Australian Journal of Science and Technology

ISSN Number (2208-6404)
Volume 8; Issue 2; June 2024

Original Article

Study of mechanical and water absorption properties of marble dust-reinforced unsaturated polyester resin concretes

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ABSTRACT

Unsaturated polyester resin (UPR) polymer concretes were prepared using marble dust by the open tool technique. The marble dust consisting predominantly of calcium oxide (CaO), and sieved to 0.075 mm particle size had the following properties: Specific gravity (2.97), pH (8.63), bulk density (1.56), moisture content (6.91%), and oil absorption (15.75 g/1000 g). It was used within 0–30 wt. % filler content in formulating the UPR concretes. Results showed that the tensile, and compression strength of the concretes decreased with filler content whereas the impact strength, hardness, and specific gravity properties increased with filler content. The water absorbed by the concretes containing 15–30 wt. % marble dust, generally decreased with filler content and was within 7.0–5.29%. Thus, the concrete sample containing 30 wt. % marble dust absorbed the least amount of water (5.29%) whereas the sample containing 10 wt. % marble dust absorbed the highest amount of water (10.37%). The study indicated that marble dust obtained from marble waste particulates could be utilized in fabricating sustainable hybrid polyester resin concretes possessing improved impact and hardness properties for different construction applications especially, where water absorption is not a critical factor.

Keywords: Concrete, marble dust, tensile strength, unsaturated polyester resin, water absorption

Submitted: 09-05-2024, **Accepted:** 05-06-2024, **Published:** 30-06-2024

INTRODUCTION

Composites are materials that result from the combination of two or more materials, whereby the different components retain their individual properties. One of the materials may be in the form of fibers, particles, or sheets, and is called the reinforcing material, which is embedded in the other called the matrix. The reinforcing material is the load-bearing material while the matrix constitutes the phase. The matrix (or binder) helps to maintain the position and orientation of the reinforcement. They are heterogeneous in nature and find applications in areas, such as automobiles because of their excellent mechanical properties.[1,2] Composite materials have advantages over conventional materials, such as wood and metals, and these advantages include higher stiffness, specific strength, and fatigue characteristics.[3] Types of composites include engineering composites, such as concrete and reinforced plastics, such as fiber-reinforced polymer, metal composites, and ceramic composites.[4] Polymer composites have a wide range of applications that touch virtually all industrial sections and are characterized by lightweight with high strength and stiffness properties.

The development of low-cost composite materials possessing improved properties for industrial applications has led to the emergence of polymer concrete (PC) also, known as synthetic resin concrete, and plastic resin concrete in the building/construction sector. This novel material system, which involves the use of low-cost fillers and cost-effective processing techniques, is prepared by filling polyester resin with fillers such as sand and $CaCO_3$. PC was developed in the late 1950s as a replacement for cement concrete in

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some specific applications, such as construction, repair of structures, highway pavements, bridge decks, and structural and decorative construction panels due to its rapid setting, high strength properties, and ability to withstand corrosive environments.[4,5] Unsaturated polyester resins (UPR) and epoxy resins are commonly used to produce PC because of their easy availability, processing, good mechanical and chemical properties, competitive price, and easy handling.[3,4] The resins cure after the addition of additives, such as catalysts and accelerators. PC produced using different materials has been reported, and these include sand,[3,6] eggshell,[7] fly ash,[8,9] red mud,[8] silica powder,[10] granite,[11,12] Huracrepitan pod,[13] waste glass,[14] snail shell,[15,16] coconut fiber,[17] limestone floor,[18] and concrete sleepers.[19]

Marble waste particulates are produced in large quantities from different marble processing activities, such as cutting and polishing, and can be seen accumulated in the open at operation sites. These wastes constitute contaminants in air and water thereby, posing environmental concerns to plants, humans, and animals. The use of marble waste particulates in sustainable production of innovative polymer materials will lead to effective handling, and consequently, management of the waste for a clean and green environment.

This study reports the sustainable utilization of marble waste powder collected from a marble processing outfit at Owerri, Nigeria, in producing UPR PC. The marble powder sieved to 0.075-mm particle size and characterized for filler properties was used within filler content, 0–30 wt. %. The formulated concretes were characterized for mechanical and water absorption properties. The use of marble waste particulates as a reinforcing filler in producing innovative materials is gaining the attention of researchers.[20-24] There are also reports of using marble particulates in producing polyester concrete.[25-27] These efforts are aimed at finding sustainable and cost-effective ways of replacing traditional fillers and other conventional fillers with marble particles thereby, affording their management and subsequent disposal from the environment. The present study thus adds to other reports in the literature where polyester resin PCs were prepared using marble particulates.

MATERIALS AND METHODS

The following materials were used in this study:

i UPR: This is a product of Daily Polymer Corp, Kaohsiung City, Taiwan, and was purchased from Carpal Scientific and Technological Co. Ltd, Onitsha, Nigeria.
ii Marble dust: This was prepared from marble waste particulates collected from a marble processing outfit at Owerri, Nigeria.
iii Methyl ethyl ketone peroxide and cobalt naphthenate: The initiator, methyl ethyl ketone peroxide (MEKP), and accelerator, cobalt naphthenate were purchased from a chemical store at Onitsha, Nigeria.

Analysis of Marble Dust

The marble dust was analyzed for specific gravity (ASTM D 153–84), refractive index (ASTM D 1208–96), metallic oxide content (ASTM D 5381–94), pH (ASTM D 1208–960), bulk density, and moisture content.

Preparation and Characterization of Concrete Samples

The UPR concrete samples were prepared following the method described previously.[12] Marble dust content studied were 0, 5, 10, 15, 20, 25, and 30 wt. %. Cobalt naphthenate and methyl ethyl ketone peroxide were used as accelerator and initiator, respectively. Aluminum molds were used as the casting surfaces.

The prepared concrete samples were characterized for tensile, compression, impact strength, hardness, specific gravity, and water absorption properties following a previously described method.[12]

RESULTS AND DISCUSSION

Characteristics of Marble Dust

The marble dust used in preparing the polyester resin concrete had the following properties: pH (8.63), bulk density (1.56), moisture content (6.91%), oil absorption (15.75 g/100 g), specific gravity (2.97), and refractive index (1.10). The result showed that marble dust is basic in character. The compositional analysis of marble dust indicated an appreciable presence of calcium oxide (56.47%), followed by silicon oxide (2.61%), while the other oxides were mainly present in minute quantities.

Properties of Prepared Polyester Resin Concrete

Figures 1-6 illustrate the effects of marble dust content on the properties of polyester resin concretes.

Tensile Strength

Figure 1 shows that increases in marble dust content decreased the tensile strength of the prepared polyester concretes, which were generally lower than that of cured UPR (43.70 MPa). The decrease in tensile strength with filler content may be attributed to insufficient adhesion between the polymer matrix and the marble dust filler. Similar decrease of tensile strength of reinforced UPR with filler content had been reported in the literature.[12,14]

Compression Strength

The compression strength of the formulated concretes illustrated in Figure 2 decreased with filler content, and were generally lower than that of cured UPR (90.10 MPa). Ismail

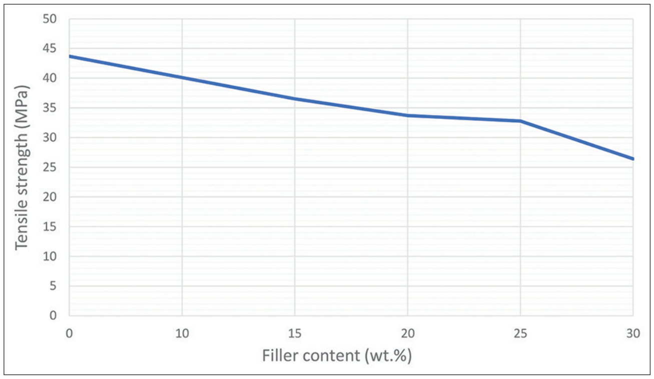

Figure 1: Effect of marble dust content on tensile strength of concrete samples

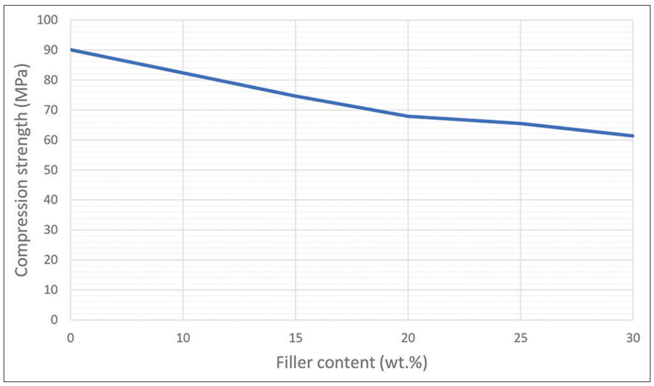

Figure 2: Effect of marble dust content on compression strength of concrete samples

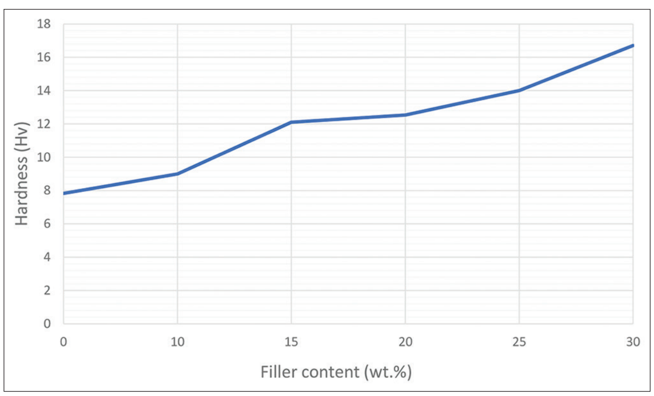

Figure 3: Effect of marble dust content on the hardness of concrete samples

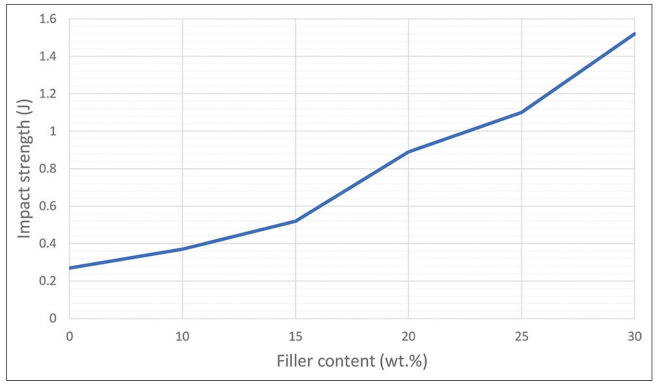

Figure 4: Effect of marble dust content on the impact strength of concrete samples

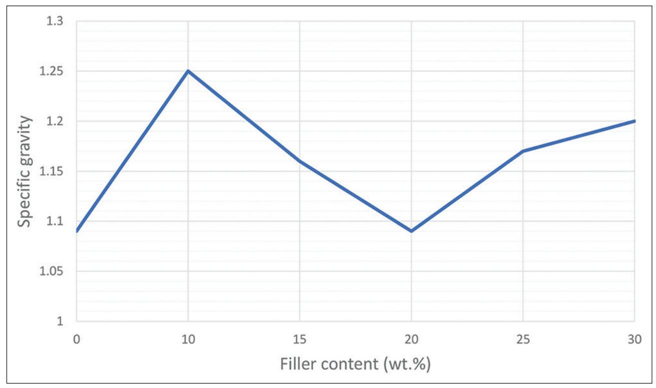

Figure 5: Effect of marble dust content on the specific gravity of concrete samples

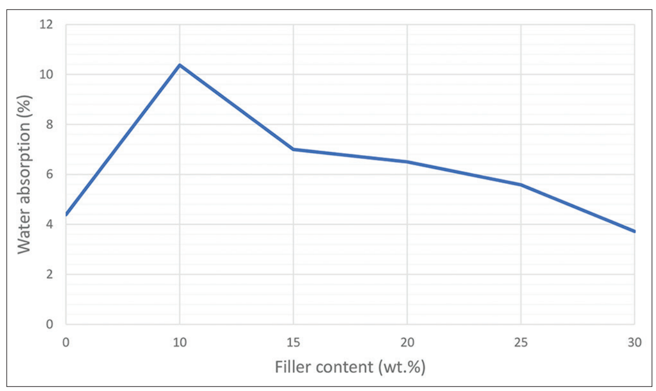

Figure 6: Effect of marble dust content on water absorption of concrete samples

et al.[6] working on sand-reinforced polyester composites reported increasing compressive stress with clay ratio at particle size <0.5 mm due to the catalytical effect of clay constituents. However, Sultana *et al*.[3] found that the compressive strength of sand-reinforced polyester composites decreased with sand content and that the lower compressive strength of sand-reinforced polyester composites was due to the lower magnitude of cross-linking reactions.

Hardness

Figure 3 illustrates the effects of marble dust content on the hardness of prepared polyester resin concretes. The figure showed that the sample hardness increased with marble dust content and was in the range of 9.0–16.71 Hv for the marble dust content studied (0–30 wt. %). Cured UPR exhibited a hardness of 7.83 Hv. The increase in concrete hardness is attributed to the reinforcing effect of marble dust filler.

Sultana *et al*.[3] reported increases in Vickers hardness of sand-reinforced polyester concrete with sand content while Chukwu *et al*.[16] reported decreases in hardness of snail shell-filled terephthalate UPR with filler content. Material hardness depends on such factors as strength, stiffness, ductility, and strain of the sample.

Impact Strength

Figure 4 shows the variation of impact strength of formulated polyester resin concrete samples with marble dust content. The impact strength of the samples increased with filler content and was generally greater than the one of cured UPR (0.27 J). The 30 wt. % marble dust formulated polyester resin concrete exhibited the highest impact strength (1.37 J) while 10 wt. % marble dusts formulated polyester resin concrete exhibited the least strength (0.37 J).

Specific Gravity

The specific gravity of cured UPR is 1.09. As shown in Figure 5 shows that the 10 wt.% marble dust formulated polyester resin concrete sample exhibited the highest Gravity (1.25). At filler contents, 20–30 wt. %, the specific gravity of marble dust formulated concrete samples increased with filler content and was generally greater than the one of cured UPR. Both the cured UPR and 20 wt. % marble dust formulated polyester concrete had the same specific gravity.

Water Absorption

The water absorbed by the prepared polyester resin concretes is illustrated in Figure 6. The addition of 10 wt. % marble dust increased the water absorbed by the concrete to 10.37%.

The sample containing 30 wt. % marble dust absorbed the least amount of water (5.29%). The water absorbed by concrete samples containing 15–30 wt. % marble dust generally decreased with filler content and is attributed to increased tightness, and consequently, a decrease in sample pores as a result of improved adhesion between the filler and polymer matrix. This resulted in low water absorption by the concretes. The cured UPR absorbed 4.39% water. The prepared polyester resin concretes generally absorbed more water than the cured UPR. The water absorbed by the concrete samples containing 15–30 wt. % marble dust lies between 3 and 7%. The decrease in water absorbed by polyester PC with filler content has been reported in the literature.[3]

CONCLUSION

UPR concretes were successfully prepared using marble dust of particle size, 0.075 mm.

i The tensile, and compression strength of the concretes decreased with marble dust content.

ii The impact strength, hardness, and specific gravity of the concrete samples increased with marble dust content.

iii Incorporation of 10 wt. % marble dust into the polyester resin increased the concrete water absorption to 10.37% after which the water absorbed by the concrete samples decreased with filler concrete.

The present study has highlighted the utility of marble dust filler in formulating sustainable, cost-effective hybrid PCs possessing good impact and hardness properties for applications in areas where water absorption is not a critical factor. Since the generation of marble particulate waste causes environmental and economic problems, the potential application of marble dust powder in the composite industry will lead to effective management and reuse of the waste for a clean and green environment.

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