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

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ABSTRACT :

In the current investigation, the mechanical properties of the polymer composites fabricated with polyester as a matrix material and marble stone dust particulates as a filler material. Polyester-based composites are prepared using the hand lay-up method by varying the content of marble dust up to 40 wt. %. The mechanical properties investigated are tensile strength, tensile modulus, flexural strength, flexural modulus, compressive strength and hardness. From the study, it is observed that the inclusion of marble stone dust in the polyester resin decreases the tensile strength and flexural strength of the composite body. Against that, the tensile modulus, flexural modulus, compressive strength and hardness of the composite increase with filler loading as a linear function of filler content.

**Keywords:** Polymer composites, Polyester, Marble stone dust, Mechanical properties.

## Introduction :

A large number of stone industries are present in Rajasthan, a state of India Among all the industries, 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/cm3.

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.

**Table 1 - List of polyester-based composites filled with marble dust**

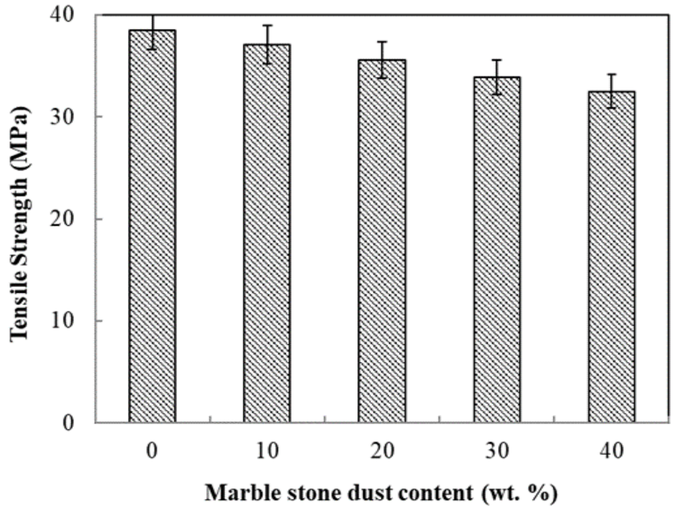
| S. No. | Composition |
|---|---|
| PE | Neat polyester |
| PEMD10 | Polyester + 10 wt. % Marble dust |
| PEMD20 | Polyester + 20 wt. % Marble dust |
| PEMD30 | Polyester + 30 wt. % Marble dust |
| PEMD40 | Polyester + 40 wt. % Marble dust |

The tensile strength of the composites is measured with a computerized Instron 1195 universal testing machine in accordance with the ASTM D638 procedure by applying uni-axial load through both ends. Static uniaxial compression tests on specimens are carried out using the same computerized universal testing machine. The method by which the compression test is conducted is in accordance with ASTM D695. The three-point bend test was carried out in accordance with ASTM D790 to measure the flexural strength of the composites. The hardness test was carried out by ASTM D-2240 using a PosiTector SHD Shore hardness Durometer.

## Results and Discussion :

Figure 1 shows the tensile strength of polyester composites with different amounts of marble stone dust. The graph indicates that as the marble dust content increases, the tensile strength of the composite decreases. Pure polyester has a tensile strength of 38.5 MPa. When 40% marble dust is added, the tensile strength drops to 32.5 MPa, a decrease of about 15.58% as compared to that of neat polyester. In summary, adding more marble dust to the polyester composite decreases its tensile strength due to particle clumping and increased surface area, which prevents proper bonding. These factors together lead to a significant reduction in the material's ability to withstand tensile stress. Figure 2 shows how marble stone dust affects the tensile modulus of polyester composites. The graph indicates that as more marble dust is added, the tensile modulus increases. Pure polyester has a tensile modulus of 3435 MPa. When 40% marble dust is added, it rises to 4387 MPa, an increase of about 27.7%. This increase is because marble dust particles are hard and add rigidity to the polyester matrix.

**Fig. 1 - Tensile strength of polyester/marble stone dust composites.**



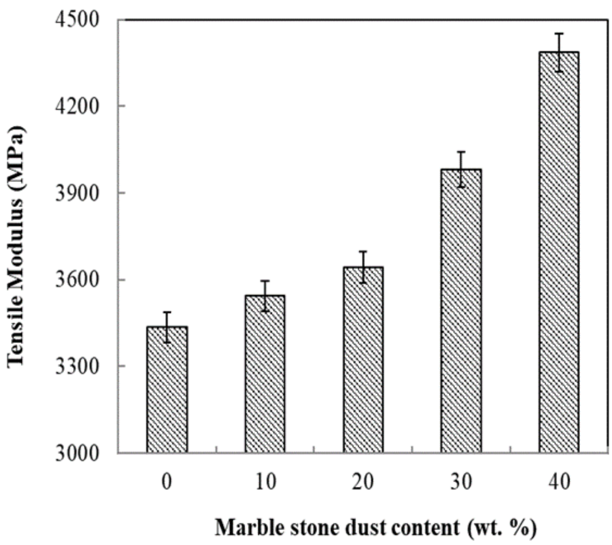



**Fig. 2 - Tensile modulus of polyester/marble stone dust composites.**

Figure 3 shows how marble dust content affects the flexural strength of polyester-based composites. The trend is similar to that observed for tensile strength: as the amount of marble dust increases, the flexural strength decreases. Pure polyester has a flexural strength of 45.2 MPa, but with 40% marble dust, it drops to 36.2 MPa, a decrease of 19.9%. The reduction in flexural strength occurs for the same reasons as the tensile strength decline. Increased filler content leads to particle agglomeration, causing uneven stress distribution and reducing the material's overall strength. Additionally, more filler particles increase surface area, preventing proper bonding and further weakening the material.

Figure 4 illustrates that, unlike flexural strength, the flexural modulus increases with more marble dust. Pure polyester has a flexural modulus of 3143 MPa, which rises to 4444 MPa with 40% marble dust, a notable improvement of 41.39%. This increase is due to the high rigidity of marble dust compared to polyester. Adding high-modulus marble dust to the polyester matrix enhances the composite's overall modulus, making it more rigid and less prone to deflection under load.

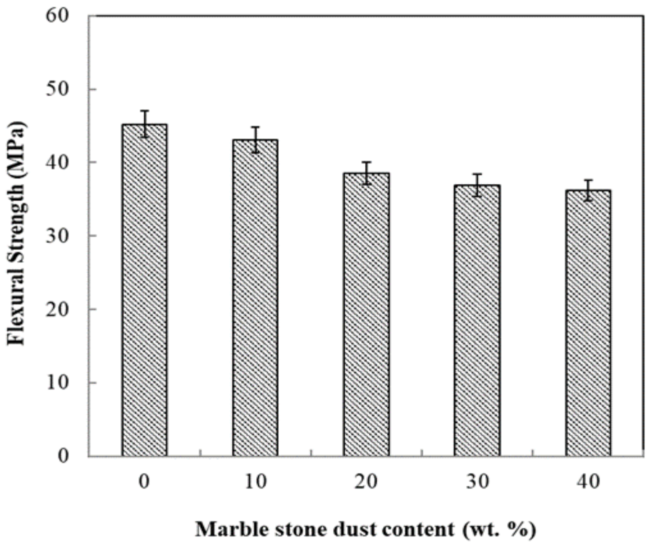



**Fig. 3 - Flexural strength of polyester/marble stone dust composites.**

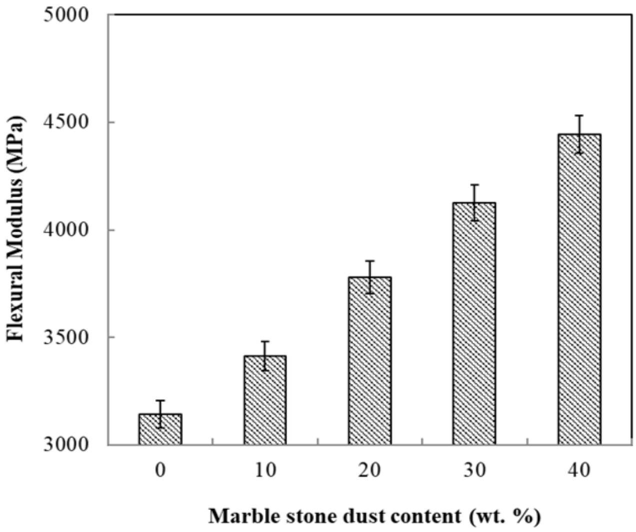



**Fig. 4 - Flexural strength of polyester/marble stone dust composites**

Figure 5 shows the compressive strength of polyester composites with different amounts of marble stone dust. The graph indicates that adding marble dust to the polyester matrix improves compressive strength linearly. Pure polyester has a compressive strength of 77.5 MPa. When 10% marble dust is added, the strength increases to 81.5 MPa, a 5.16% improvement. With 40% marble dust, the compressive strength reaches 91.3 MPa, a significant 17.8% increase over pure polyester. The enhancement in compressive strength with added filler is due to the high compressive strength of marble dust.

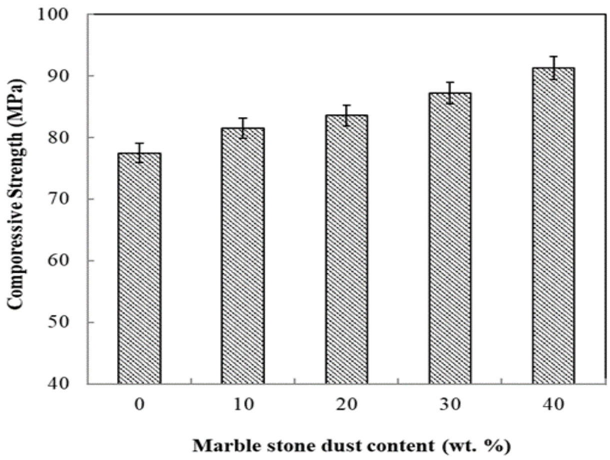



**Fig. 5 - Compressive strength of polyester/marble stone dust composites**

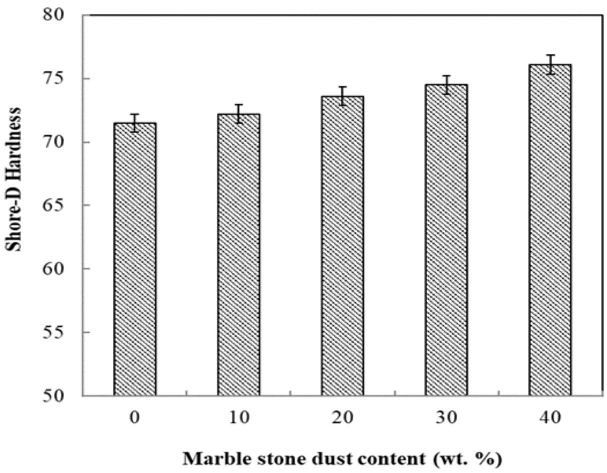



**Fig. 5 - Compressive strength of polyester/marble stone dust composites**

Figure 6 shows the hardness of the polyester composites with marble stone dust. The hardness of pure polyester is measured at a Shore-D value of 71.5. Adding marble dust to the polyester matrix increases the hardness. With 10% marble dust, the Shore-D value rises to 72.2. When the marble dust content reaches 40%, the hardness increases to 76.1, showing an improvement of 6.43%. The increase in hardness is due to the high hardness of marble stone. Hardness measures localized deformation under specific conditions. Adding marble dust makes the polyester less likely to deform plastically and acts as a barrier to dislocation movement in the matrix. This results in a harder composite material.

## Conclusion :

This present investigation has led to the following conclusions:

1. The inclusion of marble dust in the polyester matrix reduces the tensile strength of the polyester as a function of filler loading. The minimum tensile strength of 32.5 MPa is registered for the polyester composites filled with 40 wt. % of marble stone dust. The tensile modulus of the composite material increases with an increase in marble stone dust content. The maximum tensile modulus reported is 4387 MPa.
2. The incorporation of marble stone dust in the polyester matrix reduces the flexural strength of the material. The minimum flexural strength of 36.2 MPa is measured for the polyester filled with 40 wt. % of marble stone dust. The flexural modulus of the composite material increases with an increase in the content of the marble dust. The maximum flexural modulus obtained is 4444 MPa.
3. The addition of marble stone dust in the polyester matrix increases the compressive strength and hardness of the material as a function of filler content. With the addition of 40 wt. % of the filler, the compressive strength of the polyester/marble stone dust composite increases to 91.3 MPa, and the hardness of the polyester/marble stone dust composite increases to 76.1 Shore-D number

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