

The effect of fibre loading and graphene on the mechanical properties of goat hair fibre epoxy composite

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Abstract. Composite materials are heterogenous materials containing one or more solid phases. In recent years cost-effective composite making is an ideal task. Hence we have come out with a natural fibre composite, which contains goat hair and epoxy as a binding element, with the combination of Graphene as a main source of enhanced mechanical property. Fabrication of natural composite consists of five layers of goat hair sandwiched in epoxy matrix. These composites made are tested for mechanical properties including Tensile strength, Flexural strength, Inter laminar shear and Impact strength. The mechanical properties of the six composite sets are analyzed and reported.

1. Introduction

As the world of nanotechnology is emerging rapidly, noble awarded material Graphene is highly playing its role in all the field of sciences [1]. Graphene with its extraordinary electrical, optical, mechanical, thermal properties sweeps the industries all over the world [2]. In recent times, composite materials are being used in numerous application fields [2, 3]. Composites are materials consisting two or more chemically distinct constituent on a micro scale having a distinct interface separating them [4, 5]. One or more phase is embedded in a continuous phase to form a composite. The discontinuous phase is usually harder and stronger than the continuous phase and is called the reinforcement, whereas the continuous phase is termed as matrix [6]. Goat hair is a natural fibre which possesses good mechanical properties like tensile strength, resistance to decomposition, reusable resource hence can replace synthetic fibres. Now the combination of goat hair and Graphene enhances all the major properties of a composite material covering its tensile strength, impact tensile strength, flexural strength, impact strength; inter laminar shear strength and hardness [6].

2. Goat hair

Goat hair is a natural fibre extracted from the skin of goat. The goat hair varies between 40 to 120mm in length, diameter between 80 to 105microns, tensile strength 90 to 120MPa, moisture absorption 7%, and elongation at shear 10 to 30%, bio-degradable, eco-friendly, smooth, wear resistant, soft, elastic, low-cost and available in plenty. Even though goat hair is used for many other applications not much work has been tried out using goat hair for making composite. Disposal of goat hair in tannery process is a perennial problem in waste management. The above issues triggered the author to make goat hair composite and to study them by varying the fibre loading.



The method, that was being used in the fabrication of composite material, is followed by several researchers [7, 8]. The goal of this work is to study and develop a low cost natural composite material using goat hair fibre with improved mechanical properties like wear resistance, tensile and impact strength, inter laminar bonding strength and surface flexural rigidity.

3. Experimental set-up

This experimental set up is designed to make six composites, varying the percentage of goat hair and epoxy as shown in Table 1. Finally composite 6 is fabricated by addition 0.1% Graphene into it. Layers of sheets of goat's hair are piled up one over the other with epoxy matrix in between each layer. The mould set is placed in the compression moulding press under pressure, undisturbed for period of 72 hours for proper setting.

Table 1. Material composition for development and processing of composites.

Sample code	Goat hair fibre (%weight)	Epoxy matrix (%weight)	Graphene filler (% weight)
Composite 1	20	80	0
Composite 2	30	70	0
Composite 3	37.5	62.5	0
Composite 4	40	60	0
Composite 5	50	50	0
Composite 6	37.5	62.4	0.1

3.1. Specimen Preparation



Figure 1. Goat hair epoxy composite

Goat hair epoxy composite fabricated and specimen for tensile testing is shown in figure 1. Composite 1 with 20% goat hair fibre loading is made with five layers of goat hair fibre. Mould plate of 180mm x180mm x8mm thickness dimension is placed and covered with 4mm thick wooden strips and mould release is applied. Epoxy and hardener are mixed in the ratio 10:1 and applied on the mould and then five layers of goat hair are laid over it after applying resin in between each layer. Finally resin is applied on the top of goat hair layer and top mould plate is placed on top and the mould set is kept in compression moulding press, undisturbed for three full days and finally composite 1 is removed from the mould.

Composite 2 with 30% goat hair fibre loading is made by compression molding with five layers of goat hair fibre in epoxy matrix. The composite made is placed under pressure for three days and then removed from mould. Composite 3 with 37.5% goat hair fibre loading is made by compression moulding with five layers of goat hair fibre sandwiched in epoxy matrix. The composite made is placed under pressure for three days and then removed from mould. Composite 4 with 40% goat hair fibre loading is made with five layers of goat hair. Same way, composite 5 with 50% goat hair fibre loading is prepared by 5 layers of goat hair. Finally, our target composite 6 is made by addition of 0.1% of Graphene with goat fibres of 5 layers each with 37.5% fibre loading.

4. Results and discussion

4.1. Tensile Test

Tensile strength is a measurement of force required to pull a material to the point where it breaks [9]. A tensile strength of a material is the maximum amount of tensile stress that it can take before breaking. Tensile strength for all the composites was taken. Graphs are drawn for stress vs. strain, load vs. displacement, and stress vs. Displacement [10, 11]. Consecutive reports of the graphs are shown above. The tensile test results are shown in figure 2 and 3.

Therefore, increase in the tensile strength of 36% is abruptly shown in composite 6, due to the addition of Graphene compared with composite 3 showing 33% of tensile strength with 0% of Graphene. Tensile testing, also known as tension testing is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. Composites are tested for tensile strength as per ASTM D638-03 test standard[12].

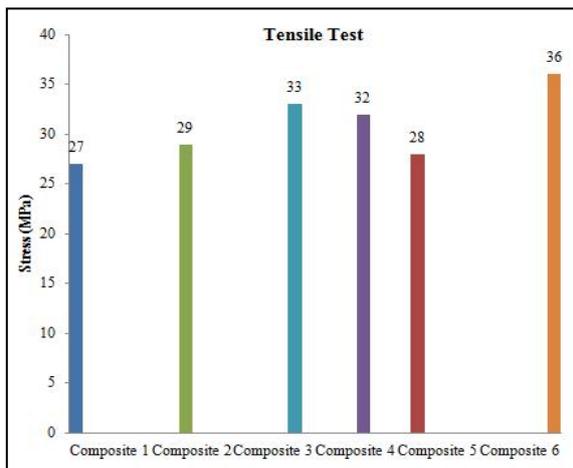


Figure 2. Tensile strength of composites

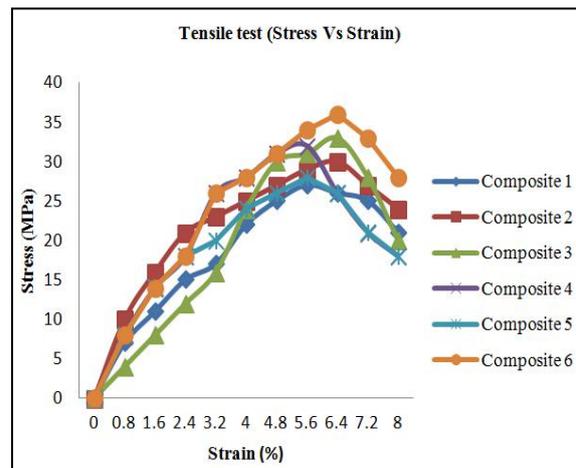


Figure 3. Tensile stress vs % strain

4.2. Flexural Strength

Flexural strength is a measure of an unreinforced concrete beams or slab to resist failure in bending [13,14]. Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load is conducted as per ASTM D790 test standard [15,16]. The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a three point contact technique. The flexural test results are shown in figure 4 and 5.

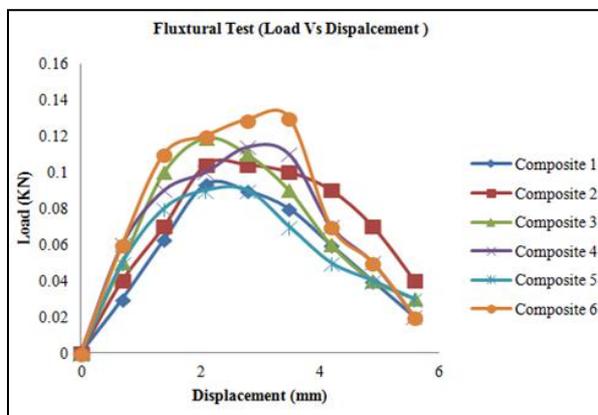


Figure 4. Flexural load vs displacement

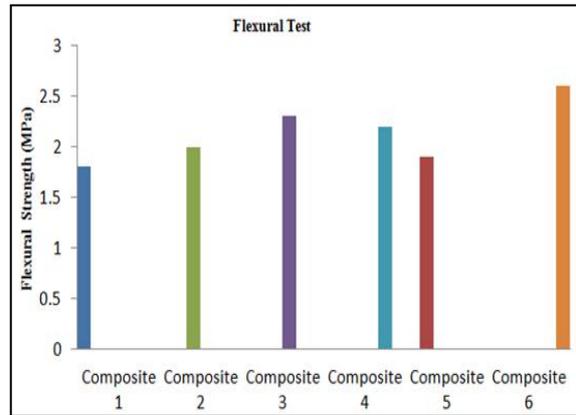


Figure 5. Flexural strength of composites

Composite 1, made by compression moulding, which has got five layers of goat hair with fibre loading of 20% withstands a flexural load of 0.09kN for 5.9mm displacement only and it breaks giving a flexural strength of 1.8Mpa. Composite 2, made by compression moulding, which has got five layers goat hair with fibre loading of 30% withstands a flexural load of 0.1N and it started to bend. It is observed that the material break after a displacement of 5.9mm. Thus flexural strength is 2.0Mpa. Composite 3, made by compression moulding, which has got five layers of goat hair and fibre loading of 40% withstands a flexural load of 0.12%KN and then starts to flex. It is observed that the specimen break after a displacement of 5.9mm giving a flexural strength of 2.3Mpa. Thus it increases continuously. But then a break down of flexural strength takes places due to over fibre load.

Composite4, of fibre loading 50% withstands a flexural load of 0.11KN it starts to flex and breaks down at a displacement of 5.9mm., giving a flexural strength of 2.2Mpa and composite 5 with a flexural strength of 1.9 Mpa with a load of 0.08KN showing displacement of 5.9mm. Finally by adding graphene, composite 6 shows a good flexural strength of 2.6 Mpa compared to other composites.

4.3. Impact Strength

The charpy impact test, carried out as per ASTM D256 test standard, also known as the charpy v-notch test, is a standardised high strain rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of composite materials notch toughness and acts as a tool to study temperature-dependent ductile-brittle transition [17,18]. The impact test results are shown in figure 6.

Composite 1, made by compression moulding, which has got five layers of goat hair with fibre loading of 20%, has got Impact strength of 0.54 Joules. Composite 2, made by compression moulding, which has got five layers goat hair with fibre loading of 30%, has got impact strength of 0.64 Joules, which is more than composite1. As the fibre loading increases impact strength also increases. Composite 3, made by compression moulding, which has got five layers of goat hair with fibre loading of 37.5% has got an impact strength of 0.73 Joules. The rise in impact value compared to composite 2 is due to the increase in percentage of fibre loading. Composite4, made up of five layers of goat hair with 40% of fibre loading gives an impact of 0.75%. Composite 5 of fibre loading 50% gives impact energy of 0.79%. Composite 6, with 0.1% of Graphene and fibre loading of 37.5% holds an impact strength of 0.81% which is highest among the six composite.

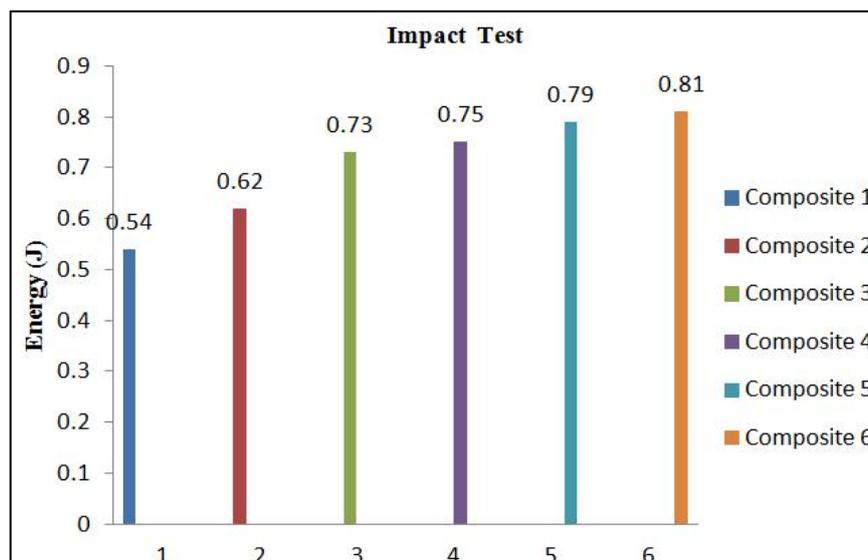


Figure 6. Impact strength of composites

4.4. Inter Laminar Shear Test

Inter laminar shear induces a stress in every composite layer to determine the displacements of the sheets of fibre [19, 20]. The inter laminar shear stiffness relative to the fibre reinforced composite is

typically much smaller than the homogenous material. The ILSS test results are shown in Table 2 and figure 7.

Table 2. Inter laminar shear strength of composites

Sample code	ILSS (MPa)
Composite 1	4.50
Composite 2	5.10
Composite 3	6.25
Composite 4	7.30
Composite 5	7.50
Composite 6	8.15

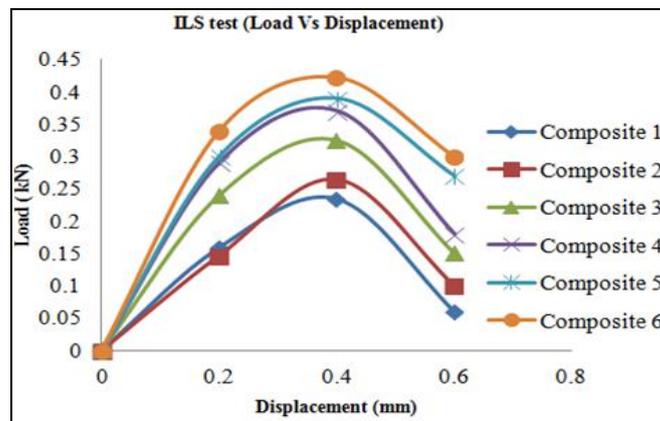


Figure 7. ILSS load Vs displacement

Composite 1 shows shear strength of 4.50 MPa with load 0.2 KN for a displacement of 0.6mm followed by composite 2 showing shear strength of 5.10Mpa with load 0.25KN and displacement of 0.6mm. Composite 3 showing shear strength of 6.25Mpa, at load 0.3 KN. It shows a displacement at a point 0.6 mm. Then composite 4 withstands a load of 0.35 KN for a displacement of 0.6 mm, giving laminar shear of about 7.30Mpa. Composite 5 with a load 0.39 KN at 0.6mm displacement gives a laminar strength of 7.5Mpa. Composite 6 shows a laminar shear at 8.15 Mpa with 0.44 KN load at displacement of 0.6mm.

4.5. Applications

Goat hair fibre epoxy composite can be used to manufacture fibre boats which are very safe even in rough seas and ocean currents. They can be used for noise dampening in generators. They can be used for making helmets. Due to its wear resistance property they can be used for laying roads. They can be used in manufacture of electrical panel boards, doors and windows. They can be used in automobiles for making car bumpers and dash boards. They can be used for manufacturing water tank door lids.

5. Conclusion

Tensile strength of composite increases from 20% fibre loading to 37.5% fibre loading, the maximum value observed being 33MPa. Beyond 37.5% fibre loading the tensile strength drops and finally upon addition of 0.1% graphene in 37.5% fibre loading tensile strength increases from 33 MPa to 36MPa. Fibre loading of 37.5% gave better results in the experiments conducted and addition of graphene increases the tensile strength.

Flexural strength of composite increased from 1.8 MPa to 2.3 MPa upto 37.5% fibre loading, beyond 37.5% fibre loading continuous drop in flexural strength is observed and the flexural strength 2.6 MPa is maximum for Graphene added composite with 37.5% fibre loading.

Impact energy increases from 0.54 Joules to 0.73 Joules when fibre loading increases from 20% to 37.5%. Upto 50% fibre loading we could see a small increase in impact strength. Graphene addition increases the strength from 0.73 Joules to 0.81 Joules.

Inter laminar shear strength increases from 4.50 MPa to 8.15 MPa. From 20% fibre loading to 37.5% fibre loading the increase was sharp then beyond 37.5% fibre loading the increase percentage slows down. Adding graphene increases the impact strength from 6.25 MPa to 8.15 MPa.

Addition of graphene to a smaller extent increases the mechanical properties of the composite and 37.5% fibre loading displays better mechanical properties in the experiment carried out. Further trials could be conducted with hybrid composites to validate the results obtained.

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