Physical Properties of Polyester Composites Filled with Micro-sized Marble Stone Dust Particulates

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Abstract

This paper presents an experimental study on the physical behaviour of the polymer composites prepared with polyester as base matrix material and micro-sized marble stone dust particulates as a filler material. In the current investigation, the probability of using marble dust as a filler material in the polyester resin is explored to develop the composite body. Polyester-based composites are prepared by varying the content of marble dust up to 40 wt. % using the hand lay-up method. The properties investigated are density, void content and water absorption rate. From the study, it is observed that the inclusion of marble stone dust in the polyester resin increases the density along with the void content in the composite as a linear function of filler loading. It is further observed that the addition of marble stone dust does not cause a very high rate of water absorption as it is limited to a very low value even for a high filler loading.

Keywords: *Polymer composites, Polyester, Marble stone dust, density, voids content, water absorption rate.*

Introduction

In India, Rajasthan is a state which has a large number of stone industries. Among them, marble stone industries are large numbers and produce an enormous quantity of waste. Hence proper recycling of this waste is the need of an hour. For that reason, the utilization of waste from stone industries for the design of novel materials is an appropriate solution. In that sense, different researchers utilize stone dust for the manufacturing of clay bricks, concrete and polymeric composites. In our study, the interest is in the usage of these stone industries' waste in the polymeric composite. In this context, marble dust and granite dust have been explored globally. Cinar and Kar [1] used marble dust as a filler material with polyethene terephthalate (PTE) waste for the preparation of the composite body to reduce this waste in the environment at a low cost. Awad and Abdellatif [2] studied the effect of marble dust loading on different, physical, mechanical, and thermal properties of the Low-density polyethene (LDPE) composites. From the analysis, they found that the flexural strength and flexural modulus of the material increase with an increase in the content of marble dust. A similar trend is obtained for compressive strength, compressive modulus, and hardness as well. Nayank and Satapathy [3] studied the sliding wear behaviour of polyester composites filled with micro-sized marble dust. rate decreases. Bakshi et al. [4] used the injection moulding method for preparing polypropylene/marble dust composites for different filler content (20 wt. %, 40 wt. %, 60 wt. %, and 80 wt. %) and at varying processing temperatures (160 oC, 180 oC, and 200 oC). The fabricated samples were tested for their physical, mechanical, and thermal properties. Khan et al. [5] used the combination of low-density polyethene with marble dust for the development of a composite with varied content of marble dust up to 50 wt. %. The fabricated set of composites was tested for their mechanical and thermal properties. From the experimentation, they found that the flexural strength and thermal conductivity of the material increase with an increase in the content of marble dust, whereas, the tensile strength and impact strength of the material decrease as the marble dust content increases. Lendvai et al. [6] investigated the incorporation of waste marble dust into poly(lactic acid) (PLA) to create biocomposites, focusing on their mechanical, thermal, and wear properties. In another work, Lendvai et al. [7] explored the development and characterization of composites made from recycled polyethylene terephthalate (rPET) and waste marble dust. Singh et al. [8] focused on selecting sustainable polymer composites filled with waste marble dust using a multi-criteria decision-making (MCDM) technique. The study aimed to identify the optimal polymer matrix for enhancing the properties of marble dust-filled composites by evaluating mechanical, thermal, and environmental performance.

Apart from the content of filler, the effect of the size of marble dust particles on different properties of the material is of great concern. On that note, Awad et al. [9] studied the effect of marble dust particle size and loading on different mechanical properties of the polypropylene-based composite material. They performed the analysis for four different size marble particles (1350 µm, 475 µm, 387 µm, and 37 µm). While studying the effect of particle size on the material's properties, they found that smaller particles result in higher properties compared to larger particles. A similar study was performed later by Nayak and Satapathy [10] where they studied the effect of marble dust particle size on different mechanical properties of polyester composites. For performing the study, they selected three different sizes of dust particles i.e., 58 µm, 110 µm, and 155 µm and fabricated composites with filler content varied up to 40 wt. %. While measuring the tensile and flexural strength, they found that the strength of the material decreases with an increase in filler content, whereas, composites prepared with smaller size particles deliver better strength in terms of tensile and bending loading than composites prepared with larger size particles. Against that, compressive strength, impact strength, and hardness of the material increase with filler loading and particle size. The present work focuses on the bulk utilization of marble stone dust as a filler material in polymeric resin. Marble dust will be used as a single filler material in polyester resin to fabricate composites. In the current investigation, physical properties like density, void content and water absorption rate of the samples are evaluated experimentally.

Material considered and composite fabrication

Unsaturated isophthalic polyester is taken as the matrix material in the present investigation. It is used with its corresponding accelerator and catalyst. Polyester resin is also known as a thermosetting plastic, which implies plastic sets at high temperatures. Polyester resin composites are cost-effective because they require minimal setup costs and the physical properties can be tailored to specific applications. Polyester resins are the most economical and widely used resin systems, especially in the marine industry. Their advantages include low viscosity, low cost, and fast cure time. In addition, polyester resins have long been considered the least toxic. Isophthalic polyester resins exhibit higher thermal stability, dimensional stability, and creep resistance. Marble dust in the form of micro-particulates is chosen as a matrix material in the present investigation. The waste marble dust is collected from a local construction site during the cutting of marbles and then the dust is sieved to obtain a mean particle size of 80 microns. The estimated density of marble dust is taken as 2.80 g/cm^3.

A simple hand lay-up technique is used in the present investigation for the fabrication of marble dust in a polyester matrix. This method is considered the simplest technique for composite fabrication. Composites were fabricated with different weight fractions of filler ranging from 0 wt. filler i.e. neat polyester to 40 wt. % marble dust particulate filler. The composite fabricated under the investigation is given in Table 1.

Set	Composition
PE	Neat polyester
PEMD10	Polyester + 10 wt. % Marble dust
PEMD20	Polyester + 20 wt. % Marble dust
PEMD30	Polyester + 30 wt. % Marble dust
PEMD40	Polyester + 40 wt. % Marble dust

Experimental details

The experimental density (ρ_{ce}) of composites under study is determined by using the Archimedes principle using distilled water as a medium (ASTM D 792-91). The theoretical density (ρ_{ct}) of composite materials in terms of weight fractions of different constituents can easily be obtained using a rule of the mixture model. The volume fraction of voids in the composites is calculated with the help of experimental and theoretical density. Water absorption tests were carried out to analyze the behaviour of the composite in the presence of water-affected environments. Mainly the test was conducted in normal water to assess the amount of water absorbed by the composite according to ASTM D 570 standard.

Results and Discussion

Density and voids content

Figure 1 shows the density of polyester/marble dust composites, determined both by Archimedes' principle and the rule of mixtures model. The figure illustrates that the composite density rises linearly with increased marble dust content in the polyester matrix. The density of pure polyester is recorded at 1.145 g/cm³. Adding 10 wt. % marble dust increases the composite density to 1.195 g/cm³ and with 40 wt. % marble dust, the density rises to 1.405 g/cm³.

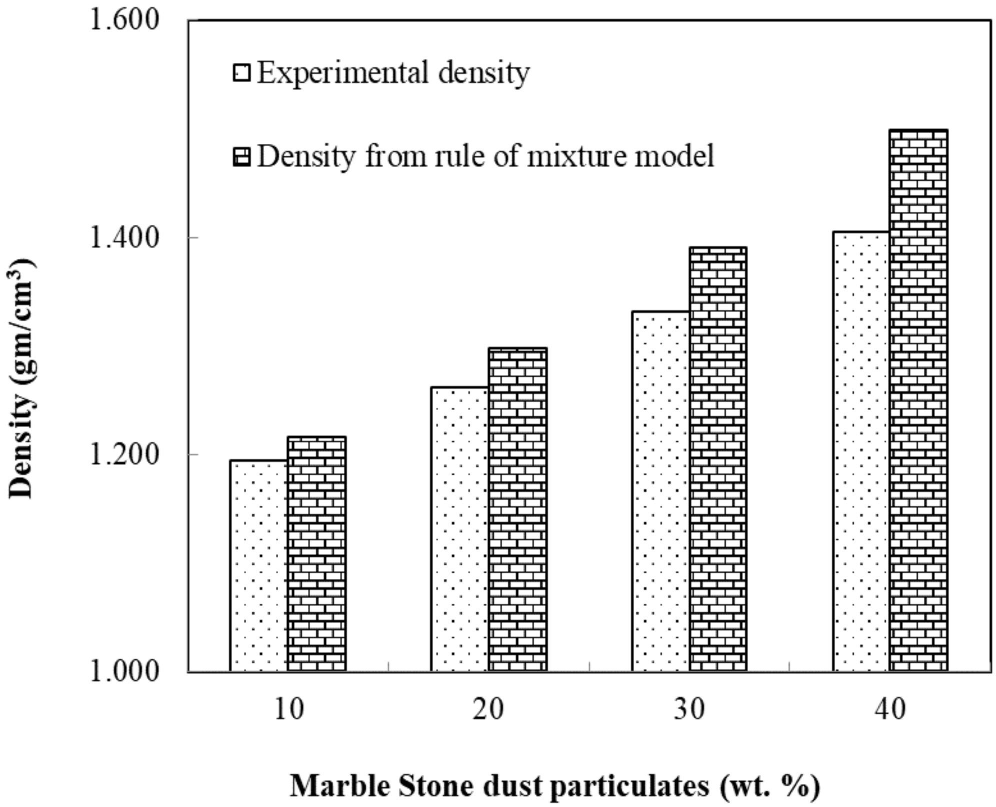

Figure 1. Measured density and calculated density of polyester/marble dust composites.

The composite density increases with filler loading because the filler used has a higher intrinsic density than the matrix. A similar trend is observed when using the rule of mixtures model to determine composite density, with the maximum density reaching 1.499 g/cm³. The calculated density values are consistently higher than the measured ones due to air voids in the fabricated composites. The rule of mixtures model does not account for these voids, resulting in a discrepancy between theoretical and actual values. Since voids have a lower density than the other phases in the composites, the measured density is lower than the calculated density. Figure 2 illustrates the voids generated during fabrication and curing, which increase with higher filler loading. Consequently, the deviation between measured and calculated densities grows with increased filler content. The maximum void content observed is 6.27% for composites with 40 wt. % marble dust.

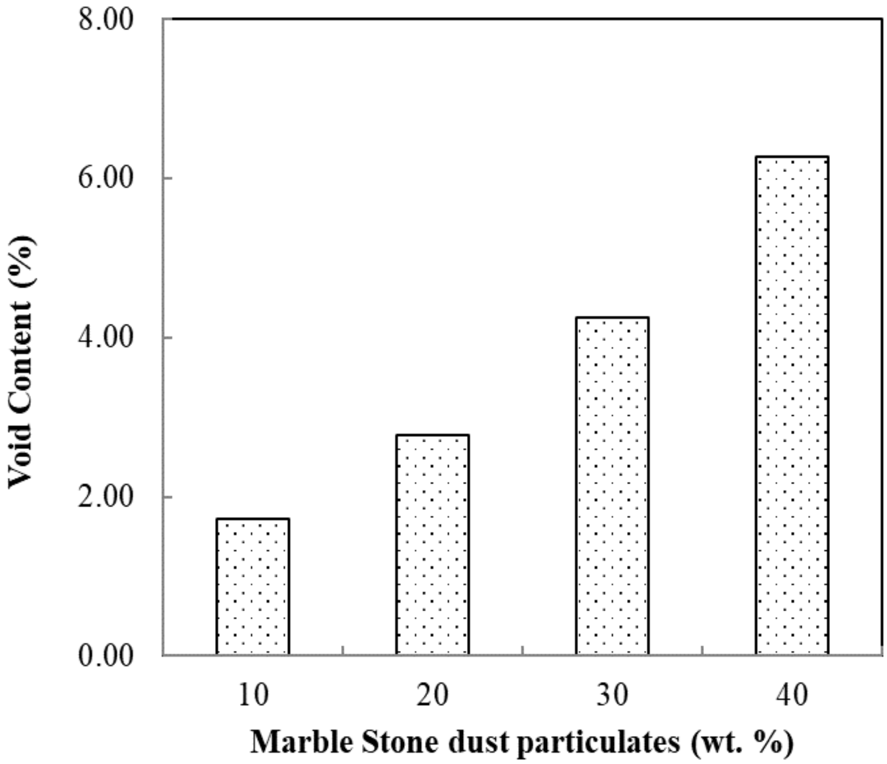

Figure 2. Void content of polyester/marble dust composites.

Water absorption behaviour

Figure 3 illustrates the water absorption rate of polyester composites filled with micro-sized marble dust particles, showing variations at different filler loadings and immersion times. Unfilled polyester has a very low water absorption rate of 0.57% after 168 hours. With the addition of fillers, the water absorption rate increases with both filler loading and immersion time. This is due to the increased hydrophilic surface area and voids created by the filler, which provide more pathways and space for water. The maximum water absorption observed is 1.36% at the highest filler content and immersion time. Despite marble's hydrophilic nature, water primarily accumulates on the surface of the powder rather than penetrating the polymer grains, resulting in low water intake. The graph shows that overall water absorption for the polyester/marble dust combination is minimal, indicating good compatibility and bonding between the phases. Initially, water molecules penetrate the composites quickly, causing a rapid weight gain, but this slows down as saturation occurs and no additional space is available for water absorption. This is the reason why after a certain duration of time, the water absorption rate decreases and reaches a saturation stage where further absorption of water is not possible. The water absorption rate is very low in the present investigation which is a motivation as low water absorption is required.

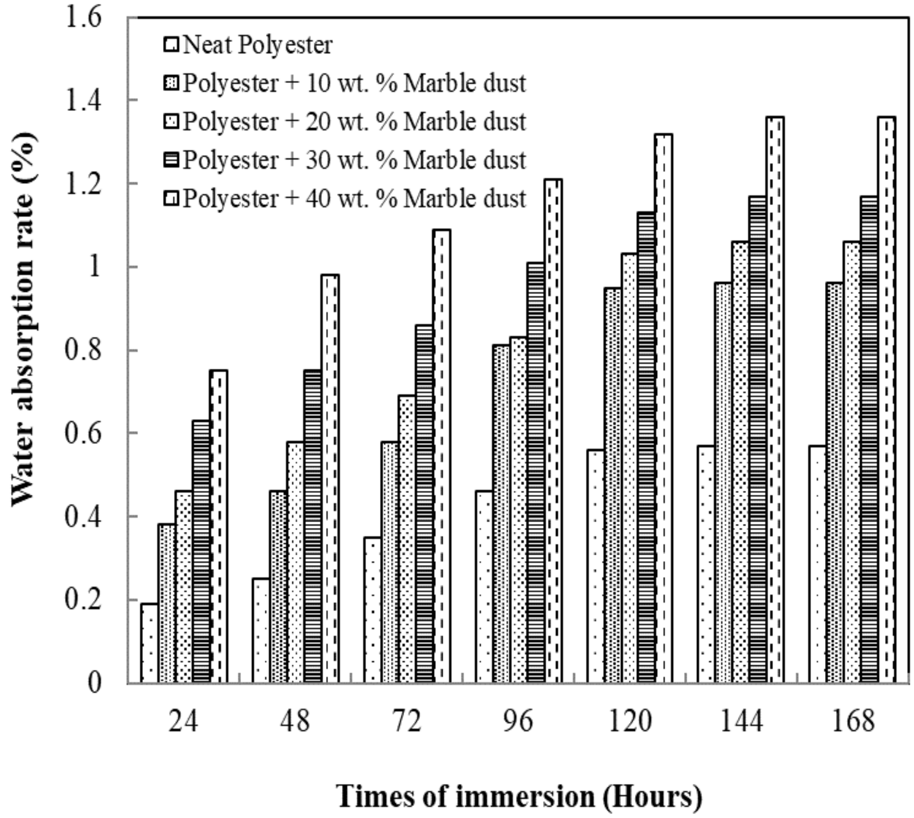

Figure 3. The water absorption rate of polyester/marble dust composites.

Conclusions

This experimental investigation on marble dust micro-particulates filled polyester composites has led to the following specific conclusions:

1. Successful fabrication of polyester composites filled with marble stone dust as filler for the development of polymer composites is possible by simple hand lay-up method. This is considered to be the simplest and cheapest technique for fabricating the composite body.

2. The density of the composites increases with an increase in the content of the filler as the density of the filler is higher than the density of the polyester matrix. The density of pure polyester is 1.145 g/cm³ and increases to 1.405 g/cm³ with the addition of 40 wt. % of marble dust. These composites possess a low amount of porosity. The porosity of the material also increases with an increase in the content of fillers. The maximum void content observed is 6.27% for composites with 40 wt. % marble dust.

3. The water absorption rate of the polyester composite increases as the content of marble dust in the composite increases. Further, the water absorption increases with the time of immersion. The maximum water absorption is recorded for a composite prepared with 40 wt. % of marble dust for an immersion time of 168 hours. The maximum value of water absorption is 1.36 %.

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