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INVESTIGATIONS ON THE MECHANICAL PROPERTIES OF RED MUD FILLED SISAL AND BANANA FIBER REINFORCED POLYESTER COMPOSITES

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Abstract. Addition of red mud (an industrial waste) in to sisal fiber, banana fiber reinforced unsaturated polyester (USP) is discussed in this study. Red mud is the caustic insoluble waste residue generated during the alumina production from bauxite. Composites were fabricated separately with sisal/USP, banana/USP and each of them was filled with red mud also through compression molding process. Static mechanical tests like tensile, flexural, impact were conducted as per ASTM. Experimental results show that the addition of red mud promotes a marginal increase in the mechanical strength.

1. Introduction

The utilization of various fillers along with natural fibers creates much interest among researchers due to its low cost, easy availability and greater enhancement in mechanical properties. The usage of red mud an industrial waste along with polyester resin was justified by A. Akinci et al. X-Ray Diffraction (XRD) and Differential Scanning Calorimeter (DSC) analysis were carried out and the results indicated that the crystallization effect of the polymer increased with the increase in red mud content [1]. Singh et al. reported about sisal fiber reinforced polyester filled with red mud and the results were compared with glass fiber. Flexural Strength, Tensile Strength and water absorption studies were carried out for the prepared specimens and reported about the addition of red mud for different fiber loading [2]. Biswas and Alok Satapathy carried out a study on bamboo fiber and glass fiber reinforced epoxy matrix composites filled with different weight proportions of red mud and their mechanical properties shows improvement by the addition of red mud. Erosion tests were also carried out and it showed good results to prove red mud as a potential filler along with polymer matrix composites [3].The addition of fillers along with natural fiber which are all the renewable sources available such as sisal and jute fiber along with industrial wastes such as fly ash, red mud have been used for value added composite materials. The study also indicated that engineering properties such as physical and mechanical and resistance to abrasive wear were improved in a better way by the addition of filler [4]. Kuruvilla Joseph et al. revealed a detailed report about the various work carried out in the area of sisal fiber polymer composites by giving importance to the processing techniques, physical and mechanical properties [5]. By modifying the polyester matrix mechanical properties of sisal fiber reinforced composites shows marginal increase in the properties. Tensile, flexural and water absorption properties of sisal reinforced polyester composites were carried out by compression moulding and resin transfer molding techniques for different fiber loading and fiber length and results were compared [6, 7]. S.M. Sapuan dealt the tensile and flexural properties of banana fiber reinforced with epoxy. The statistical analysis carried out, showed an increase in mechanical properties [8]. Dynamic studies on mechanical properties of randomly mixed sisal and banana fiber were carried out and it is observed that the flexural and tensile modulus shows improvement in results. The damping behavior also improved for sisal polyester composites [9]. Venkateshwaran et al. dealt the tensile, flexural and water absorption studies of banana-epoxy composite materials which showed a poor result and it can be improved in a better way by the addition of sisal fiber along with banana fiber in different weight percentages [10]. Sisal fiber along with carbon fiber reinforced hybrid composites were prepared by hand layup technique and the mechanical and the chemical resistance properties were reported [11]. The present work focused with the main objective of introducing a new set of polymer composites using red mud as a filler to enhance the mechanical property.

2. Experimental procedure

2.1. Materials used. Fiber: Sisal is a natural fiber of Agavaceae (Agave) family that yields a stiff fiber, traditionally used in making twine and rope. Banana fiber (Musaceae family) a type of bast fiber, is extracted from the bark of banana tree. Both the fibers are purchased from the local markets in Madurai, Tamil Nadu in India.

Polyester resin: Polyester of density 1.2 g/cc is mixed with catalyst. Resin was purchased from Vasavibala Resins, Chennai, India. Accelerator and Catalyst used are Cobalt Napthane and Methyl Ethyl Ketone and 2 % of catalyst and accelerator is mixed with resin for better curing purpose.

Red mud: Red mud was collected from Madras Aluminium Company (MALCO) at Salem, India and is sieved to obtain particle size in the range of 75-100 μm. The composition of red mud is shown in Table 1.

Table 1. Composition of red mud.

SiO_2	Al_2O_3	Fe_2O_3	Na_2O_3	CaO
15.21	16.8	33.8	11.87	2.45

2.2. Fabrication of composites. Mold is used for preparing the specimen which is made up of EN90 steel and having dimensions of 180 x 160 x 3 mm. Sisal fibers are reinforced with unsaturated general purpose(GP) polyester resin filled with and without red mud and used to prepare the composites through compression molding technique.

Fig. 1. Typical specimen of RM filled sisal and banana fibre composites.

2 % of cobalt nephthalate (as accelerator) is mixed thoroughly in GP polyester resin and then 3 % methyl-ethyl-ketone-peroxide (MEKP) as hardener is mixed in the resin prior to

reinforcement. Composites (10 % red mud filling) and the fiber loading of weight composition (20 %), for fiber length (10 mm) are made on random basis. The specimens are kept under load for about 5 hours for proper curing at room temperature. Similar procedure was adapted for the preparation of the banana fiber and glass fiber reinforced polymer composites. Typical specimen is shown in Fig. 1.

3. Results and discussion

3.1. Impact strength. The impact energy value of sisal and banana fibre reinforced red mud filled polyester composites is shown in Fig. 2.

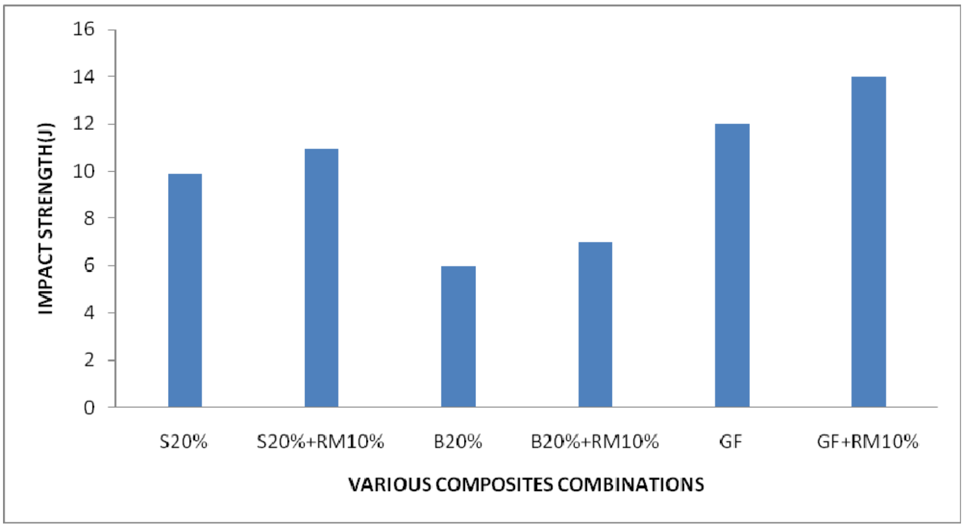

Fig. 2. Effect of red mud content on impact strength of sisal/banana fibre composites.

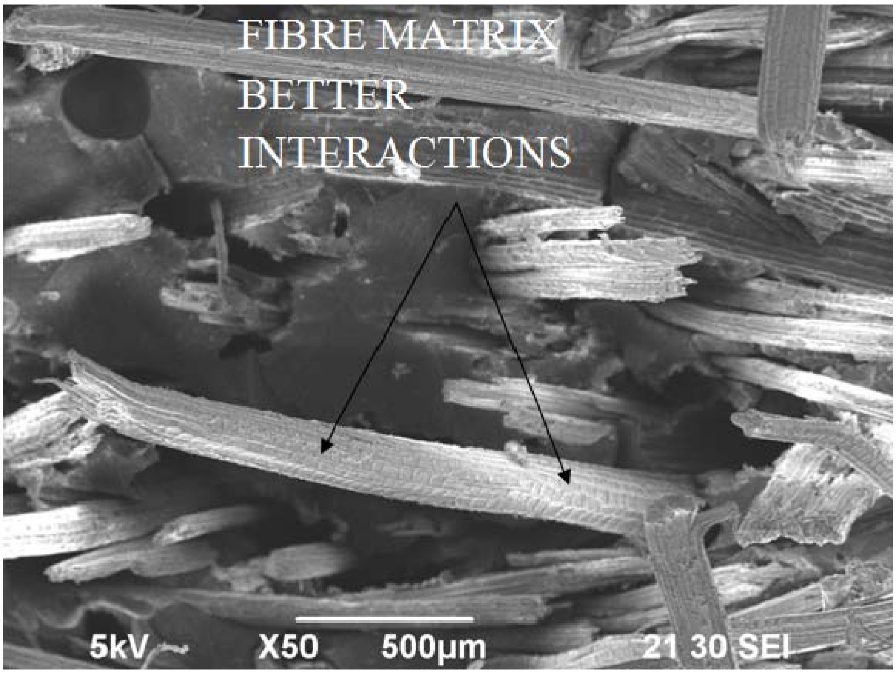

Fig. 3. SEM image of RM filled SF/USP after impact test.

In all cases the addition of red mud increases the impact strength, when compared to the sisal and banana fiber without red mud filling. Sisal fiber gives a maximum impact strength value of 11 J and for banana fiber impact strength value is just 6 J. At the same time when comparing with natural fibers, glass fibers possess a very high impact strength value of 18 J by the addition of RM. When compared with banana fiber, sisal fibre possess a very good impact strength also from the SEM image shown in Fig. 3. Strong bonding of fiber and matrix is noted. Also fiber pull out does not take place and so it results in high impact strength compared with banana fibre. In the case of BF/USP composite shown in Fig. 4 the formation of voids which leads to crack propogation results in complete disattachment of fiber from matrix and so results in less energy absorption.

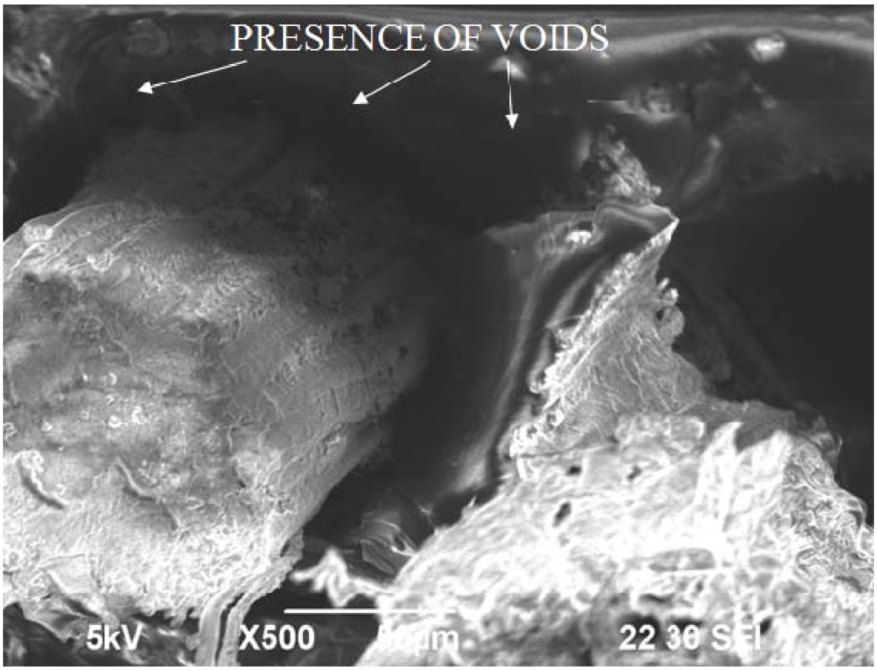

Fig. 4. SEM image of RM filled BF/USP after impact test.

3.2. Flexural strength. The flexural test is performed in UTM (capacity-3T) and a span of 50 mm with cross head speed of 2 mm/min. Figure 5 shows the variation in flexural strength by the addition of red mud filler along with sisal and banana fiber.

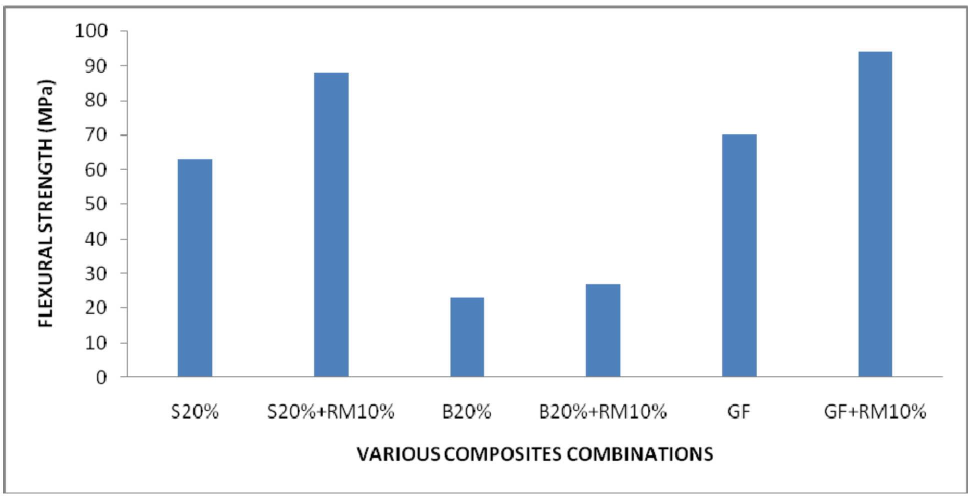

Fig. 5. Effect of red mud content on flextural strength of sisal fiber composites.

The test results show that sisal and banana fiber combination of 10 mm length and 20 % wt with 10 % wt red mud filler addition increases the flexural strength for both banana and sisal fiber. There is strong bonding between fiber and matrix which results in high flexural strength. Even though fiber pullout takes place, the presence of red mud particles provides better adhesion between fiber and matrix as shown in Fig. 6 which results in high flexural strength for sisal fiber.

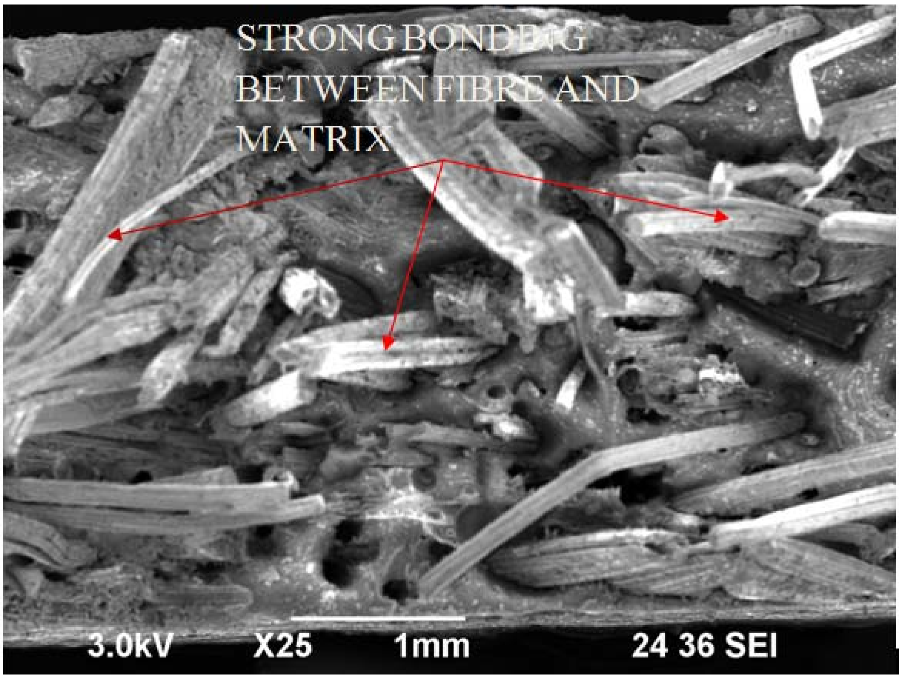

Fig. 6. SEM image of RM filled SF/USP after flexural test.

3.3. Tensile strength. Specimen with dimension of 165 mm x 10 mm x 3 mm is maintained for the unfilled as well as particulate filled composite specimen to carry out the tensile strength. A uniaxial load is applied through the ends. The results in Fig. 7 show that more addition of red mud decreases the tensile strength value.

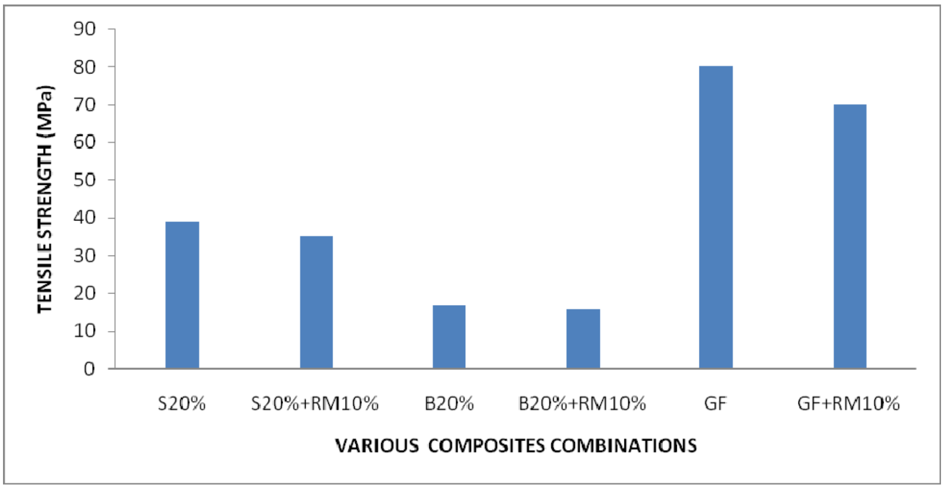

Fig. 7. Effect of red mud content on tensile strength of sisal/banana fibre composites.

This is due to the chemical reaction at the interface between the filler particles and the matrix getting too weak to transfer the tensile stress. Both for banana and sisal fiber there is no evidence of increase in tensile strength by the addition of red mud filler. Either the value goes on increasing or it comes nearer to the value of fiber without filler. The maximum result value obtained is 35 MPa for sisal fiber and in the case of banana fiber it is only 15 MPa. From SEM images in Fig. 8 and Fig. 9 the fibralisation process takes place which results in poor strength. It happens in both the cases of sisal as well as banana fiber. Also the non uniform size of redmud particles and its distribution over the surface occupying the edges of the matrix result in decrease in strength.

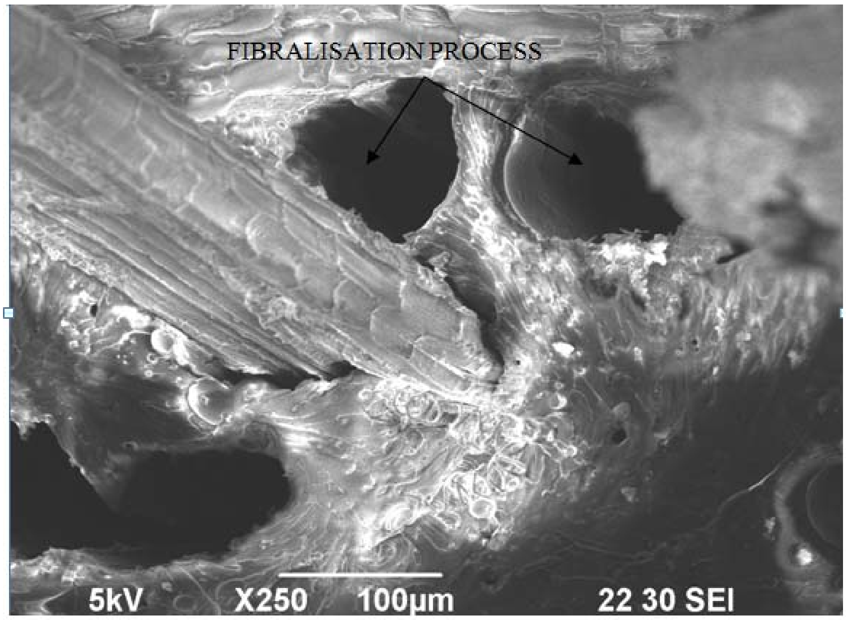

Fig. 8. SEM image of RM filled SF/USP after tensile test.

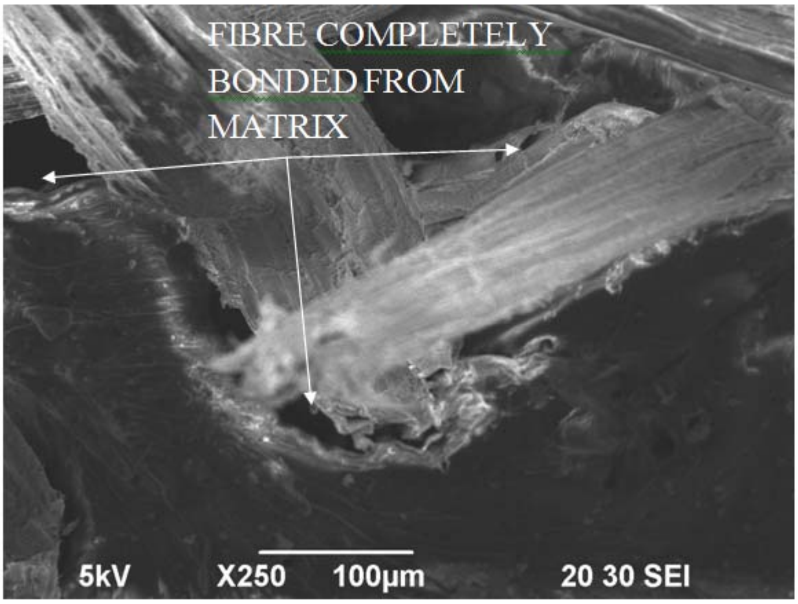

Fig. 9. SEM image of RM filled BF/USP after tensile test.

4. Conclusions

- Red mud is used to fabricate Polymer Matrix Composites successfully. It shows the potential applicability of red mud for making low cost composites and also reducing environmental related issues.

• It is observed that impact strength and flexural strength of the composites increase for randomly taken fiber length and fiber weight percentage by the addition of red mud, but tensile strength value decreases due to the distribution of the particulates along with matrix which results in poor stress interface between matrix and filler

• Impact and flexural for red mud filled sisal polyester composites are more when compared with that of banana fiber composites. The addition of red mud along with sisal and banana fiber increases impact and flexural strength.

• Due to high impact and flexural strength, red mud filled polymer matrix composites are suitable for high load withstanding and load bearing capacity applications.

• From the SEM observation it is clear that the addition of red mud increases the impact strength and flexural strength for both cases in sisal as well as banana fiber but also decreases in tensile strength, which results due to the fibrilisation process.

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