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Original Article

Sorption properties of granite quarry dust reinforced unsaturated polyester resin tiles

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ABSTRACT

Unsaturated polyester resin (UPE) tile samples reinforced with granite quarry dust were prepared by simple casting method. The resin was cross-linked with methyl ethyl ketone and the granite quarry dust was used within filler contents, 0–60 wt.%. Results indicated that the tile samples formulated with granite quarry dust of particle size, 150 μm are vitreous, and the water absorbed by the tile samples generally decreased with filler content. The weight change in 10% HCl exhibited by the tile samples after 72 h immersion was within 0.50–0.10% and was generally lower than that of cured UPE. The tile samples containing 20 and 40 wt.% granite quarry dust (53 μm), and 40 wt.% granite quarry dust (150 μm) exhibited low weight changes of 0.38, 0.41, and 0.40%, respectively, on immersion in 10% NaOH. Similarly, the tile samples containing 10 and 30 wt.% granite quarry dust (150 μm), and 10, 30, and 40 wt.% granite quarry dust (53 μm) exhibited no weight change after 72 h immersion in toluene. This study has highlighted the technical feasibility of fabricating a sustainable composite from a waste that is capable of withstanding different weathering conditions.

Keywords: Unsaturated polyester resin, tile, granite quarry dust, vitreous, weight change, sorption, filler

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INTRODUCTION

Granite quarry dust is a fine industrial waste that results from granite stone processing which can be seen stockpiled in different granite processing sites around the world. Unfortunately, the dust is non-biodegradable and has no economic value. The dust is reported to consist mainly of quartz and feldspar with small proportions of mica, amphiboles, and other minerals.[1] The high production and utilization of granite in Nigeria has resulted in the production of huge waste of granite quarry dust that has potential to contaminate the air and water, and this represents the most direct and hazardous problem of granite quarrying industries. The unregulated dumping of granite quarry dust can have adverse effects on farm productivity since the slurry of the dust in water can lead to water clogging of farm land, and in the process, increase soil acidity.

The development of innovative advanced materials with granite quarry dust will contribute an economic way of disposing the waste, and make the environment clean and green. This, no doubt, will be an efficient way of handling and disposing the waste. Thus, granite waste has been used as filler in the production of the following advanced materials: Polycarbonate toughened epoxy resin,[1] concrete stone,[2] marine clay,[3] vinyl ester resin,[4] epoxy resin,[5] and high-density polyethylene.[6] The utilization of granite quarry dust as a filler in the formulations has the tendency to reduce the overall cost of production of the items.

Unsaturated polyester resin (UPE) is used in the building industry because of its high corrosion resistance, good mechanical properties, and ablative property.[7,8] Its light weight is a desirable property that enables its utilization in the aerospace and electrical industries. The utility of UPE in the polymer industry is attributed largely to the resins ease of processing and comparative cost advantage.[9] In the composite industry, tiles produced using UPE are associated with brittle failure and limited toughness.[10-12] Icduygu *et al*.[13] have suggested the use of more than 1 reinforcing fillers to address the above drawbacks associated with the use of UPE tiles.

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This study reports the utilization of granite quarry dust in processing UPE tiles. The granite dust was collected from Conrok Quarry, Afikpo, Nigeria, and was a by-product of quarry processing. The granite quarry dust was sieved to 53, and 150 µm particle sizes, and used within filler content, 0–60 wt.% in producing the UPE tiles. The sorption properties of the produced tile samples were studied in water, toluene, hydrochloric acid, and sodium hydroxide solution. The present report is an extension of previous one[14] where the mechanical properties of unsaturated polyester composite tiles of granite quarry dust filler were reported.

Granite quarry dust is an industrial processing waste that is not saleable, and can be seen dumped at different locations at rock quarrying sites in Nigeria. The absence of government regulated dumping and disposal of the waste causes environmental hazards, thereby, affecting the clean and green initiative of the government. The present utilization of granite quarry dust in formulating UPE tiles for domestic and industrial applications is expected to reduce not only the cost of tile production but also offer an effective economic way of disposing the waste. Granite quarry dust is presently under investigation in our laboratory for sustainable production of economic products and its usage in alkyd paint formulations possessing anti-corrosive property on mild steel has been reported.[15]

MATERIALS AND METHODS

Materials

The following materials were used in this study.

(i) Granite quarry dust was collected from Conrok Quarry, Afikpo, Nigeria, and used as a filler. It was sieved to two particle sizes, 50 and 150 µm.
(ii) Medium soybean oil alkyd resin used as a matrix was obtained from a chemical store at Onitsha, Nigeria, and has an acid number 6.13 mg KOH/g resin.
(iii) Methyl ethyl ketone peroxide was purchased from Campal Scientific and Technological Co. Ltd., Onitsha, Nigeria, and used as an initiator.
(iv) Cobalt naphthenate obtained from Tonyker Nigeria Ltd., Onitsha, Nigeria, was used as an accelerator.
(v) Silicon oil used as a mold release agent was purchased from a local store at Owerri, Nigeria.

The preparation of granite quarry dust filler and subsequent determination of its chemical composition were as described previously.[14] The granite quarry dust was found to consist predominantly of silicon dioxide (59.62%), followed by aluminum oxide (13.92%), potassium oxide (7.98%), calcium oxide (5.14%), iron (II) oxide (3.00%), copper oxide (2.55%), and silver oxide (2.14%) with the other oxides present in smaller proportions.

The granite quarry dust (particle sizes, 53 and 150 µm) reinforced UPE tile samples was prepared as described previously.[15] The uptake of chemicals by the prepared tile samples was determined as follows.

Each of the prepared tile samples was cut into a test specimen of dimensions, 15 by 15 mm. The test specimen was first weighed (W_1) and put into a clean beaker of 250 cm^3 capacity. A 150 cm^3 of distilled water was poured into the beaker, and the top was covered with a filter paper. The beaker with the content was kept in a safe place for 72 h at room temperature (32°C). At the expiration of this period, the tile sample was carefully removed from the beaker using a pair of tweezers. The water adhering on the surface of the specimen was carefully wiped out using a wrapped filter paper. Care was taken to ensure that the water absorbed by the specimen was not removed during the wiping process. The wet specimen was weighed again (W_2). The above procedure was repeated using the chemicals, 10% HCl, toluene, and 10% NaOH. The chemical absorbed by the tile sample was calculated as follows,

$$\text{Chemical absorbed (\%)} = W_2 - W_1/W_1 \times 100 \quad (1)$$

Where, W_1 = Initial dry weight of the sample (g)
W_2 =Weight of sample after 72 h immersion in chemical medium (g).

RESULTS AND DISCUSSION

The absorption of chemicals by granite quarry dust reinforced UPE tile samples is shown in Figures 1-4.

Water Absorption

Figure 1 illustrates the effect of granite quarry dust content and particle size on water absorption by the tile samples. The figure shows that the tile samples produced using granite quarry dust of particle size, 150 µm are vitreous. This is because a vitreous tile is one whose water absorption property is more than 0.50% but <3.0%.[16] Consequently,

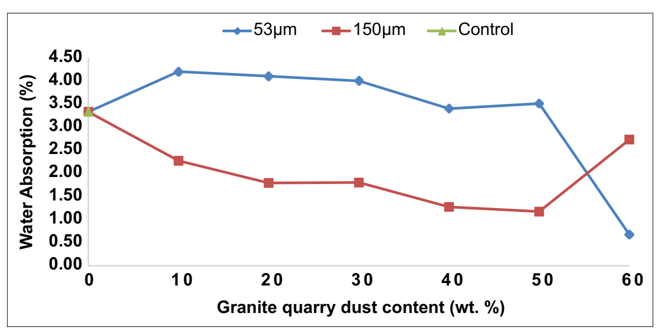

Figure 1: Effect of granite quarry dust content and particle size on water absorption of tile samples

tiles produced using granite quarry dust (53 µm) should be suitable for use in environments such as kitchens where they can get wet occasionally.

Figure 1 also shows that the tile sample containing 60 wt.% granite dust (53 µm) is vitreous while the other formulations are semi-vitreous that absorbed <7.0% water but more than 3.0%. The latter tiles can be suitable for use in areas such as kitchen backsplashes. The granite quarry dust (53 µm) formulated tiles absorbed more water at filler contents, 10–50 wt.% than those formulated with granite quarry dust of particle size, 150 µm. However, at 60 wt.% granite quarry dust content, the granite quarry dust (150 µm) formulated tile absorbed more water (2.73%) than those of granite quarry dust of particle size, 53 µm which was 0.67%. The decrease in the amount of water absorbed by some formulated tile samples is attributed to increase in tightness, and consequently, decrease in pore sizes with increasing dust content. The hydrophobic nature of granite quarry dust may also play a role in reducing the amount of water absorbed by the tile samples. The amount of water absorbed by granite quarry dust (150 µm) formulated tile samples was less than that of the cured UPE (3.33%). The granite quarry dust (53 µm) formulated tile samples exhibited least water absorption at 60 wt.% granite quarry dust content while that for granite quarry dust of particle size, 150 µm was at 53 wt.% dust content. Sultana *et al*.[17] who studied sand reinforced unsaturated polyester composites reported that the amount of water absorbed by the composites decreased with sand content. Similarly, Ismail *et al*.[18] found that the water absorbed by sand polyester composites decreased with the increase of UPE to sand ratio.

Hydrochloric Acid Sorption

The weight change of the tile samples on immersion in 10% HCl is shown in Figure 2. The weight change of cured UPE after 72 h immersion in 10% HCl is 0.63%. The highest weight change (1.20%) was recorded for the tile sample containing 20.0 wt.% granite quarry dust (53 µm). This was followed by the tile sample containing granite quarry dust (150 µm) which exhibited a weight change of 1.08%. The least weight change (0.08%) of the tile samples on immersion in 10% HCl was observed for the formulation containing 10 wt.% granite quarry dust (150 µm). The granite quarry dust (53 µm) formulated tile samples generally exhibited higher weight change after 72 h immersion in HCl than those containing granite quarry dust of particle size, 150 µm. The granite quarry dust content did not exhibit any definite order of variation of weight change in the tile samples on immersion in 10% HCl. Yaya *et al.*[19] who studied clay/unsaturated polyester composites reported an increase in weight change in 10% HCl with clay content.

Sodium Hydroxide Sorption

The sorption of 10% NaOH by the prepared tile samples as illustrated in Figure 3 showed that the cured UPE exhibited a weight change of 0.48%. The weight change of the formulated tile samples in this medium was within 0.30–1.36%. The granite quarry dust (53 µm)

formulated tile samples exhibited the highest weight change (1.20%) in 10% NaOH at filler content, 60 wt.% while that for granite quarry dust (150 µm) tile samples was 1.36% at filler content, 20 wt.%. The least weight changes observed for the tile samples containing 20 and 40 wt.% granite quarry dust (53 µm), and 40 wt.% granite quarry dust (150 µm) were 0.38, 0.41, and 0.40%, respectively. No definite order of variation of weight changes with granite quarry dust content was observed in this study. Jaya *et al*.[19] in their studies of sand/unsaturated polyester composites in NaOH reported considerable weight loss of the composites in the medium and attributed this to heavy cation exchange within the clay matrices where the heavy ions of aluminum and iron were replaced with the lighter sodium ions.

Toluene Sorption

The toluene sorption properties of the formulated tile samples are shown in Figure 4. The figure shows that at

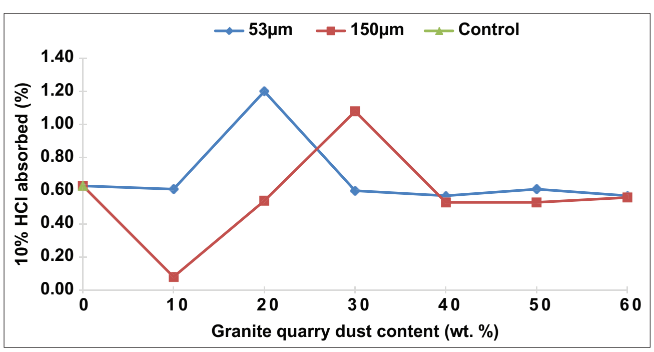

Figure 2: Effect of granite quarry dust content and particle size on weight change of tile samples in 10% HCl

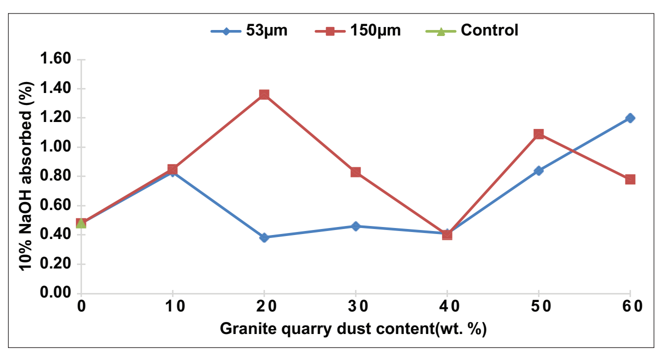

Figure 3: Effect of granite quarry dust content and particle size on weight change of tile samples in 10% NaOH

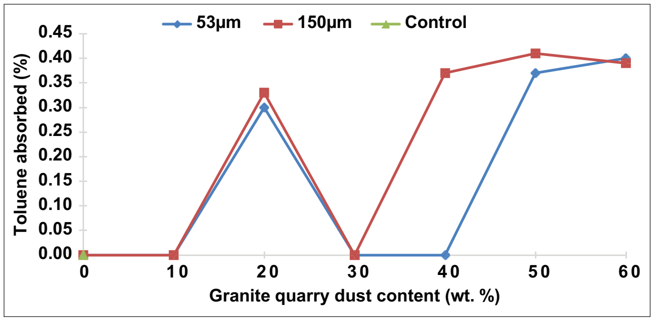

Figure 4: Effect of granite quarry dust content and particle size on toluene absorption of tile samples

10 and 30 wt.% granite quarry dust (150 µm) content, the formulated tile samples exhibited no weight change while at 50 wt.% granite quarry dust content, the weight change was 0.40%. Similarly, the granite quarry dust (50 µm) formulated tile samples exhibited no weight change on immersion in toluene at 10, 30, and 40 wt.% filler contents. The granite quarry dust (150 m) formulated tile samples exhibited the highest weight change of 0.40% on immersion in toluene at 40.0 wt.% filler content.

CONCLUSION

Granite quarry dust of particle sizes, 53 and 150 µm, was successfully used to reinforce UPE tiles.

(i) The tile samples reinforced with granite quarry dust (150 µm) were vitreous, and water absorbed was generally lower than those formulated with granite quarry dust of particle size, 50 µm.

(ii) The tile sample containing 10 wt.% granite quarry dust (150 µm) exhibited the least weight change on immersion in 10% HCl. The weight change for the cured UPE was 0.63%.

(iii) The UPE tile sample of granite quarry dust (53 µm) containing 20 wt.% filler exhibited the least weight change (0.38%) on immersion in 10% NaOH. The weight change of cured UPE in 10% NaOH was 0.48%.

(iv) The formulated tile samples exhibited no weight change on immersion in toluene at 10 and 30 wt.% filler contents.

The present study has highlighted the utility of using granite quarry dust in fabricating sustainable UPE tiles. Granite quarry dust is an industrial waste and its usage in tile production will be generally cost effective in addition to ensuring a clean and green environment.

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