Mechanical Properties of Epoxy Composites Filled with Kota Stone Dust Particulates

Ajay Ahirwar, Virendra Rajput and Syed Faisal Ahmed

Department of Mechanical Engineering, Sagar Institute of Research and Technology-Excellence, Bhopal 463041, Madhya Pradesh, India

Abstract

The present work aims at developing a class of polymer composites consisting of thermoset polymer i.e. epoxy as a matrix material with Kota stone dust in the form of micro-particulates as a filler material. A set of composites with varying filler loading has been fabricated by a simple hand lay-up technique. The effect of filler content on the mechanical properties of such fabricated samples is investigated and presented in this work. The various property evaluated is tensile strength, tensile modulus, compressive strength, flexural strength, flexural modulus and hardness of the fabricated samples. The values obtained under controlled laboratory conditions are analyzed to identify its behaviour. From the experimental results, it is observed that the inclusion of Kota stone dust in the form of micro-particulates gainfully improves the various mechanical properties of the material under investigation. Further, it is observed that the inclusion of Kota stone dust in the epoxy resin enhances the brittleness of the material as it reduces the elongation at the break of the material.

Keywords: *Polymer matrix composites, Epoxy, Kota stone dust, Mechanical properties.*

1. Introduction

Recycling is considered an important aspect of today's world in every sector. The waste produced by different industries causes huge trouble to the environment. One such industrial waste is obtained from the stone industry. The major contributions of waste from such industries are in the form of dust representing around 50 % of the total generated waste. This waste is dumped on roads and scattered all over by the effect of the wind. In Rajasthan, a huge quantity of stone dust was produced during the process of machining and cutting the stone. The major portions of them are generated from the marble industry, granite industry, and Kota stone industry. Marble stone dust obtained from the marble industry has been used as filler material in polymeric resin for quite since time. Cinar and Kar [1] used marble dust as a filler material with polyethene terephthalate (PTE) waste for the preparation of the composite body and studied the mechanical and thermal properties. From the experimental analysis, they found that the hardness and flexural strength of the samples increase with an increase in the filler content, whereas, the impact energy of the composite system decreases. While studying the thermal properties, they found that the thermal conductivity of the material increases as a function of marble dust content. Awad and Abdellatif [2] studied the effect of marble dust loading on different, physical, mechanical, and thermal properties of the low-density polyethylene (LDPE) composites and found improvement in the different properties with filler loading. Nayank and Satapathy [3] studied the sliding wear behaviour of polyester composites filled with micro-sized marble dust and found improvement in wear resistance of the material. Khan et al. [4] used the combination of low-density polyethene with marble dust and the composites was tested for their mechanical and thermal properties. From the experimentation, they found that flexural strength and thermal conductivity of the material increase with an increase in the content of marble dust, whereas, tensile strength and impact strength of the material decrease as the marble dust content increases. Bakshi et al. [5] prepared polypropylene/marble dust composites for different filler content (20 wt. %, 40 wt. %, 60 wt. %, and 80 wt. %) and at varying processing temperatures (160 ^{o}C, 180 ^{o}C, and 200 ^{o}C). The fabricated samples were tested for their physical, mechanical, and thermal properties.

Granite stone dust has also been explored by various researchers in the past as filler material in a polymeric resin. Subhash et al. [6] used granite dust with an epoxy matrix and performed the water absorption test, hardness test, and impact test on all sets of fabricated composites. From the measurement they found an improvement in the various properties of the material. Garigipati and Malkapuram [7] studied the hardness, and thermal properties of the poly

benzoxazine-filled granite powder. From the hardness testing, they found that with an increase in filler content, the hardness of the material increases. Further, they performed the thermo-gravimetric analysis of the material. From the analysis, they found that, the thermal stability of the material increases as the filler content increases. Mathavan and Patnaik [8] studied the effect of the inclusion of granite dust in a polyamide matrix in terms of its hardness and erosion wear rate. They reported that, with increased hardness, erosion wear resistance of the material also increases.

However, it has been found that very less report is available for the usage of Kota stone dust as filler material in the polymeric composites. Rajput et al. [9-11] were the only group worked on this note. In their work, they used a combination of Kota stone dust with an epoxy matrix (Lapox L12) and explored the physical and mechanical properties of the composite body as a function of filler loading. They also implemented AHP and TOPSIS methods to evaluate the best possible combination of filler and matrix body on the basis of the physical and mechanical properties of the composite body. From the implemented technique, they came to the conclusion that the combination of epoxy with 20 wt. % of the Kota stone dust is the best combination of filler and matrix body. In their other analysis, Rajput et al. [12] used a hybrid combination of Kota stone dust with fly ash and prepared a hybrid composite with Lapox L12 as a base matrix. The properties evaluated by them are physical, mechanical and tribological properties. From the experimental investigation, they found that the inclusion of fly ash in a hybrid combination of Kota stone dust results in the improvement of different properties under investigation. They reported achieving remarkable improvement in the wear-resistant properties of the composite material and suggested the application accordingly. They also found that the tensile and flexural strength which was otherwise decreasing with high loading of Kota stone dust also gets improved when the hybrid combination of fillers is used. Hence, it is found that very few work is reported on the utilization of Kota stone dust as a filler material in the polymeric resin. Against this background, an attempt has been made in this research work to develop epoxy composites with micro-sized Kotas tone dust using a simple hand lay-up technique and to study their mechanical properties i.e. tensile strength, flexural strength, compressive strength and hardness.

2. Material considered and composite fabrication

Epoxy (LY 556) is chosen as the matrix material for the present research work. It provides a solvent-free room temperature curing system when it is combined with the hardener tri-ethylene-tetramine (TETA). Kota stone dust in the form of micro-particulates is used as a filler material in the epoxy matrix. In the present investigation, a Kota stone dust filled epoxy composite is fabricated using a simple hand lay-up technique. Composites were fabricated with different weight fractions of filler ranging from 0 to 50 wt. %.

3. Experimental details

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 in accordance with ASTM D-2240 using a PosiTector SHD Shore hardness Durometer.

4. Results and Discussion

4.1 Tensile strength

Figure 1 shows the effect of the addition of the Kota stone dust on the tensile strength of the epoxy composites. It can be seen from the figure that the inclusion of Kota stone dust in the epoxy resin results in the improvement of the tensile strength of the material. The tensile strength of the unfilled epoxy resin is 34.4 MPa and the same increases to 37.2 MPa with the addition of 10 wt. % of the Kota stone dust. This is an improvement of 8.13 %. The rate of an increment is high till the filler loading is 30 wt. %. At this filler loading, the tensile strength reaches 43.1 MPa showing an increment of 25.29 %. When the content of filler increases above 30 wt. %, the rate of increment in the tensile strength drastically reduces. For a filler loading of 40 wt. % and 50 wt. %, the tensile strength obtained is 43.6 MPa and 44.1 MPa respectively which is an increment of 26.74 % and 28.19 % respectively. It is clear that the increment at this filler loading is negligible as compared to the tensile strength obtained for 30 wt. % filler loading.

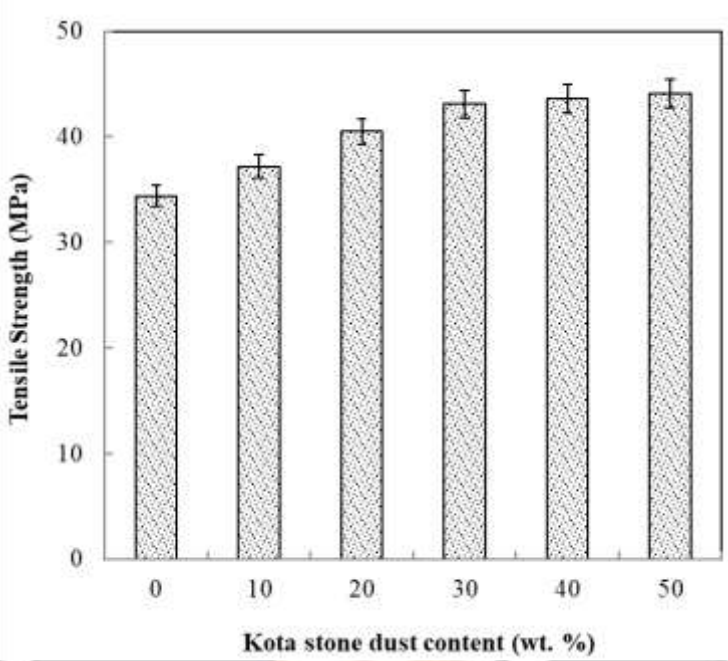

Figure 1: Tensile strength of epoxy composites filled with Kota stone dust

4.2 Flexural strength

Figure 2 reflects the variation in the value of flexural strength of epoxy composites prepared with varied content of Kota stone dust. From the figure, it is clear that the trend obtained for flexural strength is very similar to the trend observed for the tensile strength of the material. The filler content up to which the rate of increment is good is 30 wt. %. The flexural strength of the neat epoxy is 42.4 MPa and the same increases to 56.6 MPa when 30 wt. % of the Kota stone dust is added in the epoxy matrix. This shows an increment of 33.5 % over neat epoxy. With the further addition of the Kota stone dust, the flexural strength slightly increases. For 50 wt. % of the Kota stone dust, the flexural strength obtained is 58.1 MPa which is 37 % higher than the flexural strength of the neat epoxy and only 2.65 % higher than the flexural strength of epoxy/30 wt. % Kota stone dust composite. The reason for such a trend is the agglomeration and improper wetting of the filler particles at a high filler loading.

4.3 Compressive strength

The compressive strength of the epoxy composite as a function of Kota stone dust particulate loading is presented in Figure 3. It is clear from the graph that the inclusion of Kota stone dust particulates gainfully improves the compressive strength of the material. The compressive strength of the neat epoxy is 74.3 MPa. The compressive strength starts to increase with the inclusion of a small amount of the filler material. When 10 wt. % of the Kota stone dust is incorporated in the epoxy resin, the compressive strength increases to 77.5 MPa showing an increment of 4.3 %. The increment follows the same trend as the filler loading. When 50 wt. % of the Kota stone dust is added in the epoxy matrix, the compressive strength increases to 93.1 MPa registering an appreciable improvement of 25.3 % over the neat epoxy.

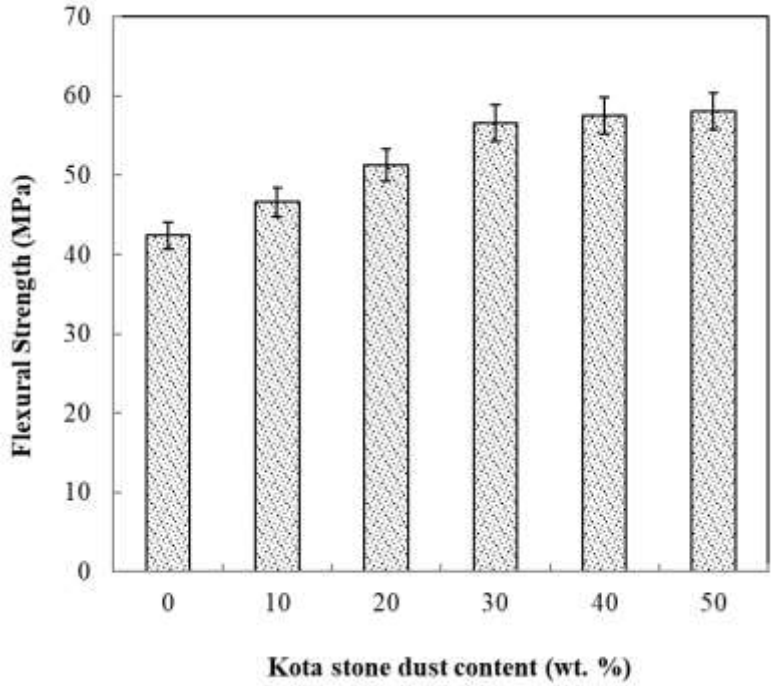

Figure 2: Flexural strength of epoxy composites filled with Kota stone dust

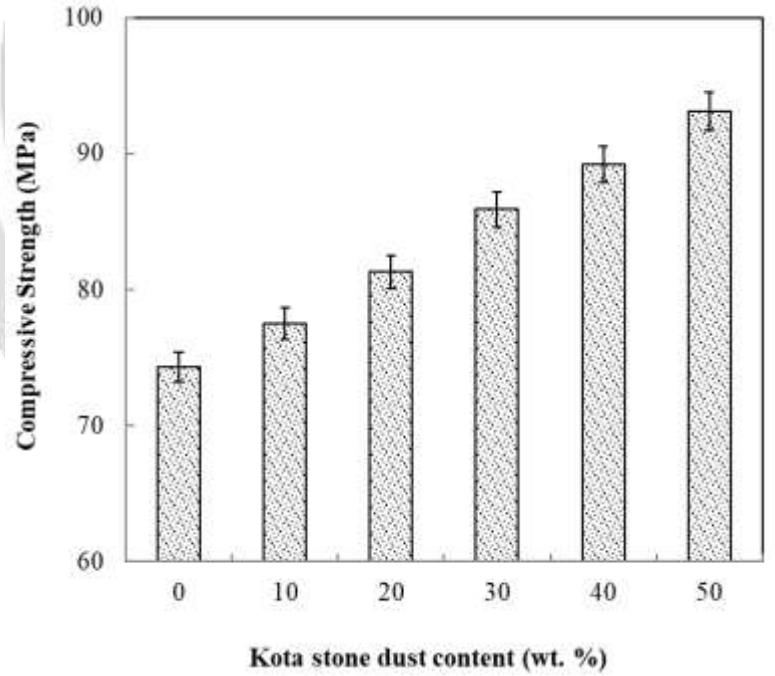

Figure 3: Compressive strength of epoxy composites filled with Kota stone dust

4.4 Hardness

The hardness of the epoxy filled with micro-sized Kota stone dust as a function of filler loading is presented in figure 4. The hardness of the unfilled epoxy is 77 Shore D number and the same increases to 79 with the addition of 10 wt. % of Kota stone dust. This shows a small increment of 2.5 %. The increasing trend continue with the filler loading. For a filler loading of 50 wt. %, the Shore D number of the composite increases to 87.

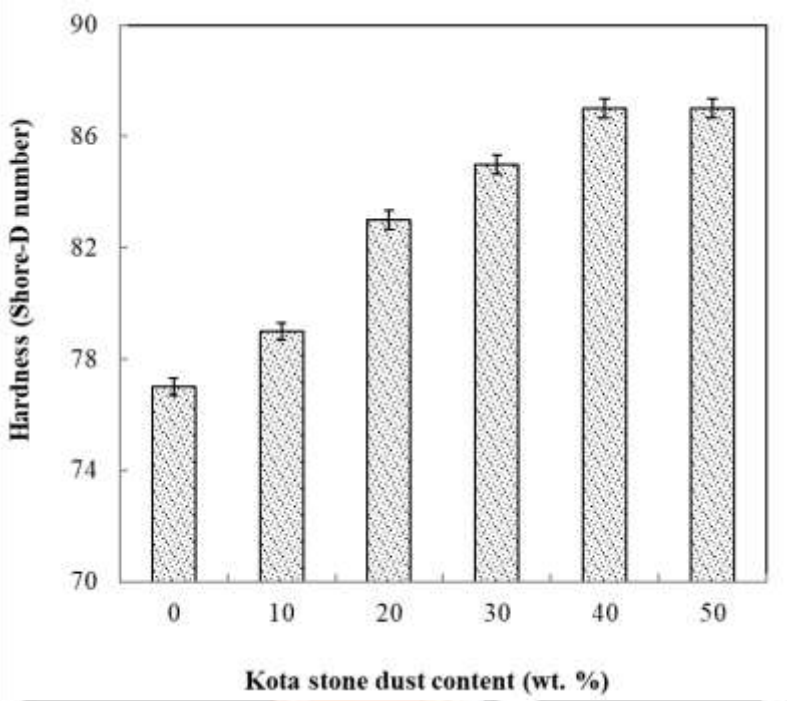

Figure 4: Hardness of epoxy composites filled with Kota stone dust

This shows an increment of 12.9 %. It is further observed that the same hardness is obtained for composite prepared with 40 wt. % Kota stone dust. Hence it is observed that the hardness of the composite not increased once the filler loading reached 40 wt. %. The reason for such increasing trend in hardness is due to the high hardness of Kota stone as compared to unfilled epoxy.

5. Conclusions

This experimental investigation on Kota stone dust filled epoxy composites has led to the following specific conclusions:

1. The maximum tensile strength is obtained for a composite prepared with a maximum filler loading of 50 wt. %. At this filler loading, the tensile strength obtained is 44.1 MPa showing an appreciable improvement of 28.19 %.
2. Incorporation of Kota stone dust in the epoxy matrix increases the flexural strength of the material. With the inclusion of 50 wt. % of the Kota stone dust, the maximum flexural strength is 58.1 MPa showing an increment of 37 % over the neat epoxy.
3. The compressive strength of the material also increases with filler loading in the present work. The compressive strength of the neat epoxy is 74.3 MPa and the same increases to 93.1 MPa registering an appreciable improvement of 25.3 % over the neat epoxy.
4. The hardness of the epoxy increases appreciably with the inclusion of Kota stone dust particulates due to the hard nature of the stone. The maximum value of the Shore D number obtained is 87 for a filler loading of 50 wt. % showing an increment of 12.9 %.

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