Investigation of Mechanical Behaviours of Natural Fiber and Particulate Reinforced Hybrid Polymer Composites

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***Abstract*:- Natural fiber has recently become attractive to researches, engineers and scientists as an alternative reinforcement for polymer (FRP) composites. Due to low cost, fairly good mechanical properties, they are exploited as a replacement for the conventional fiber, such as glass, aramid and carbon. The use of natural fibers reinforced polymer (NFRP) composites in automobile and commercial application stands as an evidence for remarkable development in NFRP composites. The impregnation of bio particles in natural composites has improvement in the mechanical properties, which extended the use of NFRP composites as engineering materials. The present work described the development and characterization of a natural fiber and particulates based polymer composite consisting of polyester resin. Babul wood is used as particle reinforcement along with natural green fibers like Sisal and Roselle in polyester matrix. The newly developed composites were characterized with respect to their mechanical properties. Experiments were carried out to study the effect of Babul wood particle on mechanical behavior of this polyester based polymer composite like tensile, flexural and impact behavior.**

Keywords: Alternative reinforcement, natural green fibers, Sisal and Roselle

I. INTROCUCTION

1.1 Polymer Matrix Composites (PMCs)

The most common advanced composites are the polymer matrix composites. These composites consist of a polymer, such as thermoplastic or thermosetting resins, reinforced with fibers such as natural, carbon, boron, aramid and glass fiber etc. These materials can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with resistance to corrosion. The general reason for these being most common is their low cost, high strength and simple manufacturing principles. Due to the low density of the constituents the polymer composites often show excellent specific properties.

Fiber Reinforced Polymer Composites (FRPC) consists of fibers as the reinforcement medium with polymer resin as the matrix. These materials are used in the greatest diversity of composite applications, as well as in the largest quantities, in the light of their room-temperature properties, ease of fabrication, and cost .The matrix is required to perform several functions, most of which are vital to the satisfactory performance of the composite. The roles of the matrix in the fiber and particle reinforced composites are quite different. The binder for the particulate aggregate simply serves to retain the composite mass in a solid form, but the matrix in a fiber composite performs a variety of other functions, which characterize the behavior of the composite. It binds the fibers together, holding them aligned in the important stress direction. Loads are applied to the composite, then transferred into the fibers, which constitute the principal load bearing component, though the matrix, enables the composite to withstand compression, flexural and shear forces as well as tensile load.

II. SELECTION PROCESS

2.1 SELECTION OF REINFORCEMENT MATERIALS

2.1.1. SISAL FIBER

Sisal fiber is derived from the leaves of the plant. It is usually obtained by machine decortications in which the leaf is crushed between rollers and then mechanically scraped. The fiber is then washed and dried by mechanical or natural means. The dried fiber represents only 4% of the total weight of the leaf. Once it is dried the fiber is mechanically double brushed. The lustrous strands, usually creamy white, average from 80 to 120 cm in length and 0.2 to 0.4 mm in diameter**.** Sisal fiber is fairly coarse and inflexible

Sisal Fiber is one of the most widely used natural fiber and is very easily cultivated. It is obtaining from sisal plant. The plant, known formally as Agave sisalana. These plants produce rosettes of sword-shaped leaves which start out toothed, and gradually lose their teeth with maturity. Each leaf contains a number of long, straight fibers which can be removed in a process known as decortication. During decortication, the leaves are beaten to remove the pulp and plant material, leaving the tough fibers behind. The fibers can be spun into thread for twine and textile production, or pulped to make paper products.

Sisal fiber is fully biodegradable, green composites were fabricated with soy protein resin modified with gelatin. Sisal fiber, modified soy protein resins, and composites were characterized for their mechanical and thermal properties. It is highly renewable resource of energy. Sisal fiber is exceptionally durable and a low maintenance with minimal wear and tear.

TABLE 2.1. CHEMICAL COMPOSITION OF SISAL FIBER

Cellulose	67-78%
Hemicellulose	10-14%
Lignin	8-11%
Pectin	10%
Others	1%
Waxes	2%
Water	11%

2.1.2. ROSELLE FIBER

The common word for Roselle is Mesta which produces good fiber of commerce. There are major yielding species in India. Roselle fibers find traditional, age-old applications in the form of high strength ropes in India, especially in Tamilnadu villages. The roselle fiber is used as low weight and high strength ropes to lift the heavy weight from well etc,. This fiber has been the main source of revenue of the people in this area. In Tamilnadu region, the roselle fiber is cultivated in many villages to protect the food plants, as a sides for food, medical purposes and specifically for fibers to produce the high strength rope and gift articles etc, This plant is an erect, branched, smooth or nearly smooth annul herb 1 to 2 metres in height. Roselle fiber is suitable alternative for glass fibers due to their specific strength and stiffness.

The fully-grown plant is used to extract fibers. For the production of fiber the roselle crops should be harvested at the bud stage. The stalks are tied into bundles and retted in tanks or well for 3-4 days. The retted stem of the roselle plant is washed in running water. Then the fibers are removed from stem and cleaned and died in the sun.

These fibers are also separated by mechanical crushing between the rollers and followed by cleaning with motorized combing device. The separated fibers are then dried under sunlight.

TABLE 2.2. CHEMICAL COMPOSITION OF ROSELLE FIBER

Cellulose	62-65%
Hemicellulose	16-20%
Lignin	2-5%
Pectin	0.5-1%
Others	0.5%
Water	8%

2.2 SELECTION OF PARTICLES

Particles are micro particles which are used to increase the mechanical and surface property of composite lamina. Particles increases the bond strength of resin and fiber particles. The size of the particles used here is 100µm

2.2.1 BABUL (Acacia Nilotica) PARTICULATE

Particles or fillers added to fiber reinforced polymer composites increases modulus, reduce mould shrinkage, control viscosity and produce smoother surface with improved stiffness, dimensional stability and better thermal properties. Research conducted in the past years has evidenced the usefulness of adding particles or fillers in fiber reinforced polymer composites.

Babul (Acacia nilotica) is a moderate sized tree with a spreading crown. In India, natural babul forests are generally found in Maharashtra, Andhrapradesh, Karnataka and Tamilnadu. Babul is truly a multipurpose tree. Its timber is valued by rural folks, its leaves and pod are used as fodder and gum has a number of uses. It tolerates extremes of temperature and moisture. It can survive both drought and flooded conditions. In Tamilnadu, the species grows widely in the districts of Salem, Erode, Dharmapuri and Coimbatore. Its wood is hard and coarse and resistance against termite and water proof so it is desirable for train traverses, handle for tools and still is used for shipbuilding and furniture. Babul wood is highly valued for agricultural implements and house construction.

TABLE 2.3. Chemical Compositions of Babul Wood Particulates	
Cellulose	38-45%
Hemicellulose	14-18%
Lignin	16-20%
Ash	3.2-5.9%
Others	7-8%

Babul wood is an easy wood to convert particulate when green, but it becomes harder and tougher when air dried. Hence a 5-year-old babul is cut and air dried for 4-5 days, then chopped into pieces and sieved finely to obtain particle size in the range of 50-100 micrometer. This particulate is dried in sunlight to remove moisture content for 6-7 days.

2.3 SELECTION OF RESIN SYSTEM

Thermoset resins are usually liquids or low melting point solids in their initial form. By its three-dimensional cross-linked structure, they have high thermal stability, chemical resistance, good dimensional stability and also high creep properties. The most common thermosetting resins used for composite manufacturing are unsaturated polyesters, epoxies and vinyl esters. Unsaturated polyester is economical as is used due to its excellent process ability and cross-linking tendency as well as mechanical properties when cured and due to these reasons unsaturated polyester has been chosen. For easy fabrication and better mixing of the polyester MEKP as catalyst and cobalt octoate as accelerator

III. EXPERIMENTAL WORK

3.1 SPECIMEN FABRICATION

3.1.1. COMPRESSION MOLDING

The Compression Molding procedure for required Composite fabrication, are given below, by this method we can able to get required dimension composite plates. A compression molding machine was used for composite fabrication. A stainless-steel mold having size of 300 mm×300 mm×3 mm was used for composite fabrication in compression molding process. The operating pressure of 2.6 MPa and temperature of 60°C was maintained for 1 hour for uniform curing of composite sheets.

1. The mold is held between the heated platens at a temp around 80°C of the hydraulic press.
2. A prepared quantity of Sisal and roselle fiber, Babul particles & matrix compound is placed in the mould, usually by hand, and the mould placed in the press at a pressure range of 2.6MPa.
3. The press closes with sufficient pressure to prevent or minimize flash at the mold part line.
4. The compound softens and flows to shape, the chemical cure then occurs as the internal mould temperature becomes high enough.
5. If necessary, cooling takes place, although for the vast majority of thermosets this is not needed.
6. The press is opened and the molding removed. Frequency, the mould is removed from the press and opened on the bench to extract the molding. It is reloaded with a fresh charge before returning it to the press to commence another cycle.
7.

Figure 3.1. Photographic image of Compression Molding Machine

Table 3.1. Weight percentage Combination of composite Plate

Lamina Number	Sisal Fiber %	Roselle Fiber %	% Particle	Polyester Fiber %
1	0	0	40	60
2	0	40	0	60
3	40	0	0	60
4	30	0	10	60
5	20	10	10	60
6	15	15	10	60
7	10	20	10	60
8	0	30	10	60

3.2 TESTING METHODS AND PROCEDURES

3.2.1 Mechanical Test

The prepared fabricated composites tested for various mechanical testing are done by experimentally investigated. And it has important role in evaluating fundamental properties of engineering materials as well as in developing new materials and in controlling the quality of materials for use in design and construction. If a material is to be used as part of an engineering structure that will be subjected to a load, it is important to know that the material is strong enough and rigid enough to withstand the loads that it will experience in service. As a result, engineers have developed a number of experimental techniques for mechanical testing of engineering materials subjected to tension, compression, bending or torsion loading.

3.2.1.1. Tensile Test

The static tensile test samples were cut according to ASTM D638 for the specimen dimension of 165 mm×25 mm×3 mm and the tensile behavior of natural fiber - polyester composites was measured using a Tinius Olsen , Make 10 kN, Dual Column Table Top Universal Testing Machine. The tensile specimen had straight-sided, constant cross-section. The tensile specimen was held in a testing machine by wedge action grips and pulled at a crosshead speed of 1.5 mm/min. Five readings for each identical specimen were taken and their average result was determined.

3.2.1.2. FLEXURAL TEST

Flexural strength testing was out using a Tinius Olsen Impact tester as per ASTM D790. The sample was incised into the dimension of 125 mm×12.5 mm×3 mm. The test specimen was supported in between the two spans, the sample should have kept in 100 mm in between the span and the above press will being kept to test the flexural for the given the relative humidity of 55%. Photographic image of impact tester is shown in fig 3.8sample materials. Five readings for each identical specimen were taken and their average result was taken. The tests were carried out at room conditions for the temperature of 27°C and relative humidity of 55.

3.2.1.3. IMPACT TEST

Impact strength testing was carried out using a Tinius Olsen Impact tester as per ASTM D256. The sample was incised into the dimension of 65 mm×12.5 mm×3 mm. The test specimen was supported as a vertical cantilever beam and broken by a single swing of a pendulum. Five readings for each identical specimen were taken and their average result was taken. The tests were carried out at room conditions for the temperature of 27°C and the relative humidity of 55%.

IV. RESULTS AND DISCUSSIONS

4.1 TENSILE TEST

The figure 4.1 and 4.2 shows the tensile strength for sisal and roselle with impregnated particulates hybrid composites. The lowest tensile strength 31.5MPa is obtained with inclusion of 40% Roselle fiber and 60% Polyester resin of all the comparisons of composite plates. The highest tensile value as 61.7MPa is achieved for 15% Sisal and 15% Roselle fiber, 10% Babul particulates with 60% Polyester resin. It shows the better hybrid reinforcement than the other compared values obtained of particulate hybrid composites.

Table 4.1 Experiment result for tensile test

S.No.	Composites Taken	Tensile Strength (MPa)
1.	40%Babul Particles + 60%Polyester	37.6
2.	40%Roselle + 60%Polyester	31.5
3.	40%Sisal + 60%Polyester	43.7
4.	30%Sisal + 10%Babul Particles + 60%Polyester	48.3
5.	20%Sisal + 10%Roselle + 10%Babul Particles + 60%Polyester	52.9
6.	15%Sisal + 15%Roselle + 10%Babul Particles + 60%Polyester	61.7
7.	10%Sisal + 20%Roselle + 10%Babul Particles + 60%Polyester	56.1
8.	30%Roselle+ 10%Babul Particles + 60%Polyester	44.0

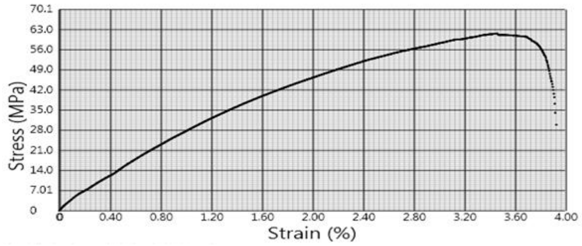

Fig 4.2 Stress and Strain curve tensile test for 15%Sisal + 15%Roselle + 10%Babul Particles + 60%Polyester

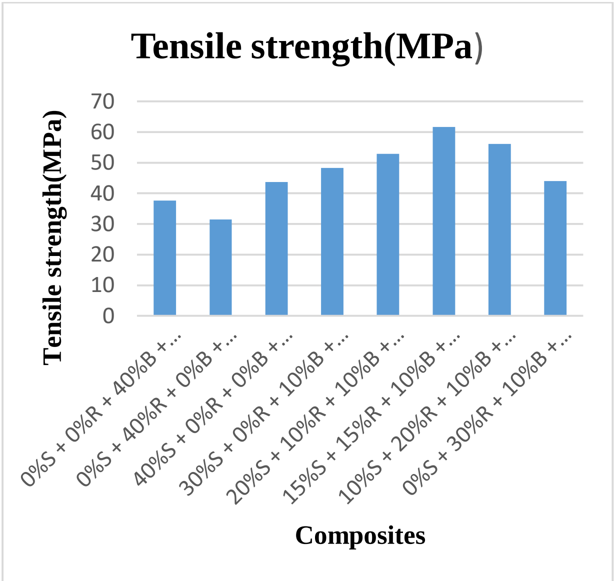

Fig 4.1 Tensile behavior of following specimen

4.2 FLEXURAL Test

The experimental results for flexural properties of fiber are given in Table 4.2 and Figure 4.3 and 4.4 shows the comparison results of flexural strength of the sisal, Roselle and babul particulates hybrid composites. The result for flexural strength of the composites concluded that the better result is produced for the 15% sisal, 15% Roselle and 10%babul particulates with polyester resin of 81.07MPa of all over the compared composites present.

Table 4.2 Experiment result for flexural test

S. No.	Composites Taken	Flexural Strength (MPa)
1.	40%Babul Particles + 60%Polyester	55.80
2.	40%Roselle + 60%Polyester	66.43
3.	40%Sisal + 60%Polyester	60.63
4.	30%Sisal + 10%Babul Particles + 60%Polyester	63.41
5.	20%Sisal + 10%Roselle + 10%Babul Particles + 60%Polyester	72.95
6.	15%Sisal + 15%Roselle + 10%Babul Particles + 60%Polyester	81.07
7.	10%Sisal + 20%Roselle + 10%Babul Particles + 60%Polyester	69.54
8.	30%Roselle+ 10%Babul Particles + 60%Polyester	58.01

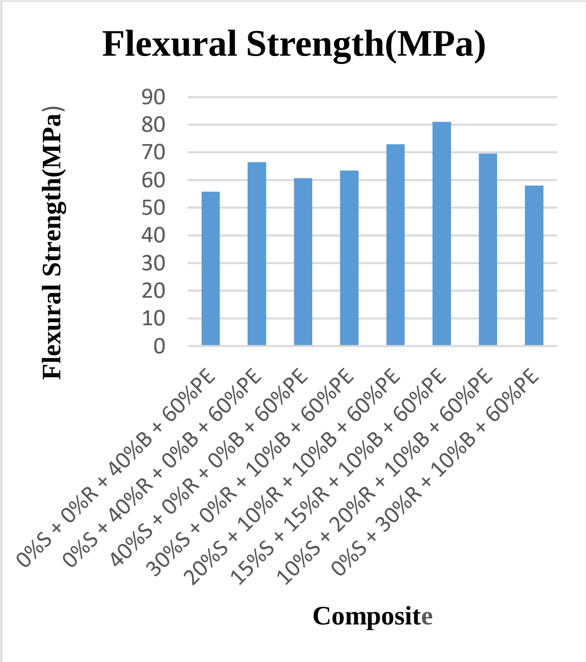

Fig 4.3 Flexural behavior of following specimen

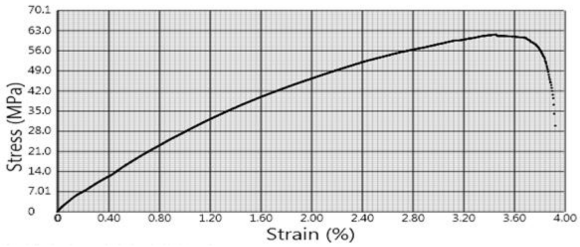

Fig. 4.4 Stress and Strain curve flexural test for 15%Sisal + 15%Roselle + 10%Babul Particles + 60%Polyester

4.3 IMPACT TEST

The impact behavior of material directly relates to the toughness of the material. The impact strength of natural fiber particulate polyester composites was illustrated in Table 4.3 and comparison of impact strength was shown in Figure 4.5.

The first strength in the graph shows low indication of impact strength of babul particulates and polyester resin of (26.6849MPa) which is very low compared to other composites obtained in all composition of composites fabricated. While adding fiber and particulates 15%sisal, 15%roselle and 10%babul particles (90.0400MPa) is higher than comparing the other composite combinations shown below.

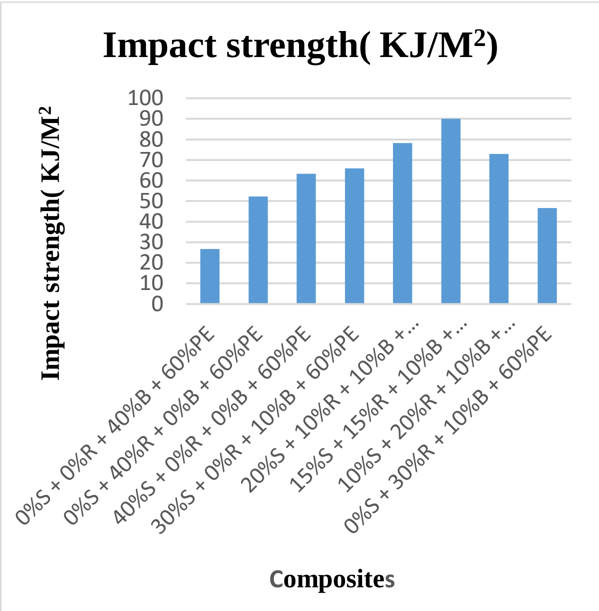

Fig 4.5 Impact behavior of following specimen

Table 4.3 Experiment result for impact test

S. No.	Composites Taken	Impact Strength
1.	40%Babul Particles + 60%Polyester	26.6849
2.	40%Roselle + 60%Polyester	52.2891
3.	40%Sisal + 60%Polyester	63.2486
4.	30%Sisal + 10%Babul Particles + 60%Polyester	65.9857
5.	20%Sisal + 10%Roselle + 10%Babul Particles + 60%Polyester	78.2500
6.	15%Sisal + 15%Roselle + 10%Babul Particles + 60%Polyester	90.0400
7.	10%Sisal + 20%Roselle + 10%Babul Particles + 60%Polyester	72.9197
8.	30%Roselle+ 10%Babul Particles + 60%Polyester	46.6380

V. CONCLUSION

In this paper, a detailed study was conducted on the mechanical behavior of fiber and particulate reinforced polyester composites.

- The tensile, flexural and impact properties of eight different combination of composites were evaluated as per ASTM D639 and ASTM D790, ASTM D256 respectively.
- The better value of tensile strength of 61.7 MPa was obtained for the combination of 15%sisal -15%roselle – 10%babul particulates – 60%polyester hybrid composite.
- The better value of flexural strength of 81.07 MPa was obtained for the combination of 15%sisal -15%roselle – 10%babul particulates – 60%polyester hybrid composite.
- The better value of Impact strength of 90.0400 kJ/sq-m was obtained for the combination of 15%sisal -15%roselle – 10%babul particulates – 60%polyester hybrid composite.
- Hence from the following results of the composite lamina with combination of 15%sisal -15%roselle – 10%babul particulates – 60%polyester hybrid composite exhibits better mechanical properties.

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