ENHANCED POLYESTER REINFORCED CONCRETE COMPOSITE FOR TILES PRODUCTION

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ABSTRACT

This paper is aimed at assessing the influence of granite particle aggregate on the mechanical properties of polyester reinforced concrete composite for tiles production. It is noted that polymer concrete cures fast with high specific strength which makes it suitable for the production of thin oven layers, floors and precast components. The conventional hand lay-up method used for fabrication of thermoset polymer was used for the production of the concrete tiles. The results of the hardness and impact test were obtained using Vickers Hardness and Charpy Impact Machines and recorded in Tables 1and 2, respectively. For percentage filler content of samples 15, 25, 35, 45 and 55 %, the corresponding hardness of 8.5, 9.7, 11.6, 12.4 and 14.2 hv; and 0.3, 0.31, 0.45, 0.90 and 1.20 J of impact strength were obtained, respectively for sieve size of 100 µm. Similarly, the percentage filler contents of samples 15, 25, 35, 45 and 55 % had corresponding hardness values of 9.6, 10.5, 12.0, 13.7 and 15.0 hv; and 2.0, 0.8, 0.7, 0.5 and 0.4 J of impact strength were obtained, respectively for sieve size of 150 µm. These results revealed that there was a net increase in hardness with increasing aggregate content for the hardness and an increase in void fraction with increasing filler content.

***Keyword**:* Tile, impact test, hardness test, filler content, granite.

INTRODUCTION

Quarry tiles are made of red clay that is either hand or machined shaped. The clay is fired to extremely high temperatures much higher than ceramic tiles and this renders the quarry tiles naturally dense, non-porous and water resistant with low water absorption (Hunker, 2020). Quarry tile is a hard, impervious paving tile made from the ground minerals formed and fired. High quality quarry tiles are extruded and unglazed, naturally appealing and very practical. They are slip resisting and an excellent choice for areas subject to heavy spills and moisture. Quarry tiles also perform well in outdoor applications even in extreme climates.

There are three basic types of tiles viz; ceramic, concrete and metal tiles. Ceramic tiles are aesthetic and durable with good insulation among other characteristics. However, ceramic tile is expensive and quite heavy. Concrete tiles are cheaper but less attractive, hard and permeable and possess a low resistance to frost. Polymer tiles on the other hand do not break during transportation, installation and even when falling from heights and possess long service life. Further, polymer tiles are resistant to changes in temperature and retain properties up to 150 ^{o}C, lightweight and resistant to aggressive environment (such as acids and alkalis). In addition, Polymer tiles practically have low (or near zero) water absorption, hence do not increase the weight of roofing tiles (Kim, 2013).

Theoretical Framework

Polymer concrete is a type of concrete that uses polymers to replace lime-type cements as a binder (Kim,2013). In some cases, the polymer is used in addition to Portland cement to form polymer cement concrete (PCC) or polymer modified concrete (PMC). Polymer concrete is composed of aggregates that include silica, quartz, granite, limestone and other high quality material. The aggregate must be of good quality, free of dust and other debris. Failure to fulfill these criteria can reduce the bond strength between the polymer binder and the aggregate (Kim,2013).

Polymer concrete may be used for new construction or repairing of an old concrete. The adhesive properties of polymer concrete allow repair of both polymer and conventional cement-based concretes. The low permeability and corrosion resistance of polymer concrete allows it to be used in swimming pools, sewage structure applications, drainage channels, electrolytic cells for base metal recovery, and other structures that contain liquids or corrosive chemicals. It is specially suited for the construction and rehabilitation of manholes due to its ability to withstand toxic and corrosive sewage gases and bacteria commonly found in sewage system (Kim,2013). Polymer concrete requires no coating or welding of PVC-protected seams. It can also be used as a bonded wearing course for asphalt pavement, for higher durability and higher strength upon a concrete substrate. Polymer concrete has historically not been widely adopted due to the high costs and difficulty associated with traditional manufacturing techniques. However, recent progress has led to significant reductions in cost, meaning that the use of polymer concrete is gradually becoming more widespread (Mehta *et al*., 2013).

Utilisation of quarry dust in concrete is recommended particularly in regions where sand is not easily available (Sukuman, 2008). The suitability of quarry dust as a sand replacement material shows that the mechanical properties including elastic modulus are improved (Hmaid, 2015). According to Chitlange and Pajgade (2010), there is consistent increase in the strength of plain concrete when natural sand is fully replaced by quarry sand. Ho *et al*., (2002) stated that the granite fines can be used in the SCC production. However, it is important to spot out that as a waste material, the properties of stone fines are likely to vary with time. Then, after that, the fineness of granite fines could solve durability problems such as silica-alkali reactions.

Problem Statement

There has been a growing interest in recent time particularly in the developing countries, to use granite quarry dust in the production of concrete and tilling products. This is partly as a result of the unchecked depletion of the natural sources of fine aggregates which has resulted to an increase in their price as a result of its environmental degradation and consequent closure of some mine sites. Attempts have been made to either partially or completely replace marble dust and sand with other materials such as granite quarry dust in the production of concrete product materials.

Aim and Objectives of the Study

Based on the aforementioned problem statement, the main aim of this study is to evaluate the mechanical performance and particle size effect of granite quarry dust used in polymer concrete tiles. Specific objectives of the study include:

i. To fabricate a polymer concrete tile by simple casting process at ambient temperature, using two different granite quarry dust particle size.

ii. To identify the effect of aggregate weight and particle size on the mechanical properties of a polymer concrete tile.

MATERIALS AND METHODS

Materials and Equipment

These include:

i. Weighing balance. It is used to weigh out the filler into the required weights

ii. Fabricated aluminium mould (150 x 150 mm dimensions)

iii. Hand brush. A small hand brush with light bristles was used to apply the beeswax on the mould.

iv. Hacksaw. This was used for cutting the samples to test dimensions.

v. Pipette. It was used for measuring out the initiator and accelerator in drops.

vi. Beakers. The beaker used was an SS- type with a 100 ml capacity.

vii. Spatula. The spatula was used for scooping the filler.

viii. Granite Quarry Dust. It was collected from Conrok Quarry, Amasiri, Afikpo North L.G.A, Ebonyi State. This aggregate was further separated by drying in open air for 5 days. After drying, it was sieved using a mesh size of 100 and 150 µm, respectively.

ix. Unsaturated Polyester Resin, Methyl Ethyl Ketone Peroxide (MEKP) was used as the initiator. Cobalt Naphthenate was used as the accelerator to activate the initiator and both were procured from Onitsha Anambra State Market.

x. Indenting machine. This machine was used in carrying out the hardness test on the produced tiles

xi. Charpy impact tester. In determining the impact strength of the tile samples, Charpy impact tester was used.

Method

Aggregate collection

The aggregate was collected from the quarry processing plant at the waste heap into a new sac bag. It was then spread out to dry in open air for five days. After drying, it was sieved using a standard test sieve with mesh size of 100 µm and 150 µm, respectively. The aggregate was subdivided into five weight fractions (15, 25, 35, 45 and 55 %) using the digital electronic weighing balance (Table 1).

Fabrication

The sample formulation was prepared by pouring out the required resin weight for each sample. The combination of the initiator, methyl ethyl ketone peroxide and the accelerator, cobalt naphthenate with resin to hardener ratio of 1 to 100 % weight was then added. In the fabrication of the first pure sample, the cobalt naphthenate was added first into the resin and stirred for 2 minutes. This was done to achieve a solution that will readily activate the initiator by decomposing it into free radicals and also to prevent ignition with the initiator. Before the addition of the initiator, the mould was prepared for curing by the application of silicon oil in trace amount on its inner surfaces. Methyl Ethyl Ketone Peroxide was then added in % of the total resin weight, after which the formulation was stirred again for 40 seconds and then poured into the mould from one edge. For the samples containing the aggregate, the prepared aggregate was added first into the resin and stirred for 5 minutes before the addition of hardener. The same procedure was repeated for both particle sizes. The samples were left to cure for 3 days before they were de-moulded. A hack saw was used to cut the samples into dimensions of 100 mm by 100 mm. The cut-out tile pieces were subjected to hardness and impact tests.

Table 1: Percentage Weight of Granite Quarry Dust and Unsaturated Polyester (with 2% hardener)

S/N	Weight fraction for 100 µm particles size (%)	Weight fraction for 100 µm particles size (%)	% Weight MEKP
1	15	15	90
2	25	25	80
3	35	35	70
4	45	45	60
5	55	55	50

Hardness and impact tests

The produced tile samples were subjected to both hardness and impact tests. The hardness test measures the resistance of the surface of a material by a hard object (Askeland and Fulay, 2010).

Types of hardness test include Brinell hardness test, Rockwell hardness test and Vickers hardness test. In this work, the Vickers hardness test was used to determine the hardness of the tile samples. The test sample (15 x 17 x 4 cm) was first polished to remove surface impurities. It was later clamped strongly in the indenting machine to prevent any movement during the testing process. The pyramid shaped diamond indenter (with an interfacial angle of 136^{o}) was pressed into the test sample with increasing loads of 0.1kg force. The indentation left on the sample was measured and converted to a hardness value. The value is the quotient of the applied test force and the surface area of the residual indent on the test sample.

Impact test measures the ability of a material to absorb the sudden applications of a load without breaking (Askeland and Fulay, 2010). The Charpy and Izod tests are the most common impact tests. Charpy impact test was used in this work. The impact strength of the prepared unsaturated polyester resin tile samples was determined using the Charpy impact tester which has its capacities ranging from 0.5 to 150 J, and an impact angle of 150^{o} . The test sample (15 x 17 x 4 cm) was first given a notch of radius, 0.25A ± 0.05 mm which acted as a stress concentration to initiate the propagation of cracks. The tester pendulum impacted the test sample and the start and finish heights of the pendulum were measured. The difference in height was equal to the energy absorbed by the test sample before it fractured. The absorbed energy is measured in joules on a scale attached to the machine.

Results and Discussion

Hardness test results

The hardness test results revealed that aggregates sieved with 150 μm mesh size (known as 150 μm particles) exhibited high hardness values than the aggregates sieved with 100 μm mesh size (known as 100 μm particles), Table 2. 100 μm and 150 μm particles recorded peak values of 14.2 Hv and 15 Hv, respectively at 55 % weight fraction. The results also show that the hardness of the particles increases with increasing aggregate content (Figure 1).

Table 2. Hardness Test Results

S/N	Weight fraction (%)	100 µm	150 µm
1	15	8.5	9.6
2	25	9.7	10.5
3	35	11.6	12.0
4	45	12.4	13.7
5	55	14.2	15.0

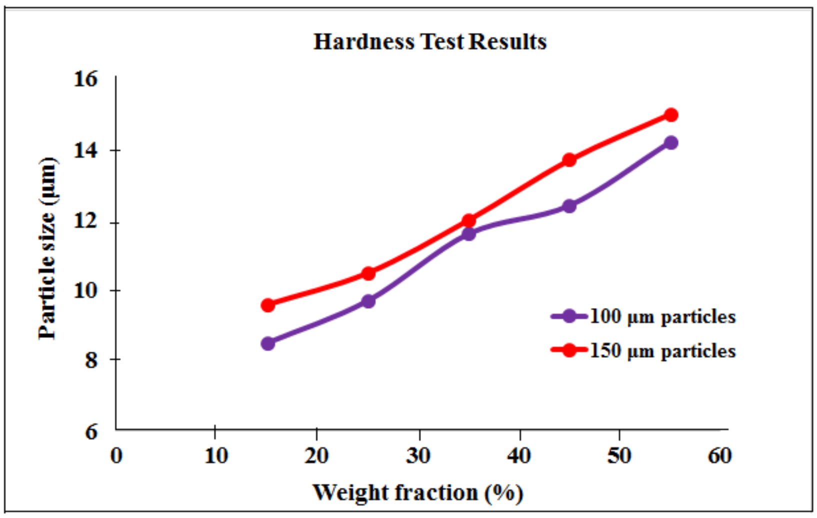

Figure 1. The hardness test results of the particle sizes (µm) relative to weight fraction (%)

Impact Test Results

As shown in Table 3, the 100 µm particles showed a uniform steady increase in impact strength with increasing aggregate weight, while the 150 µm particles showed a sharp decline in strength with increasing weight. This trend is shown in Figure 2. The highest impact strength (2.0 J) was exhibited by 150 µm particles for 15 % weight fraction The results also showed an increase in void with corresponding increase in particle size (PN-EN12350-2, 2001).

Table 3. Impact Test Results (PN-EN 12390-3, 2002)

S/N	Weight fraction (%)	100 µm	150 µm
1	15	0.30	2.00
2	25	0.31	0.80
3	35	0.45	0.70
4	45	0.90	0.50
5	55	1.20	0.40

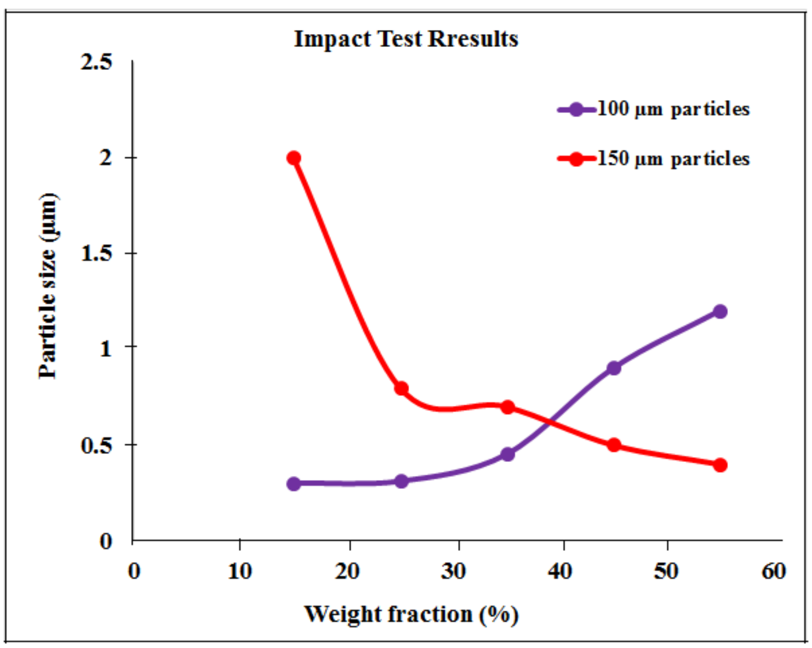

Figure 2. The Impact test results of the particle sizes (µm) relative to weight fraction (%)

Conclusion

From the test results obtained, the granite dust aggregate of 150 μm performed better in hardness than the granite dust aggregate of 100 μm. There is a clear indication that the aggregates increased the packing density of the matrix which resulted in improving its hardness. It also explains that larger particles provide better functional grading with increasing aggregate weight. The impact strength indicates that 100 μm particles showed a uniform geometric rise in impact strength with increasing aggregate weight unlike the 150 μm particles that exhibited a decline in impact strength in an increasing order of filler content. Overall, 150 μm showed a better hardness and impact properties.

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