MECHANICAL BEHAVIOUR OF POULTRY FEATHER

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Abstract

Chicken feathers are a waste product left over after processing Chickens for meat.Short fibers obtained from poultry feathers are found to possess high toughness, good thermal insulation properties, nonabrasive behavior and hydrophobic nature. Their low cost, low density and large aspect ratio can make them good reinforcing materials in polymer matrix composites. This paper reports the development of poultry feather reinforced epoxy composites and also both poultry feather fiber and glass fiber reinforced epoxy composites.

1. INTRODUCTION

1.1 Overview of composites

The advantage of composite materials over conventional materials stem largely from their higher specific strength, stiffness and fatigue characteristics, which enables structural design to be more versatile. By definition, composite materials consist of two or more constituents with physically separable phases. However, only when the composite phase materials have notably different physical properties it is recognized as being a composite material. Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix).Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position andorientation of the reinforcement. Significantly, constituents of the compositesretain their individual, physical and chemical properties; yet together theyproduce a combination of qualities which individual constituents would beincapable of producing alone.

The reinforcement may be platelets, particles or fibers and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material. Long fibers that are oriented in the direction of loading offer the most efficient load transfer. This is because the stress transfer zone extends only over a small part of the fiber-matrix interface and perturbation effects at fiber ends may be neglected. In other words, the ineffective fiber length is small [1]. Popular fibers available as continuous filaments for use in high performance composites are glass, carbon and aramid fibers.

1.2 Types of Composites

For the sake of simplicity, however, composites can be grouped into categories based on the nature of the matrix each type possesses. Methods of fabrication also vary according to physical and chemical properties of thematrices and reinforcing fibers.

(a) Metal Matrix Composites (MMCs)

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminum, magnesium and titanium. The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large co-efficient of thermal expansion, and thermal and electrical conductivities of metals can be reduced by the addition of fibers such as silicon carbide.

(b) Ceramic Matrix Composites (CMCs)

Ceramic matrix composites have ceramic matrix such as alumina, calcium, alumina silicate reinforced by silicon carbide. The advantages of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density.

Naturally resistant to high temperature, ceramic materials have a tendency to become brittle and to fracture. Composites successfully made with ceramic matrices are reinforced with silicon carbide fibers. These composites offer the same high temperature tolerance of super alloys but without such a high density. The brittle nature of ceramics makes composite fabrication difficult. Usually most CMC production procedures involve starting materials in powder form. There are four classes of ceramics matrices: glass (easy to fabricate because of low softening temperatures, include borosilicate and alumino silicates), conventional ceramics (silicon carbide, silicon nitride, aluminum oxide and zirconium oxide are fully crystalline), cement and concreted carbon components.

(c) Polymer Matrix Composites (PMCs)

The most common advanced composites are polymer matrix composites. These composites consist of a polymer thermoplastic or thermosetting reinforced by fiber (natural carbon or boron). These materials can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with resistance to corrosion. The reason for these being most common is their low cost, high strength and simple manufacturing principles. Due to the low densityof the constituents the polymer composites often show excellent specificproperties.

1.3 Natural Fiber Composites

Fiber-reinforced polymer composites have played a dominant role for a long time in a variety of applications for their high specific strength and modulus. The manufacture, use and removal of traditional fiber–reinforced plastic, usually made of glass, carbon or aramid fibers–reinforced thermoplastic and thermo set resins are considered critically because of environmental problems.

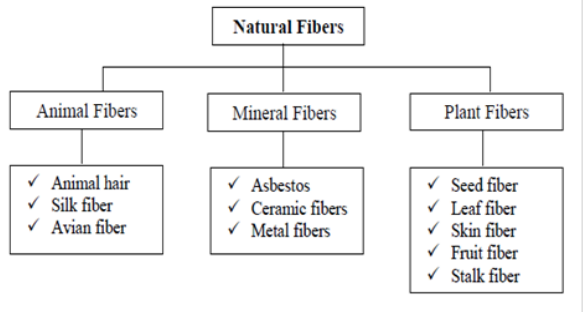


Figure 1.1 Classification of natural fibers

By natural fiber composites we mean a composite material that is reinforced with fibers, particles or platelets from natural or renewable resources, in contrast to for example carbon or aramid fibers that have to be synthesized. Natural fibers include those made from plant, animal and mineral sources. Natural fibers can be classified according to their origin. The detailed classification is shown in Figure 1.1

Animal Fiber:

Animal fiber generally comprise proteins; examples mohair, wool, silk, alpaca, angora. Animal hair (wool or hair) are the fibers taken from animals or hairy mammals. Eg.Sheeps wool, goat hair (cashmere, mohair), alpaca hair, horse hair, etc. Silk fibers are the fibers collected from dried saliva of bugs or insects during the preparation of cocoons. Examples include silk from silk worms. Avian fibers are the fibers from birds, e.g. feathers and feather fiber.

Mineral fiber:

Mineral fibers are naturally occurring fiber or slightly modified fiber procured from minerals. These can be categorized into the following categories: Asbestos is the only naturally occurring mineral fiber. Variations are serpentine and amphiboles, anthophyllite. Ceramic fibers includes glass fibers (Glass wood and Quartz), aluminum oxide, silicon carbide, and boron carbide. Metal fibers include aluminum fibers.

Plant fiber:

Plant fibers are generally comprised mainly of cellulose: examples include cotton, jute, flax, ramie, sisal and hemp. Cellulose fibers serve in the manufacture of paper and cloth. This fiber can be further categorizes into following as: Seed fiber are the fibers collected from the seed and seed case e.g. cotton and kapok. Leaf fiber are the fibers collected from the leaves e.g. sisal and agave. Skin fibers are the fibers are collected from the skin or bast surrounding the stem of their respective plant. These fibers have higher tensile strength than other fibers. Therefore, these fibers are used for durable yarn, fabric, packaging, and paper. Some examples are flax, jute, banana, hemp, and soybean. Fruit fibers are the fibers are collected from the fruit of the plant, e.g. coconut (coir) fiber. Stalk fiber are the fibers are actually the stalks of the plant. E.g. straws of wheat, rice, barley, and other crops including bamboo and grass [1].

Now we selecting chicken feather as natural fiber because short fibers obtained from poultry feathers are found to possess high toughness, good thermal insulation properties, nonabrasive behavior and hydrophobic nature. Their low cost, low density and large aspect ratio can make them good reinforcing materials in polymer matrix composites. This paper reports the development of poultry feather reinforced epoxy composites. Randomly oriented short feather fibers are reinforced into epoxy resin to prepare composite slabs. Mechanical properties such as tensile and bending strength, and fracture analysis can evaluated. The effect of thickness on the fracture toughness of natural fiber was investigated experimentally. Double-edge cracked specimens, made of fiber plate with thicknesses ranging from 2mm to about 6mm, were loaded in tension till fracture. The fracture toughness defined as the value of the integral at cracking initiation was shown to first increase with increasing thickness, then to reach a maximum for a thickness and finally to decrease at larger thicknesses. There by analyzing the effect of thickness and crack on fracture behavior of fiber composites [2].

2 MATERIALS AND METHODS

2.1. Materials used:

This chapter describes the details of processing of the composites and the experimental procedures followed for their mechanical characterization. The raw materials used in this work are

1. Chicken feather fiber.
2. Glass fiber.
3. Epoxy resin and Hardener.

2.1.1.Chicken feather fiber:

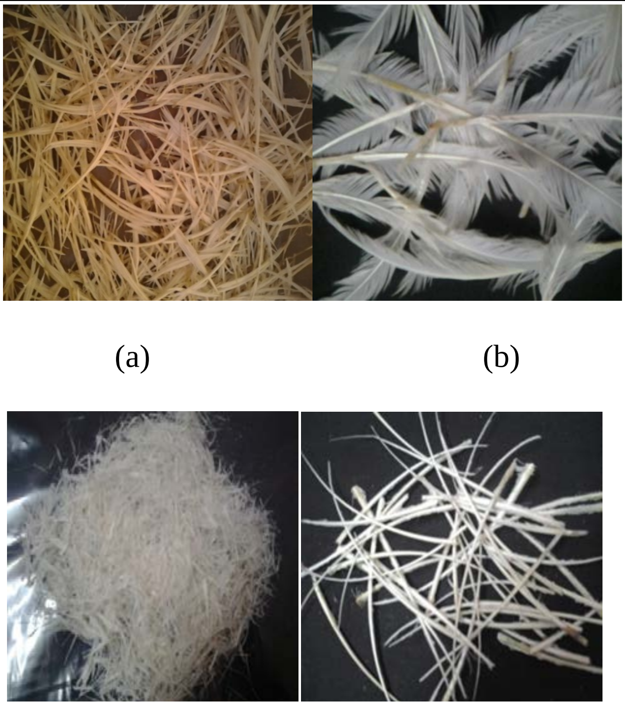
Poultry feathers are a waste product left over after processing chickens in the food processing industry. Close to $2x10^9$ kg of chicken feather waste is generated in the US each year. Chicken feather fiber offers a large, cheap fiber market as an additive for medium density fiberboard (MDF). Chicken feathers are approximately half feather fiber and half quill (by weight). The feather fiber and quill are both made from hydrophobic keratin, a protein that has strength similar to nylon and a diameter smaller than wood fiber. The quills are used in shampoo, hair conditioner, hair coloring, and dietary supplements. The fiber is more durable and has a higher aspect ratio than the quill. Finding a high volume, high value use for feather fiber, a material most commonly land-filled or used for feed protein, would greatly benefit to the poultry industry and would add a fiber source for the wood industry [2].

Chicken feathers are approximately half feather fiber (barbs) and half quill (rachis) by weight, the quill being not significantly reduced the volume of waste feathers generated each year. A number of commercial applications have been explored to utilize fibers from chicken feathers. Unfortunately, due to the low volume requirements of these products they have not significantly reduced the volume of waste feathers generated each year. Composite building materials, such as fiberboard and particleboard, are high volume, high value applications which could potentially consume a large amount of waste chicken feathers.

Poultry feathers were obtained from ‘’poultry processing factory’’. From the observation point of view, a feather is constituted of two distinct parts. The central shaft of the poultry feather is composed of a calamus (barbs) and a rachis (quill). The barbs are attached to the rachis. The length of the barbs is depending on the region location along the rachis. The barbs located at the base of the rachis are so long than those at the tip.

Preparation of feather fiber:

Waste chicken feathers were obtained from a poultry processing. Waste feathers were brought to the laboratory in sacks and washed several times with water mixed with laundry detergent and sodium chlorite to remove blood, manure and extraneous materials.The clean feathers were then spread and dried under the sun for three days. From these dried chicken feathers Quills and Barbs are separated as shown in fig.3.1.Here our project concern is about only barbs of the feather to make the composite material. The barbs are rubbed on the sieve to increase its mechanical properties. These are made in the form of mat so that it can be easily placed in the mould during preparation of slab. And these feather mats are cut into required shape, size and weight of these mats are recorded.



(a) (b)

(c) (d)

Figure.2.1. Preparation of chicken feather.
(a) Washed with hot and cold water, (b) Dried feathers
(c) Separated barbs, and (d) Separated quills.

2.1.2. Resin and hardener:

Epoxy Resins are thermosetting resins, which cure by internally generated heat. Epoxy systems consist of two parts, resin and hardener. When mixed together, the resin and hardener activate, causing a chemical reaction, which cures (hardens) the material. Epoxy resins generally have greater bonding and physical strength than do polyester resins. Most epoxies are slower in curing, and more unforgiving in relation to proportions of resins and hardener than polyesters. Superior adhesion is important in critical applications and when “glassing” or gluing surfaces – such as steel, redwood, cedar, oak and teak – as well as other non-porous surfaces. Ever coat Epoxy resins are superior to polyester resins in that they impart exceptional strength in stress areas. Epoxies will adhere to surfaces where polyesters may ruin them. Examples of areas where epoxy resins products must be used are redwood, hardwoods, Styrofoam, some plastic surfaces, and metal. They are generally higher in cost than polyester resins. Epoxy resins may be mixed with various fillers to thicken them for special applications.

The matrix material used for the fabrication of poultry feather reinforced composites consists of low temperature curing epoxy resin (Araldite LY 556) and corresponding hardener (HY951). Resin and hardener are mixed in a ratio of 10:1 by weight as recommended. Density of the epoxy resin system is 1.1 g/cc.

Properties of resin:

Viscosity at 25 °C	(ISO 12058-1)	10000 - 12000 [cps]
Density at 25 °C	(ISO 1675)	1.15 - 1.20 [g/cm3]
Flash point	(ISO 2719)	> 392 [200] °F [°C]

No volatile loss: during cure of product.
Dimensional stability during cure: They exhibit little shrinkageand can be used for very accuratereproduction.
Chemical resistance: Good resistance to a variety of chemicals (including solvents, acids, and bases) results with properly cured formulations.
Chemical inertness: They accept a wide range of fillers and pigments; they do not affect encapsulated parts or common containers.
Durability: Cured formulations exhibit good hardness, impact strength, and toughness.
Adhesion: The tenacity of epoxy adhesion to almost any surface is without equal among organic coatings.

Properties of hardener:

Viscosity at 25°C	ISO 12058	10 – 20 cps
Specific Gravity at 20°C	ISO 1675	0.98 g/cm3
Appearance	Visual	Clear liquid
Flash point	DIN 51758	110 °C

- Good mechanical strength.
- Good resistance to atmospheric and chemical degradation.
- Excellent electrical properties.

2.2. *Methodology:*

The wooden mould or die is prepared for making the composite slab of required shape. The releasing agent is applied on all the faces of mould, which helps in separating the slab from the mould after curing. After the releasing agent becomes dry, the gel coat is applied on the all the faces so as to get good surface finish of the slab. Then the die is left for drying for 20 to 30mins.

After curing of gel coat the resin mixture with appropriate ratio is prepared, which consist of resin grade epoxy LY556 and hardener 951. It is mixed in the ratio of 100:15 that is 100gms of resin and hardener of 15gms and stirred it constantly. After mixing both in correct ratio, it is applied on the cured gel coat with the help of brush or roller brush.

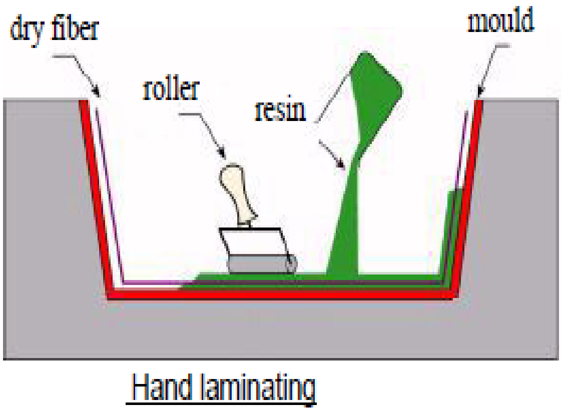
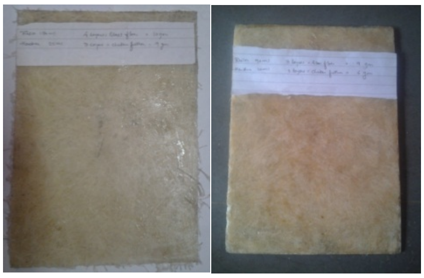


Figure 2.2. preparation of composite material in the mould.

After applying a layer of resin mixture on the mould a piece offeather fiber mat cut into required shape is placed into mould as shown in the figure 2.2.



Material 1 **Material 2**

Figure 2.3. prepared materials. Material 1 and 2 are natural composites and hybrid composites.

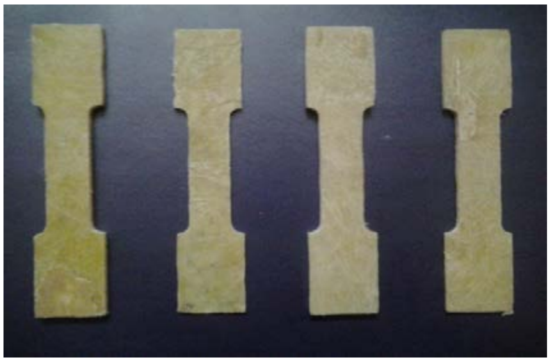
Then again resin is applied and a piece of feather fiber mat is placed on it. Placing of this alternative layer of feather fiber mat is repeated until the required thickness is obtained. The cover is placed on the mould and weights are put on it. The arrangement is kept for curing about a day. Once the material is cured it is separated from the mould.Some of the prepared materials are shown in the figure 2.3. And their composition is shown in the table 2.1. These materials are cut into required specification as per ASTE standards.

Parameters	Material 1	Material 2
Thickness	5mm	5mm
Weight of Feather fiber	16gms	12gms
Weight of resin	143gms	110gms
Weight of hardener	25gms	20gms

Table 2.1 composition of prepared material.

(a) Tensile Test

Tensile properties indicate how the material will react to forces being applied in tension. A tensile test is a fundamental mechanical test where a carefully prepared specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance. Tensile tests are used to determine the modulus of elasticity, elastic limit, elongation, proportional limit, and reduction in area, tensile strength, yield point, yield strength and other tensile properties. The main aim of the tensile test is to *determine* the elastic modulus of the material.



Tensile specimens.

Stress is a measure of the intensity of an internal force. Stress is defined as the force per unit area:

$$\text{Stress} = \sigma = \text{Load/Area} = P/A \ \text{N/mm}^2$$

Strain is a measure of the deformation that has occurred in a material. In the case where the magnitude of deformation is the same over the entire length of a body, strain may be defined as:

$$\varepsilon = \frac{L_f - L_o}{L_o} \quad \text{[in/in]}$$

Where: L_o is the initial length

L_f is the final length

When a specimen is loaded so that the resultant force passes through the centroid of the specimen cross-section, the loading is categorized as axial and can be either tensile or compressive. Tests utilizing axial loading are generally performed to determine material properties. When materials for engineering projects are procured, the engineer often must specify material property requirements to the manufacturer. After the material is received it is generally good practice, if not mandatory, to perform acceptance tests to verify the material properties before the materials are used. Therefore, it is important to understand which material properties are relevant and how those properties are obtained.

This test was carried out as per the ASTM D638 standard. Specimens have been prepared according to the standards from the composite panels. Dimensions and testing arrangements are shown in the figure 3.7.

(b) Three point Bending Test

The three points bending flexural test provides values for the modulus of elasticity in bending E_f, flexural stress σ_f, flexural strain ϵ_f and the flexural stress-strain response of the material. The main advantage of a three point flexural test is the ease of the specimen preparation and testing. However, this method has also some disadvantages: the results of the testing method are sensitive to specimen and loading geometry and strain rate. Bend or flexure testing is common in springs and brittle materials whose failure behaviors are linear such as concretes, stones, woods, plastics, glasses and ceramics. Other types of brittle materials such as powder metallurgy processed metals and materials are normally tested under a transverse flexure.

Calculation of the flexural stress σ_f

$$\sigma_f = \frac{3PL}{2bd^2}$$ For a rectangular cross section

$$\sigma_f = \frac{PL}{\pi R^3}$$ For a circular cross section

Calculation of the flexural strain ϵ_f

$$\epsilon_f = \frac{6Dd}{L^2}$$

Calculation of flexural modulus E_f

$$E_f = \frac{L^3 m}{4bd^3}$$

In these formulas the following parameters are used:

- σ_f = Stress in outer fibers at midpoint, (MPa)
- ϵ_f = Strain in the outer surface, (mm/mm)
- E_f = flexural Modulus of elasticity,(MPa)
- P = load at a given point on the load deflection curve,(N)
- L = Support span, (mm)
- b = Width of test beam, (mm)
- d = Depth of tested beam, (mm)
- D = maximum deflection of the center of the beam, (mm)
- m = The gradient (i.e., slope) of the initial straight-line portion of the load deflection curve,(P/D), (N/mm)

Bend test is therefore suitable for evaluating strength of brittle materials where interpretation of tensile test result of the same material is difficult due to breaking of specimens around specimen gripping. The evaluation of the tensile result is therefore not valid since the failed areas are not included in the specimen gauge length.

Bending specimens

This test was carried out as per the ASTM D638 standard. Specimens have been prepared according to the standards from the composite panels. Dimensions and testing arrangements are shown in the figure 3.8.

3. RESULTS & DISCUSSION:

This chapter presents the mechanical properties of the natural fiber and hybrid reinforced epoxy composites prepared for this present investigation. Details of processing of these composites and the tests conducted on them have been described in the previous chapter. The results of various characterization tests are reported here. This includes evaluation of tensile strength; flexural strength has been studied and discussed. The interpretation of the results and the comparison among various composite samples are also presented.

3.1. Mechanical properties of composites

The effect of the mechanical properties of composites on the characterization of the natural composites are shown in fig 3.1. The properties of the composites with different fiber testing's under this investigation are presented in table 3.1.

Sl no.	Composites	Thickness mm	Tensile strength MPa	Young's Modulus MPa	Bending strength MPa
1	Natural	5	12.92	646.1	155

Table 3.1. Mechanical properties of composites

4. CONCLUSION

This experimental investigation of mechanical behavior of natural and hybrid composite reinforced epoxy composites leads to the following conclusions:

- This work shows that successful fabrication of a pure chicken feather fiber, reinforced with epoxy composites is possible by simple hand lay-up technique.
- We can reduce the cost of glass fiber by reinforcing with chicken feather barbs which are available in large quantity as a waste.
- The fracture surface study of natural reinforced epoxy composites after the tensile and flexural has been done.

REFERENCE

[1] Prof.K.B.Jagageeshgouda, "Thickness effect on fracture behaviour of natural and hybrid composite material", SGBIT, Belgaum, 2011.
[2] Sanjay Kindo ,"Study On Mechanical Behavior Of Coir Fiber Reinforced Polymer Matrix Composites"National Institute of Technology, Rourkela 769008, India, 2010.
[3] V. AnandaRao, AlokSatapathy, S.C. Mishra "Polymer composites reinforced with short fibers obtained from poultry feathers", National Institute of Technology, Rourkela 769008, India, 2007.