et al [4] stressed the need for looking for an alternate use of biodegradable plastics and therefore stated that an effort in accomplishing this is a step towards achieving goal 11,12,13,14 and 15 of the 2016 sustainability development goals (SDGs) as set by the United Nations Development Programme (UNDP). There is therefore the need to remove plastics from the environment through a recycling process that converts it into useful products thus, leaving the environment free from pollution, making products are sold for commercial gain and the manufacturers are in gainful employment. Government also benefits from taxes.

The utilization of plastic as an additive in the manufacture of cement matrix tile is a major focus of this work. Tiles are used in Nigeria essentially for finishing and decoration in houses, shops and offices. Tiles have been in existence since the twentieth century and are being used worldwide till present days [5], although many materials and residues have been used in developing and manufacturing various tiles to meet set objectives. This study is aimed at using new materials (which are considered as waste) as a substitute for the conventional ones. Tiles can be described as a hard-wearing construction material developed from porcelain, heated clay or ceramics with hard glaze and mostly from other components which includes glass, metals, and stones [6]. They are mostly flat or square shaped and may vary from square tiles to complex mosaic. Tiles are regularly used to frame a building, walls and floor covers because of their tasteful and waterproof nature [6].

They are mainly made up of clay or inorganic raw material in any form. The main materials used for the manufacture of tiles are silica sand, laterite or clay, cement, and additives. Silica sand is one of the essential ingredients used in the manufacturing of wall titles. Silica is used to portray a number of minerals collectively composed of silicon and oxygen, which are the two most ample minerals found in the earth's crust. In heating, silica sand is used for its known properties such as its purity, structure, grain size, and mesh size and grain distribution [7]. They also stated that silica sand is a commonly and most extensively used material. Furthermore, they exist normally as deposits in numerous places in the country ground surfaces or the benthos of river, lake, and seashore or as sub surface deposits of various geologic formations. They are generally found in the crystalline state and not often seen in an amorphous state. Silica is composed of one atom of silicon and two atoms of oxygen resulting in the chemical formula $SiO2$ [8]. Laterite are materials rich in iron, sub-aerial, weathering product, usually thought to develop as a result of intense, in situ alteration of the substrates in tropical or subtropical climatic conditions. It includes a significant subset of a wider range of ferruginous and related aluminum (i.e., bauxite) weathering products, including ferricretes and various iron-rich paleosols. Laterite weathering profiles often develop an indurated surface layer of resistant duricrust, forming laterally extensive sheets of 1-20mm in thickness. These laterite surfaces are physically and mechanically resistant [9].

Previous research such as composite analysis of laterite-granite concrete tiles by Olusegun et al [10] shows that an impressive mechanical property was obtained when locally sourced materials used were laterite, granite and cement. Also, properties of clay, silica and cement tiles were investigated by Ohijeagbon et al [11], the investigation showed an addition of 40% to 50% silica lead to an improvement in the mechanical property. In this present study, flooring tiles were produced using laterite/silica sand/cement materials and pulverized plastic as additives. The cement and laterite quantities were kept constant while sand and recycled plastic were varied to investigate its effect on percentage water absorption and shrinkage as well as its mechanical properties namely flexural and compressive strength.

2. Methodology

2.1 Pre-experimental Analysis

2.1.1 Physical properties of raw materials

Before the tiles were produced, the materials used were subjected to physical tests. Materials were weighed using an electronic weighing balance to determine mass of the materials. Materials were then placed in a beaker with a known volume of water and stirred after which volume was obtained. Thereafter, the density was derived using equation 2.1. Also, the sieve analysis for the sand, laterite and plastic was performed. Table 1 shows the density of silica, laterite and plastic (recycled plastic) used for manufacturing the cement matrix tiles.

$$\rho = \frac{M}{V} \quad (2.1)$$

Table 1: Density

S/No	Material	Colour	Density (kg/m^3)
1	Silica Sand	Light Brown	1.72
2	Laterite	Reddish brown	1.224
3	Pulverized Plastic (recycled)	Grey	0.56

Figure 1 shows the sieve analysis curve for laterite, silica sand and pulverized recycled plastic. The sieve analysis was performed in accordance to ASTMD6913. The laboratory test sieves were mounted on a mechanical sieve shaker (Associated Scientific & Engineering Works (ASEW)) to provide a vertical or lateral and vertical motion to the sieve, causing the particles to bounce and turn so as to present different orientations to the sieving surface. This was done to determine the mesh size at which all materials to be used would be closely compacted when the tiles are to be manufactured. It also helps maximize usage.
The results obtained shows that the sieve analysis of silica, laterite and pulverized plastic particles size were retained within the 0.850mm sieve size and 0.150mm respectively. Therefore, the maximum particles size of 0.855mm mesh size was adopted for all aggregated materials to guarantee optimum materials usage.

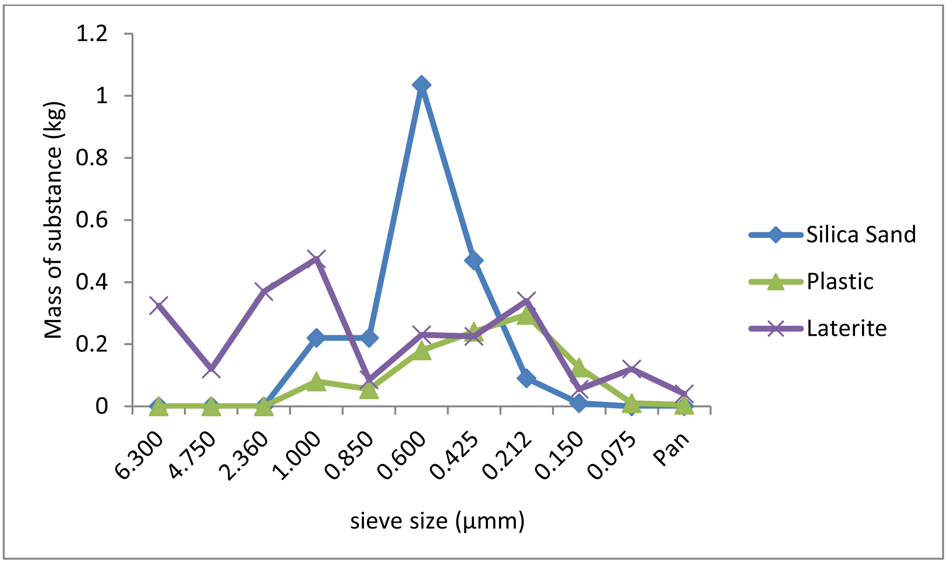

Figure 1: Sieve Analysis Curve for Cement-Matrix Tiles Material

Table 2 show the composition of the tiles manufactured in this study. The tables show that as sand percentage increases plastic percentage reduced and vice versa.

Table 2: Percentage variation Sand and Plastic Additives

S/N	Variation	Laterite %	Cement %	Silica %	Plastic %
1	$A^{30:35}$	30	5	30	35
2	$B^{20:45}$	30	5	20	45
3	$C^{10:55}$	30	5	10	55
4	$D^{0:65}$	30	5	0	65

2.2 The moulding process of the sample tiles

This procedure used for the production of the tiles is similar to those used by Ohijeagbon [12]. The manufactured tiles were produced using mild steel mould. The mould was fabricated using a mild steel material. It consists of a male and female part. The female part is a 150 mm x 150 mm box with a height of 80mm. the male part is a press with a face of 149 mm x 149 mm. The materials used were laterite, silica sand, Portland cement and water. Cement was used as a binder while silica sands as the stabilizer and plastic the addictive. Each batch ratio mixture was stirred thoroughly for about two to four minutes to maintain a uniform mixture after which water was added and stirred thoroughly to remove lumps and achieve a homogenous mixture. To avoid producing a rough pattern tile, nylon was placed over the mixture to avoid friction and the material sticking to the mould. The mixture was then placed in the square mould thereafter the male press of 25KN was applied to produce the tiles. The produced tiles were pressed in the mould to a uniform thickness of 14 mm, the process for fired tiles was concluded by placing the pressed homogenous mixture in an oven for 35 minutes while the unfired batches were placed under room temperature and cured for 7 days.

2.3 Physical properties tests for sample tiles

2.3.1 Determination of water absorption (WA)

In order to determine the water absorption, each tile sample was weighed by an electronic weighing balance before immersion for 24 hours to obtain dry mass. Thereafter the samples were retrieved, and its surfaces cleaned off with a paper towel to remove water from the surface of the tiles. The samples were then weighed to obtain the wet mass weight. The percentage water absorption was then determined using the expression in equation 2.2.

$$\%WA = \frac{Wet\ Mass - Dry\ Mass}{Dry\ Mass} \text{ x } 100 \qquad (2.2)$$

2.3.2 Determination of water shrinkage

In other to obtain the water shrinkage percentage, The tile samples retrieved from the water tank were allowed to dry for 24 hours at room temperature. The weight was than obtained after 24 hours. The recorded value was then inserted in equation 2.3 to obtain percentage water shrinkage.

$$\%WS = \frac{\text{Wet mass} - \text{dry mass}}{\text{wet mass}} \times 100 \qquad (2.3)$$

2.4 Mechanical properties of tiles samples

2.4.1 Flexural strength

The flexural strength test was performed according to those used by Ohijeagbon et al [11]. The expression in equation 2.4 was used by inserting load P (N), distance L and thickness T of the specimen tested (mm) at rapture.

$$M = \frac{8PL}{\pi T^3} \qquad (2.4)$$

Where M, modulus of rupture (MPa)

2.4.2 Compressive strength

The compressive strength test was performed according to those used by Ohijeagbon et al [11]. Equation 2.5 was used by inserting average load on the specimen at failure
P_c (N) and area of the bearing surface on the test specimen A_c, (mm^2).

$$C_s = \frac{P_c}{A_C} \qquad (2.5)$$

Where, Cs = Compressive strength of the specimen, (MPa)

3. Result and discussions

3.1 Physico-mechanical properties of batch sample of tiles

3.1.1 Water absorption

Figure 2 shows the water absorption test result for the experiment. It shows percentage water absorbed by each tile sample as sand reduced and plastic increased. As sand reduced, the percentage water absorbed reduced and vice versa. While as plastic increased, the percentage water absorbed decreased and vice versa.

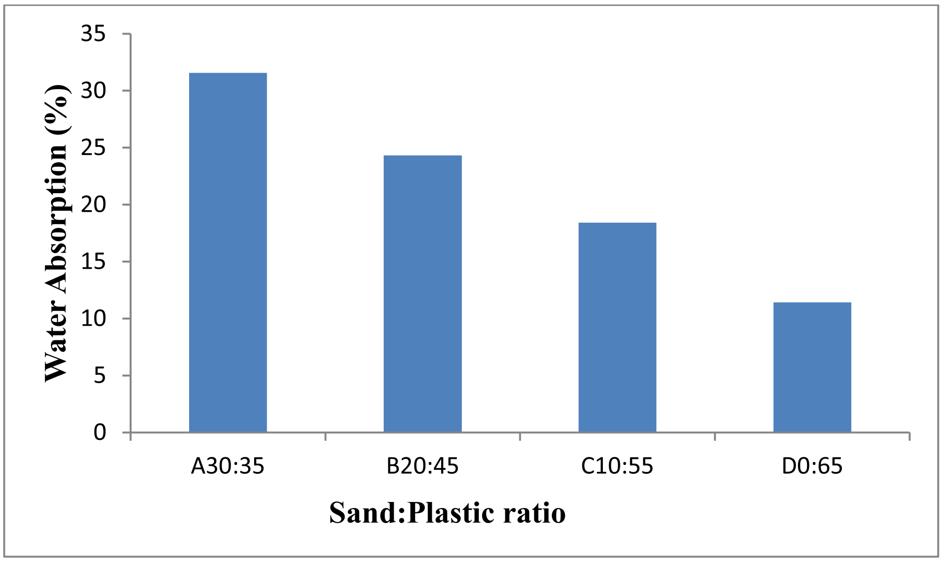

Figure 2: Percentage Water Absorption for test samples

3.1.2 Water Shrinkage

Figure 3 shows the percenatge water shrinkage for the test samples. From the figure, it is noted that the lowest percentage water shrinkage is displayed by the sample with the highest plastic and lowest sand content respectively, whiile highest percenatege water shrinkage was displayed by 20:45 (sand:plastic) samples. This result is different from what was obtained from the percentage water absorption test, because of the 24 hours waiting period before the wet mass weight was taken. Thus, the result did not follow a perticular trend. The 0;65 sample retained the leaste water because the plastic content was the highest.

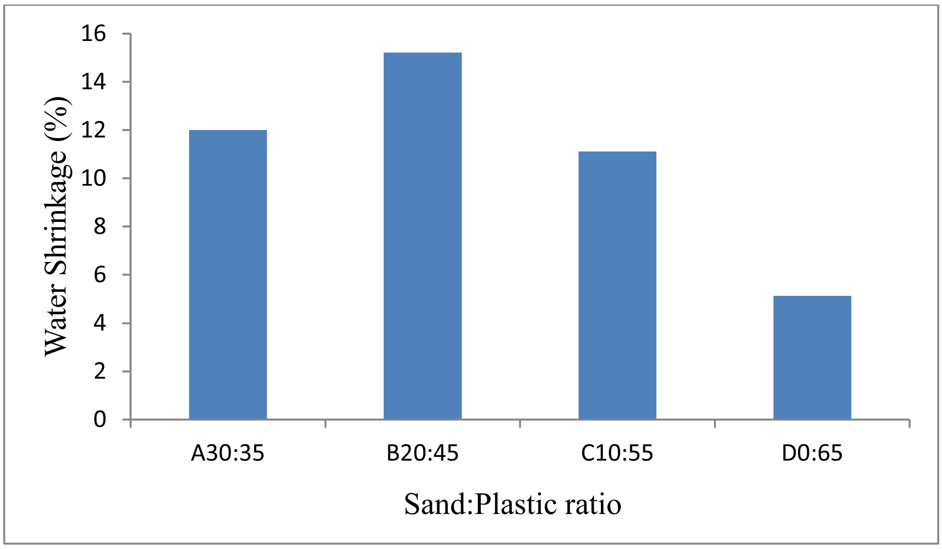

Figure 3: Percentage water shrinkage for test Samples

3.1.3 Flexural strength

Figure 4 shows the flexural strength for the test samples. It is observed that as sand content increased the flexural strength of the samples reduced, while as the plastic content increased the flexural increased. The flexural strength in increasing order was A< B < C < D. Increasing plastic content has the potentials of increasing flexural strength.

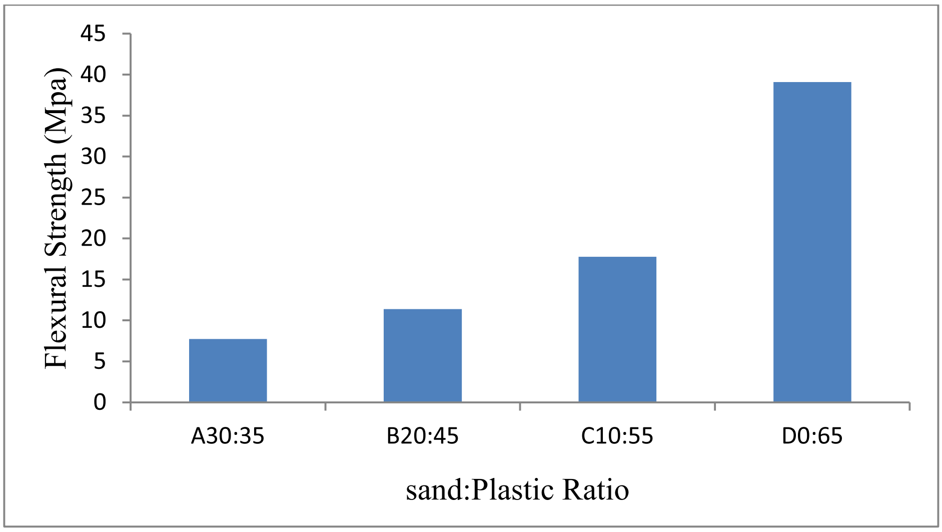

Figure 4: Flexural strength for test samples

3.1.4 Compressive strength

Figure 5 is the graphical representation compressive strength for the test samples. It was observed that as plastic content increased the compression strength also increased. This showed a direct relationship. On the other hand, as sand content reduced, a decreased in the compressive strength was noted. This again pointed to the fact that plastic content has a direct effect on the compression strength of the tiles.

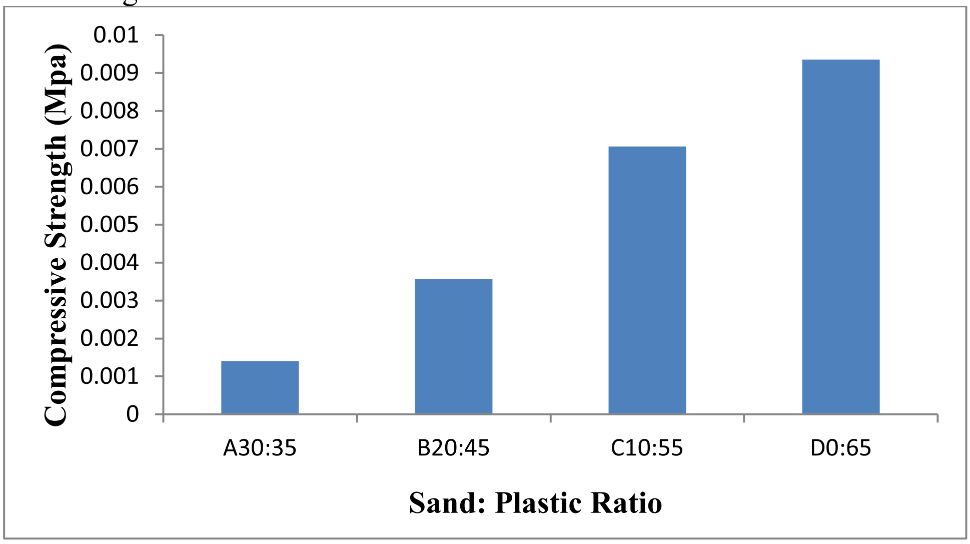

Figure 5: Compressive strength for test samples

4. Conclusion

Tile specimens with a uniform thickness of 15 ± 1 mm and facial dimensions of 150 mm x 150 mm were produced in the laboratory utilizing varying quantities of sand (30, 20, 10, 0 %) and plastic (35, 45, 55, 65 %), with constant quantities of laterite (30%) and cement (5%) additives. It was observed that 0:60 (sand:plastic) samples had the least water absorption and water shrinkage values of 11.4 and 5.3 % respectively. The higher water absorption implied that the tiles were porous, fragile and less durable. The mechanical tests showed that the flexural and compression tests data of 39.08 and 158.06 MPa respectively were highest recorded at sand:plastic ratio of 0:60 samples. It was also noted that a direct relationship existed between the quantity of plastic used and the strength of the tile produced, which means that, as the plastic content were increased, mechanical properties was increased. The unfired sample could not be subjected to mechanical tests as the bonds formed between the additives were weak.

5. Recommendation
Cement quantity used should be slightly increased to investigate its effect on the strength of the cement matrix tile.

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