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INVESTIGATION OF THE MECHANICAL PROPERTIES OF GLASS FIBER – CHICKEN FEATHER HYBRID COMPOSITE

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ABSTRACT

The production and/or worldwide consumption of chicken at an industrial or domestic level lead to a considerable quantity of chicken feather residue as a waste by-product. Chicken feathers have a possible application in preparing lightweight composites. The use of chicken feathers as a constituent to prepare hybrid composites leads to a solution for disposal of the feathers. In this study, chicken feathers were used as filler material to prepare hybrid composites. Different varieties of composites were prepared by a chicken feather hand-layup technique, and by varying the percentage weight of the chicken feathers. Specimens were prepared and tested according to ASTM standards. The 10 wt. % chicken feather-filled hybrid composites indicated the maximum tensile strength (193 MPa), flexural strength (148 MPa) and impact strength (3.65 Joules). Scanning Electron Microscopy (SEM) analysis was carried out to find the fracture and interfacial characteristics of the composites. The results indicated that, these composites can be used in domestic, automobile and structural applications which carry nominal loads.

Keywords: Chicken feathers; Hybrid composites; Mechanical properties; SEM

1. INTRODUCTION

Recently, there is growing attention in the arena of bio-waste reinforced polymer composites, using chicken feathers, egg shells, and bone powder as filler material. The production and/or worldwide use of chicken at an industrial or domestic level lead to a considerable quantity of feather residue, which is considered to be waste (Shettar et al., 2015). The existing method or practice for disposal of chicken feathers is by burning or by burying. Both methods have adverse effects on the environment. Recent studies on the use of chicken feathers to prepare composites leads to a solution for the disposal of feathers. The advantage is that chicken feathers are low-cost, biodegradable and there is ample availability.

Basically, a typical contour-shaped chicken feather is divided into two microcrystalline structural types: barbs and rachis (shaft), as shown in Figure 1. Rachis may be used only as constituent of a hybrid composite. The barbs are removed from the rachis by a mechanical process (Zhan & Wool, 2016).

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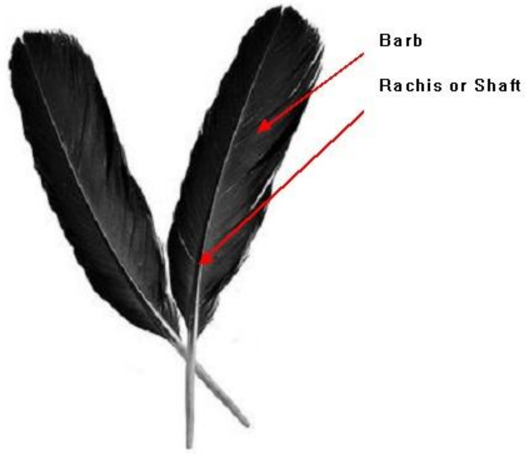


Figure 1 Typical contour-shaped chicken feather

The hydrophobic nature of chicken feather results in the reduction of density of composite materials by 30–40% (Zhan & Wool, 2016). The homogenous distribution of feathers in the polymer matrix improved the strength and modulus by restricting the mobility and deformability of the matrix (Salehuddin et al., 2014). The chicken feathers used were short length, at a low aspect (length/diameter) ratio. The low aspect ratio and the intrinsic structure of chicken feathers resulted in moderately weak mechanical strength (Reddy et al., 2014). Overall, it might not be possible to use short chicken feathers to attain higher mechanical properties, which can be accomplished with longer fibers (Acda, 2010).

Hybrid composites contain more than one type of reinforcement in a single matrix material. In a sense, many different fibers or filler materials may be mixed to form a hybrid in which it is more likely that the combination would yield more beneficial features. These composites can be fabricated like conventional composites containing one fiber. Hybrid composites have uncommon properties which are fruitful in meeting various design requirements in an economical way rather than with conventional composites. This is because expensive fibers like carbon, glass, boron etc., can be partially replaced by less expensive natural fibers or bio-wastes, such as chicken feathers used along with some other filler materials. Some of the specific advantages of hybrid composites over conventional composites include balanced strength and stiffness.

The purpose of this study is to prepare hybrid composites using chicken feathers as filler material and test the resultant hybrid composite for different mechanical properties. Chicken feather-filled, glass fiber polyester hybrid composites were prepared by a hand-layup technique. The properties viz., tensile strength, flexural strength, impact strength and percentage of chemical uptake were evaluated and discussed in detail.

2. METHODOLOGY

2.1. Selection of Materials

In this study, the composites were prepared from glass fibers as reinforcement, chicken feathers as fillers and polyester resin as matrix. The polyester resin (M 389) with curing agent MEKP (with methyl ethyl ketone peroxide hardener), supplied by J K Enterprise, Bengaluru and E-glass fiber (bidirectional woven mat – 600 GSM), supplied by Suntech Fiber Pvt. Ltd. Bengaluru, were used for the preparation of specimens. The chicken feathers were locally prepared by separating barbs and rachis.

2.2. Processing of Composites

The composite laminates were prepared on a flat metal or granite surface. The surface was cleaned by a Nitrocellulose (NC) thinner and releasing agent was sprayed on the surface. Glass fiber sheet was cut into plies as per the required dimension (300mm×300mm) and the same amount of resin – chicken feathers (short fibers) mixture by its weight was taken. The polyester resin and chicken feather mixture was prepared by adding hardener in the ratio of 1 ml per 70 ml of resin. The composite laminates were prepared by the hand-layup process, by applying the resin mixture on the glass fiber plies one above the other (by stacking up to a 3 mm thickness) (Hiremath et al., 2016). A hand roller was used to make sure that the resin and glass fiber were properly pressed and all the air bubbles were removed completely. Different laminates were prepared for the investigation as shown in Table 1.

Table 1 Details of constituents (wt%) of composites used in the study

Constituents (wt%)	C I	C II	C III	C IV
Polyester Resin Matrix	50	45	42.5	40
Glass Fiber Reinforcement	50	50	50	50
Chicken Feather Filler	0	5	7.5	10

2.3. Methods and Techniques for Testing Composites

2.3.1. Tensile strength

The specimens subjected to tensile strength were prepared as per ASTM D3039 (Ramesh et al., 2016) standards and the boundaries of the specimens were filed with precision files to attain overall length and gauge length of 250 and 140 mm respectively. An appropriate cross sectional area of 25×2.5 mm^2 was maintained and aluminum tabs with dimensions of 55×25×1 mm with 45^o filing was glued as shown in Figure 2. The test was carried out using a Universal Testing Machine (UTM)/E-40 with resolution of the hydraulic grip at 0.01 mm.

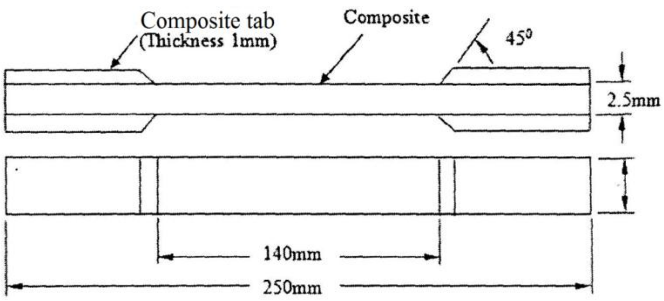


Figure 2 Tensile test specimen

2.3.2. Flexural strength

The specimens subjected to flexural strength were prepared as per the ASTM D790 (Ramesh et al., 2016) standards. The 3-point bending test was performed on all the separate sets of specimens, with different weight percentages of chicken feathers. The test was conducted using a Universal Testing Machine. The speed of testing was set at a rate of crosshead movement 1.0 mm/min for a specimen with standard dimensions as shown in Figure 3.

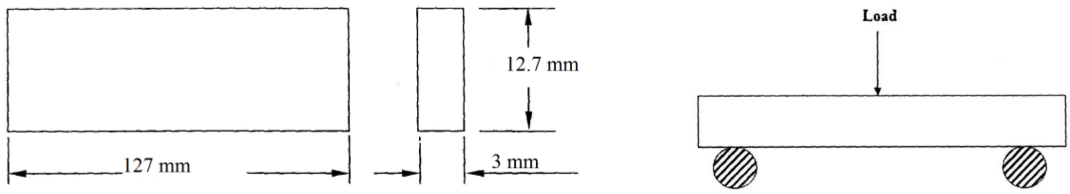


Figure 3 Flexural test specimen

2.3.3. Impact strength

The specimens for impact strength (Charpy) were prepared as per ASTM D6110 (Ramesh et al., 2016) standards. The impact test was performed on all the separate sets of specimens, with different weight percentages of chicken feathers. The shape and dimensions of the specimen is shown in Figure 4 with a central V-notch.

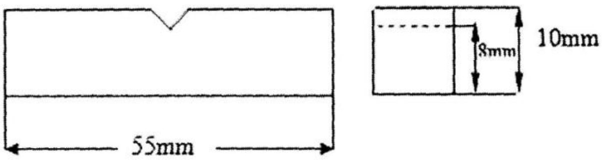


Figure 4 Impact test specimen

2.3.4. Chemical resistance test

The chemical resistance test was carried out by immersing the prepared specimens in three different types of dilute chemicals (5% by volume in water) viz., hydrochloric acid (HCl), sodium hydroxide (NaOH), sulfuric acid (H_2SO_4). The specimens were kept in the respective acid solutions for 24 hours. The weight of each specimen was measured before and after the treatment (Shettar & Hiremath, 2015).

2.3.5. Scanning electron microscope analysis

The fractured surfaces of the test specimens were analyzed using Scanning Electron Microscope (SEM); Model: JSM-6380LA, JEOL, Japan. The factors affecting their respective failure and the type of environment they were subjected to could be determined by careful observation of the SEM micrographs. SEM micrographs of the fractured surfaces of chicken feather, glass fiber, polyester hybrid composites revealed the failure modes.

3. RESULTS AND DISCUSSION

3.1. Tensile Strength

The hybridization of chicken feathers as filler and glass fiber as reinforcement in the polyester resin matrix, which played a vital role in deciding tensile strength and values varied from 124 to 193 MPa. As shown in Figure 5, it was observed that 10 wt.% chicken feather hybrid composite (C IV) displayed a better result than the other composites (C III and C II). But all the filled hybrid composites showed a decrease in tensile strength compared to the unfilled composite (C I). The 5 wt.% chicken feather hybrid composite (C II) had the lowest tensile strength among the other varieties. The tensile stress Vs tensile strain graphs for all the combinations are shown in Figure 6. It was understood that the tensile strength increased steadily up until the strain value of 0.9 and then it started decreasing. Up to 0.03% strain rate of all the composites showed the similar tensile stress values (You et al., 2015).

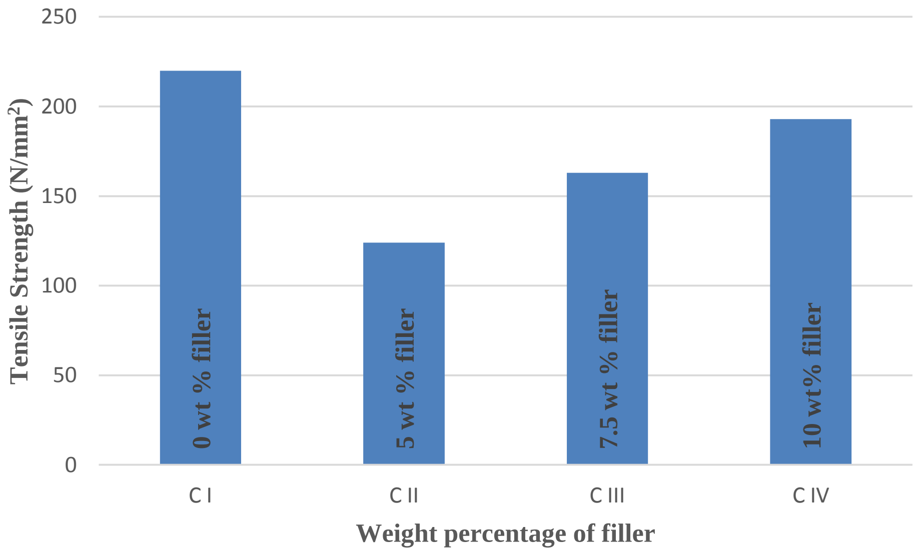


Figure 5 Average tensile strength of different composites

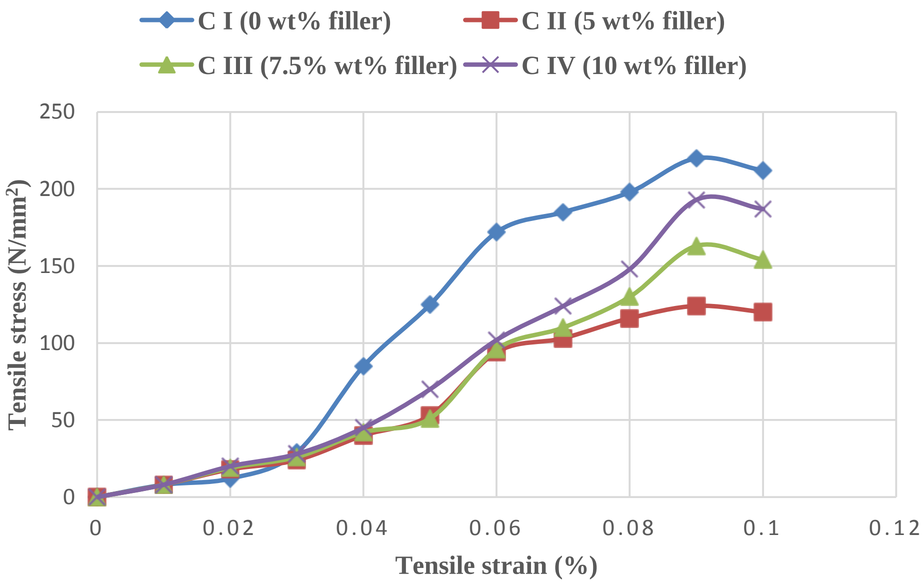


Figure 6 Tensile stress Vs tensile strain graph

3.2. Flexural Strength

The reinforcement and filler hybridization played a vital role in improving flexural strength from 94 to 148 MPa. As shown in Figure 7, it was observed that, 10 wt.% chicken feather hybrid composite (C IV) displayed a better result than the other composites (C III, C II and C I). The unfilled composite (C I) showed a lower flexural strength among all varieties. The load Vs displacement graphs for all the combinations are shown in Figure 8. It was clear that, all the composites carry the equivalent load until a displacement of around 2.25 mm, after which a meager crack/delamination was found in the composite. For the displacement, up to 0.75 mm, the load taken by all the composites was almost similar (Mohite et al., 2014). Adding chicken feather as a filler material might have resulted in restriction of the propagation of crack and delamination and resulted in holding the load up to 1.8 kN.

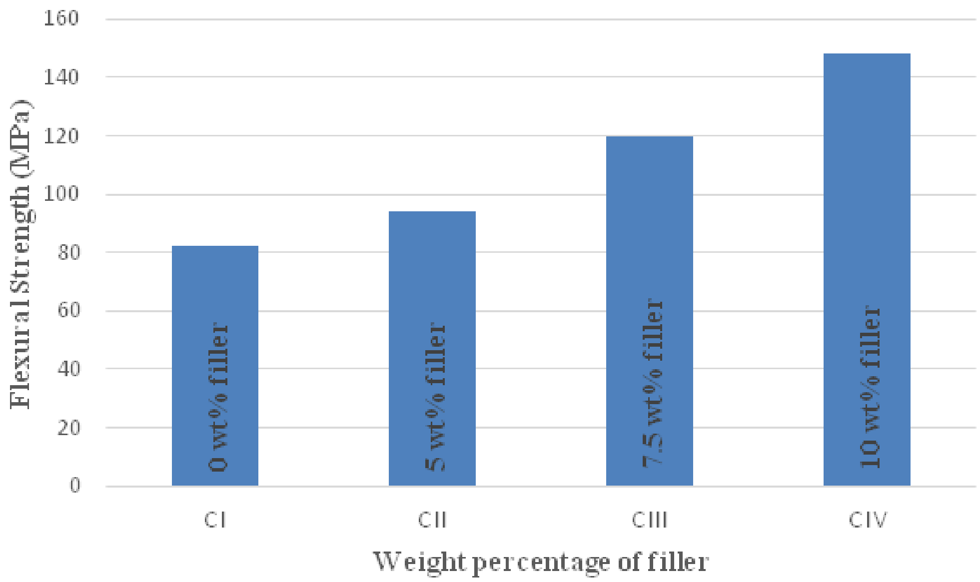


Figure 7 Average flexural strength of different composites

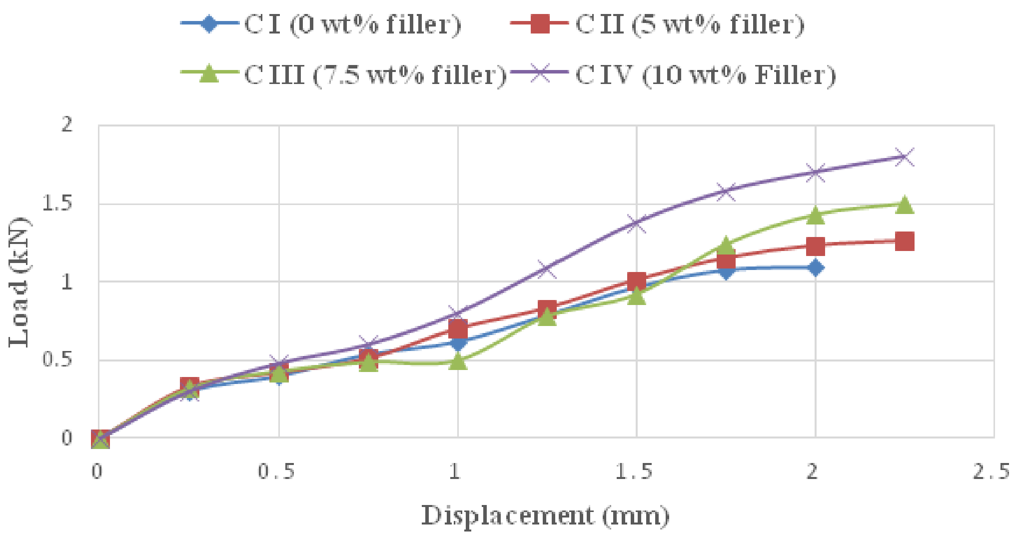


Figure 8 Load Vs displacement graphs

3.3. Impact Strength

The hybridization of reinforcements in the polyester resin matrix played a vital role in deciding impact strength. The energy absorbed by the composites varied from 3.1 to 3.65 Joules. The impact strengths of all the combinations were compared and shown in Figure 9. It can be stated that the incorporation of chicken feathers boosts the impact strength, because the percentage of filler increases the energy requirement to nucleate and propagate the crack (Kumar et al., 2013).

3.4. Chemical Resistance Test

The pre-weighed (W1) specimens were immersed in three different chemicals for 24 hours and wet weight (W2) of the specimens noted down as shown in Table 2. Later all the specimens were washed thoroughly, dried with paper napkins, followed by hot air drying (Li et al., 2013). As shown in Table 2 and Figure 10, the chemical uptake and composite loss is more in 10 wt.% chicken feathers filled with hybrid composite (C IV).

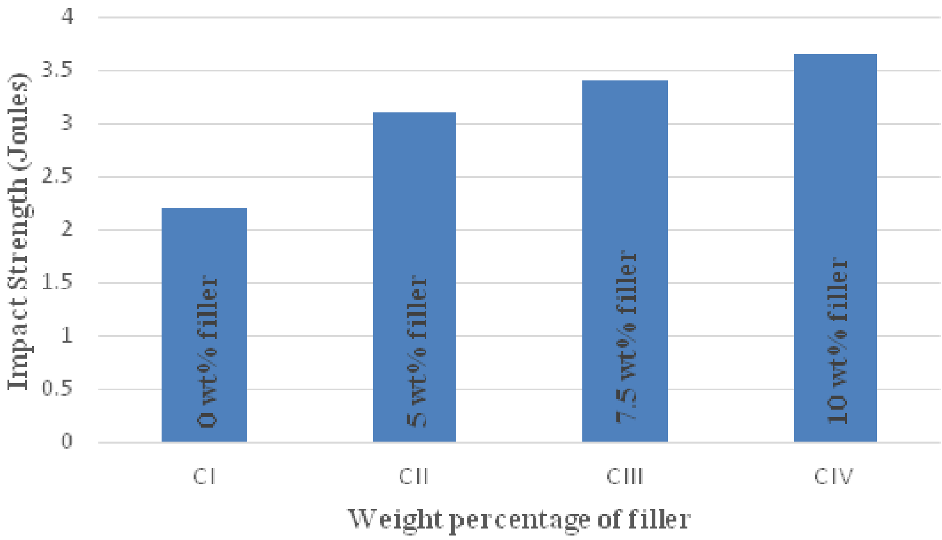


Figure 9 Average impact strength of different composites

Table 2 Specimens weight for the test

Composites	Chemicals	Weight of the specimen before test (gms) W1	Weight of the specimen after 24 hours (gms) W2	% Of Chemicals uptake = (W2-W3)100/W1	Reconditioned weight of the specimen after cleaning and drying (Gms) W3	% Composite loss = (W2-W3)100/W3
C I	NAOH	0.4813	0.4890	1.60	0.4814	1.58
	HCL	0.5992	0.6052	1.00	0.5957	1.59
	H_2SO_4	0.5861	0.5935	1.26	0.5839	1.64
C II	NAOH	0.6594	0.6744	2.27	0.6563	2.76
	HCL	0.5415	0.5550	2.49	0.5415	2.49
	H_2SO_4	0.5820	0.5950	2.23	0.5818	2.27
C III	NAOH	0.6666	0.6867	3.02	0.6656	3.17
	HCL	0.6242	0.6441	3.19	0.6249	3.07
	H_2SO_4	0.5515	0.5712	3.57	0.5530	3.29
C IV	NAOH	0.7226	0.7525	4.14	0.7178	4.83
	HCL	0.6570	0.6884	4.78	0.6559	4.96
	H_2SO_4	0.6150	0.6417	4.34	0.6160	4.17

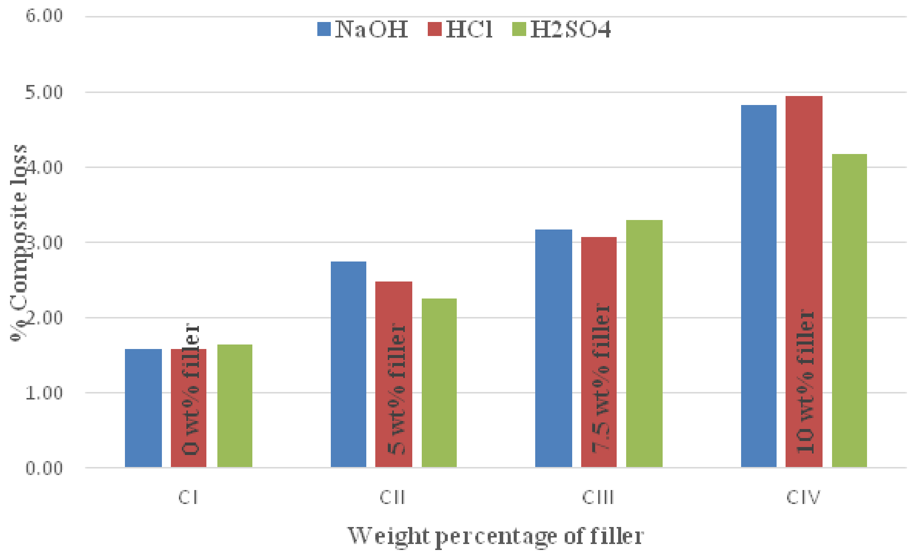
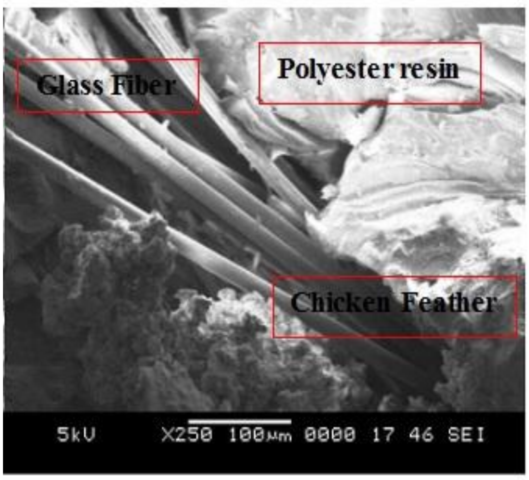


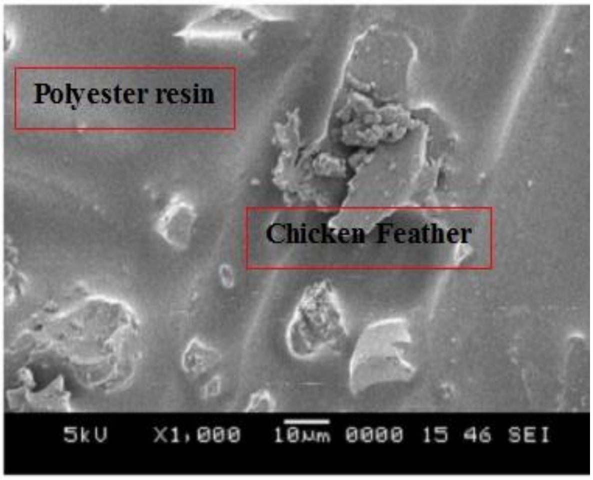
Figure 10 Percentage of composite loss

3.5. SEM Micrographs

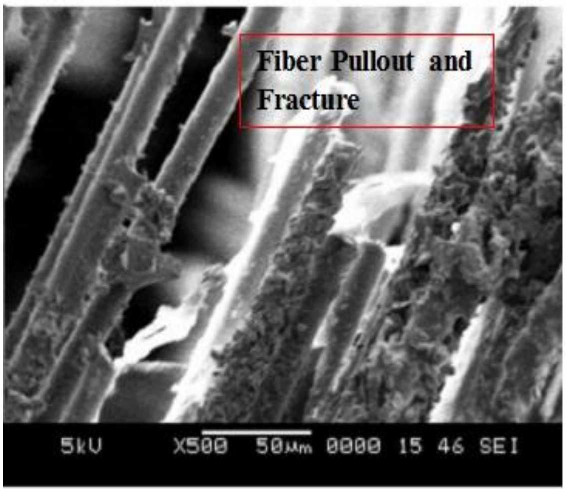
The morphology of chicken feathers, glass fiber and polyester resin and failure modes at the edges between all three constituents were investigated using SEM. The SEM images for the fractured specimens of the tensile test are shown in Figure 11. The failure, due to breakage and the pulling out of the glass fiber and chicken feathers, subjected to tensile loading, can be easily noticeable from Figures 11a, 11b, 11c, and 11d. Fiber end breakage was observed where filler material volume was less. There was good dispersion of matrix and filler in the filled composites. The interaction between the matrix and filler is also good.



(a)



(b)



(c)

(d)

Figures 11 SEM micrographs of the fracture surfaces of specimens subjected to tensile test

4. CONCLUSION

The moderate eco-friendly chicken feather, glass fiber polyester hybrid composites were prepared by a hand-layup technique. The mechanical properties viz., tensile strength, flexural strength, impact strength and chemical resistance properties of the composites were tested. The hybrid composites possessed good mechanical properties and more chemical uptake/composite loss than unfilled composites. The 10 wt.% chicken feathers-filled hybrid composite showed maximum tensile strength (193 MPa), flexural strength (148 MPa) and impact strength (3.65 Joules). SEM reveals good interfacial bonding between the feather, fiber and matrix. It can be concluded that partially biodegradable hybrid composites produced at lower cost with superior characteristics might be useful in light structural and other related engineering applications. These applications require further investigation.

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