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EVALUATION OF FLEXURAL PROPERTIES OF BAMBOO FIBER REINFORCED HYBRID COMPOSITES

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Abstract — *With advancements in the methods of research, the branch of Material Science has seen its extremes but there are some areas upon which much attention should be kept. One such area is the natural composite. This work focuses on the extraction of fibres from jute, coir and bamboo belong to this category. Fillers are used along with various commodities as well as engineering polymers to improve the properties of polymers. In this project bamboo fiber hybrid composites have been developed from polypropylene filled with fly ash of constant 10%wt Concentration. Concentration of fiber was varied up to 25 % by weight and the test specimens were prepared by Injection Moulding. Bending properties were tested by using tensometer and the Bending Strength, Bending Moment were increased with the increment of fiber weight % in the composition.*

Keywords*- Bamboo Fiber; fly ash; Polypropelene(PP); Bending strenght.*

I. INTRODUCTION

There are increasing interests in using thermoplastics to replace thermosets for laminate fabrication due to their advantages such as high toughness, shorter manufacturing cycles, no refrigeration storage required and reprocessing possibilities [1]. Carbon fiber or glass fiber reinforced thermoplastic laminates in matrices such as polyetherimide (PEI), polyetheretherketone (PEEK) and polyphenylenesulfide (PPS) have already been used extensively in the aerospace sector due to their excellent mechanical properties,heat stability and low flammability [2,3]. These matrices are, however, expensive and difficult to process due to the high processing temperature and pressure. Among the available thermoplastic polymers, polypropylene (PP) is considered a good candidate as thermoplastic composite matrix. Polypropylene is a semi-crystalline engineering thermoplastic and is known for its balance of strength, modulus and chemical resistance [4]. Polypropylene has many potential applications in automobiles, appliances and other commercial products in which creep resistance, stiffness and some toughness are demanded in addition to weight and cost savings. However, the CFRP fabrication from neat PP resin cannot meet the industrial requirements due to its low mechanical properties especially toughness and low thermal resistance. To improve the strength and thermal properties of CF composites, various types of nano-filler (such as clay, silica, graphene, and CNT) have been incorporated into the thermosets and thermoplastics matrices. The incorporation of inorganic particulate as well as fiber fillers has been proved to be an effective way to improving the physical and thermal properties.

Fiber is an anatomical structure obtained from stems, leaves, roots, fruits, and seeds. It is derived from meristematic tissue of primary or secondary origin depending on the species. Vegetable fibers consist of cellulose, lignocelluloses, pectin and hemicelluloses depending on the vegetable species.World wide, despite the availability of modern synthetic fibers, vegetable fibers remain in great demand and compete with wool, silk, and synthetics for quality resistance, durability, color, and lustre. Due to the intense competition between natural and industrial fibers, a need exists for analysis of the growth and productivity of those fiber crops most important worldwide. Farmers and researchers in the field of fiber crops face varying problems in their thrust to increase fibber productivity, not the least of which are restrictions due to uncontrollable edaphically and agro climatic factors and economic constraints at grassroots levels. The place of cotton as a fiber crop has already been well documented; therefore, this work concentrates mainly on vegetable fibbers that are long, called long vegetable fibres.

Bamboo is one of the oldest building materials used by mankind in tropical and subtropical regions. Bamboo is a kind of fast- growing and renewable resource, which is cheap and widely available. Since the 20th century, bamboo has received increasing attention for industrial applications, especially as raw material for wood-based composites. Moreover, it has the advantages of straight grain, beautiful colour, high strength and toughness, and excellent abrasion resistance. According to the mechanical properties, appropriate for composite products should be considered based on their strength to weight ratio. As a result, bamboo has a low strength to weight ratio, it is desirable for some applications. Bamboo composites have similar properties to wood composites. Then, bamboo-based composites will become a highly competitive alternative to wood-based composites and will become an important forest based product in the future. In general, bamboo is stronger than wood in bending strength, compression strength parallel to grain and is similar in shear strength parallel to grain. The strength of bamboo in grain direction is extremely high. Due to the thick wall and long Culm, bamboo can be processed into many forms of particles, such as flour, fibers, flakes, chips, excelsior, strips, strands and veneer

Fillers, such as gypsum, calcium carbonate(limestone), kaolin(clay) and alumina trihydrate are often used in composites to enhance performance and to reduce cost relative to resin and reinforcement, fillers are inexpensive. Depending on the material selected, fillers can impart certain properties, such as improved smoke and fire resistance, mechanical strength, water resistance and surface smoothness to name a few.

Fly ash is a finely divided powder generated as a solid waste during power generation. As the consumption of power is increasing day by day the solid waste is also increasing. There is a direct result of huge quantities of fly ash, about 80-90 million tonnes in India. Out of which less than half is used as a raw material for concrete manufacturing and construction; the remaining is directly dumped on landfills or simply piled up. Only a small fraction is used in the development of high value products. Due to environmental regulations, new ways of utilizing fly ash are being explored in order to safeguard the environment and provide useful ways for its utilization and disposal.

II. EXPERIMENTAL SETUP

I. Preperation of Composite

The bamboo stick is soaked in water and made it dry for 2 days and the so that it is free from moisture. After this process the fibres were subjected to a mechanical process, by beating them gently with a plastic mallet in order to loosen and Bamboo fiber is made into Micro structural analysis because it helps in effective preparation of composite specimens by Injection Moulding.

Melting process of polypropylene can be achieved via extrusion and molding. Common extrusion methods include production of melt-blown and spun-bond fibers to form long rolls for future conversion into a wide range of useful products, such as face masks, filters, diapers and wipes. The most common shaping technique is injection molding, which is used for parts such as cups, cutlery, vials, caps, containers, housewares, and automotive parts such as batteries. The related techniques of blow molding and injection-stretch blow molding are also used, which involve both extrusion and molding. The large number of end-use applications for polypropylene are often possible because of the ability to tailor grades with specific molecular properties and additives during its manufacture. For example, antistatic additives can be added to help polypropylene surfaces resist dust and dirt. Many physical finishing techniques can also be used on polypropylene, such as machining. Surface treatments can be applied to polypropylene parts in order to promote adhesion of printing ink and paints.

Fig1: Specimen Samples

II. Injection Moulding Setup

Injection capacity

The proper injection capacity is found from the relationship of the molding machine capacity for the weight of 1 shot as shown in Figure 1･1-2. It is necessary to select the molding machine that satisfies the capacity of the shaded area. This figure is the summary of the actual molding results in the past, but basically, it is based on the following idea
At the side where the capacity is small, plasticizing time and injection time become long, and it is used at the narrow capacity of the molding machine. That is, the filling shortage is caused due to the extension of molding cycle and slow filling rate.

On the other hand, at the side where the capacity is large, dwell time of the resin inside the cylinder becomes long, and the resin thermally decomposes. The capacity range in the figure is indicated rather widely, but when it is easy to be thermally decomposed with materials containing lots of pigments and additives, it is better to conduct the molding at shot weight of 70～80% of the injection capacity.

Barrel:

Generally, using the material (for example, nitride steel etc.) for the molding of Iupilon / NOVAREX is good. However,concerning the molding of glass fiber reinforced grade (Iupilon GS etc.) and optical grade (Iupilon H-400 etc.), it isgood to consider the following for the barrel material.

As for glass fiber reinforced PC, it is good to use the bimetal (double-structure cylinder covered the inside with another metal and centrifugal casting) to prevent the barrel abrasion. For example, the H alloy (Hitachi Metals Ltd.), N alloy (Japan Steel Works Ltd.), K alloy (Kobe Steel Ltd.) etc. are well known.

Nozzle:

A nozzle with the structure without PC stagnation is desirable as possible. Therefore, it is necessary to avoid using the needle shut off nozzle and torpedo nozzle due to resin stagnation. The open nozzle is the best for use. The open nozzle is easy to cause drooling, stringiness, and it is difficult to prevent them but using a long-extended nozzle and adjusting independently the temperature at two separate places of the tip and the bottom, are effective.

Heater:

Since PC is molded at high temperature, the heater with heat capacity can be heated to about 3700Cis used, and a band heater is usually used.

When disassembling to clean the nozzle and cylinder head and when the heater is stuck with drooling resin, the heater is disconnected. It is necessary to note that it is easy to cause the burn when continuing molding without being aware of heater disconnection.

Compositions used in Injection Moulding:

In this paper 7 combinations (C1-C7) of Polypropelene, Flyash and bamboo Fiber have been tested with a set of samples in each combination.

C1	PP	3 Samples
C2	PP+10wt% Fly ash	5 Samples
C3	PP+10wt%Flyash+5wt%Fibre	5 Samples
C4	PP+10wt% Flyash+10wt%Fibre	5 Samples
C5	PP+10wt% Flyash+15wt%Fibre	5 Samples
C6	PP+10wt% Flyash+20wt%Fibre	5 Samples
C7	PP+10wt% Flyash+25wt%Fibre	5 Samples

Test for Flexural Strength and Modulus:

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 flexural test technique.

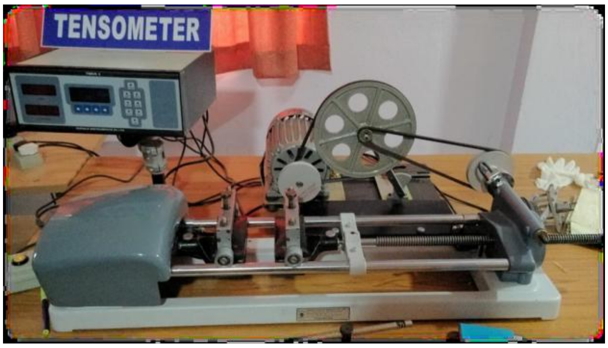

Fig2: Flexural Testing Equipment with Tensometer

Table1: Flexural Testing Equipment Specifications

Make	Mikrotech Pune
Load	0-2000KG
Elongation	0-200mm
Accuracy	0.001
Flexural Testing Carried out	ASTM – D638-89

III. TESTING PERAMETERS

Flexural strength and flexural modulus of the composites are evaluated in this paper. These are the functions of weight fraction was measured using tensometer. In accordance with ASTM D638-89 the test sample of 98 mm long, 10 mm deep and 4 mm wide were prepared.

Flexural Strength

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength is a material property, defined as the stress in a material just before it yields in a flexure test. The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress, here given the symbol σ .

Bending strength,

$$\sigma = \frac{3FL}{2bd^2}$$

where F is the maximum load

L is length of support span

b is the width of the specimen

d is the thickness of the specimen.

Flexural modulus

The flexural modulus or bending modulus is the ratio of stress to strain in flexural deformation, or the tendency for a material to bend. It is determined from the slope of a stress-strain curve produced by a flexural test , and uses units of force per area. It is an intensive property.

Bending moment=σI/y

where I is moment of inertia

σ is bending strength

y is the distance between Centroidal axis and end of specimen

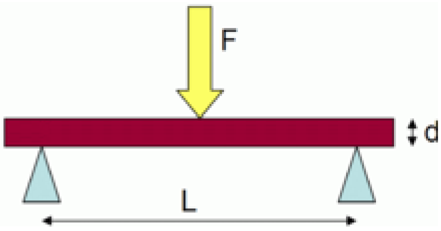

Fig3: 3-Point Bending

Flexural modulus is determined from the slope of a stress-strain curve produced by a flexural test (such as the ASTM D 790)For a 3-point test of a rectangular beam behaving as an isotropic linear material,

- Temperature - 2100 ^{o}C
- Pressure - 1100 kgf/cm^{2}
- Three point bend tests are performed in accordance with ASTM D790M test method 1, Procedure A to measure flexural properties.
- Strain rate - 0.2mm/min.

A three point bend is chosen because it requires less material for each test and eliminates the need to accurately determine center point deflections with test equipment.

IV. RESULTS & DISCUSSIONS

The following table gives the elongation, bending strength and bending modulus of composion C_1.

Table2: Readings for 100% Plain Polypropylene

Peak Load (N)	Elongations (mm.)	Banding Strength (MPa)	Bending Modulus (MPa)
40	13.2	26.25	699.95
50	14.1	32.82	874.95
60	14.4	39.38	1049.93
Average (50N)	13.9	32.81	874.94

The following table gives the elongation bending strength and bending modulus of composion C_2.

Table3: Readings for 90% Polypropylene+10%FlyAsh

Peak Load (N)	Elongations (mm.)	Banding Strength (MPa)	Bending Modulus (MPa)
40	9.2	26.25	699.96
50	12.6	32.81	874.95
70	13.2	45.94	1225
Average (53.33N)	11.67	32.81	933.3

The following table gives the elongation bending strength and bending modulus of composion C_3.

Table4: Readings for 10%FlyAsh+5%Fibre+85%Polypropylene

Peak Load (N)	Elongations (mm.)	Banding Strength (MPa)	Bending Modulus (MPa)
50	11.4	32.81	874.95
50	12.3	32.81	874.95
60	13.5	39.37	1049.93
60	14.7	39.37	1049.93
70	15.9	45.94	1225
Average (58N)	13.56	38.06	991.60

The following table gives the elongation bending strength and bending modulus of composion C_4.

Table5: Readings for 0%FlyAsh+10%Fibre+80%Polypropylene

Peak Load (N)	Elongations (mm.)	Banding Strength (MPa)	Bending Modulus (MPa)
40	10	26.25	699.96
50	12.3	32.81	874.95
70	11.7	45.94	1225
70	11.9	45.94	1225
70	14.5	45.94	1225
Average (60N)	12.08	39.38	1049.98

The following table gives the elongation bending strength and bending modulus of composion C_5.

Table6: Readings for 10%FlyAsh+15%Fibre+75%Polypropylene

Peak Load (N)	Elongations (mm.)	Banding Strength (MPa)	Bending Modulus (MPa)
60	11	39.37	1049.93
60	11.2	39.37	1049.93
70	13.5	45.94	1225
70	14.2	45.94	1225
80	14.7	52.04	1399.91
Average (64N)	12.92	44.53	1189.96

The following table gives the elongation bending strength and bending modulus of composion C_6.

Table7: Readings for 10%FlyAsh+20%Fibre+70%Polypropylene

Peak Load (N)	Elongations (mm.)	Banding Strength (MPa)	Bending Modulus (MPa)
50	12.3	32.81	874.95
50	14.3	32.81	874.95
70	15.1	45.94	1225
80	15.9	52.04	1399.91
100	18.3	65.62	1749.89
Average (70N)	15.18	45.94	1224.94

The following table gives the elongation bending strength and bending modulus of composion C_7.

Table8: Readings for 10%FlyAsh+25%Fibre+65%Polypropylene

Peak Load (N)	Elongations (mm.)	Banding Strength (MPa)	Bending Modulus (MPa)
50	10.7	32.81	874.95
60	12.7	39.37	1049.93
60	14.6	39.37	1049.93
90	15.6	59.06	1574.90
100	18.9	65.63	1749.89
Average (72N)	14.5	47.25	1259.92

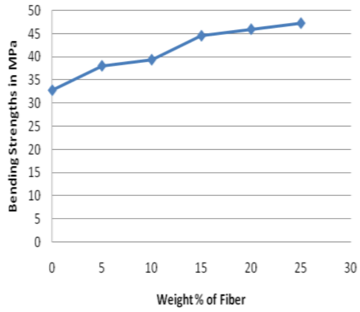

Fig4 (a)

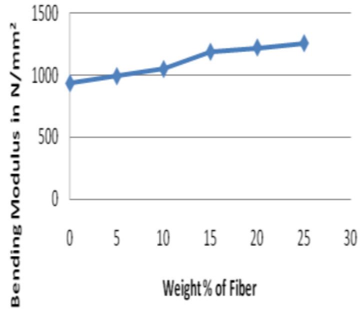

Fig4(b)

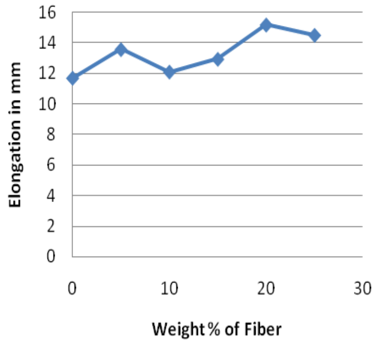

Fig4 (c)

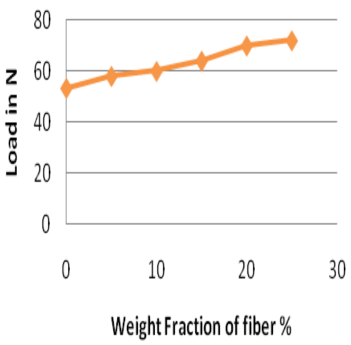

Fig4(d)

Fig4: Graphs between Percentage of Fiber Vs (a)Bending strength (b) Bending Modulus (c) Elongation and (d) Load

Observing the results show the following discussions have been made.

- The Bending Strength increases with increasing the percentage of fiber also increases (Fig 4(a)).
- The Bending Modulus increases with the increase of weight percentage of fiber (Fig 4(b)).
- The elongation fluctuates with a gradual increment and decrement with the increase in weight percentage of fiber (Fig 4(c)).
- With the addition of Fiber Weight % in the composition there is an increase in Peak Load (Fig 4(d))

IV. CONCLUSIONS

From the previous study it was known that polypropylene with fly ash composition, the maximum values are attained with10% Fly ash + Polypropylene. So in our Hybrid Composite we fixed the 10wt% of Fly ash as constant and differed the weight composition of Fiber and Polypropylene. Bamboo fiber reinforced hybrid composites (Polypropylene + Fly Ash + Bamboo Fiber) mechanical properties are studied and the following conclusions are derived.

- The flexural strength increases with the increment of weight percentage of fiber according to the compositions mentioned above and it shows maximum at 25% of fiber in the composition.
- Flexural Moment also increases with the increment of weight percentage of fiber according to the compositions mentioned above and it shows maximum at 25% of fiber in the composition.
- Load also increases with the increment of weight percentage of fiber according to the compositions mentioned above and it shows maximum at 25% of fiber in the composition.
- But elongation Fluctuates by showing an increment and decrement with the addition of fiber weight percentage.

It was found that the fibre percentage cannot be increased more than 25 % because of reduction of quantity of polypropylene in the composition, the moulds cannot be formed in Injection Moulding Machine.The Flexural Properties show a gradual increment in Bending Strength and Bending Moment because of its high strength to weight ratio of Bamboo Fiber and due to lower specific gravity and higher shear strength of Fly ash.

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