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Effect of Moisture Absorption on the Tensile Behavior of Woven Hybrid Natural Fiber Reinforced Polymer Composites

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ABSTRACT— Natural fibers are receiving considerable attention as substitutes for synthetic fiber reinforcements such as glass in polymer due to their low density, low cost, acceptable specific strength, reduced tool wear and respiratory irritation and renewable resources. The fibers are not uniformly distributed in the randomly oriented fiber reinforced hybrid composites due to manual lay-up and fibers agglomeration. This reduces the mechanical properties. The above problem can be solved by reinforcing the woven hybrid natural fiber laminated composites. Polyester resin was used as a matrix. The present work emphasis the sisal/cotton fiber woven mat reinforced polyester composites preparation and analysing the tensile behaviour (Dry and wet condition) by varying the fiber volume fraction (10, 20, 30 and 40%).At dry condition, while increasing the fiber content increases the tensile strength and modulus of the composites upto the volume fraction of 30%.Further increase in fiber volume fraction decreases the tensile strength and modulus. Water absorption was carried out for 24 hours with different condition. This reduces the tensile properties.

KEYWORDS— Natural fiber, tensile behavior, water absorption

I. INTRODUCTION

Composite materials produce combination properties of two or more materials that cannot be achieved either fiber or matrix when they are acting alone [1]. Fiber reinforced composites were successfully used for many decades of all engineering applications [5]. Glass fiber reinforced polymeric composites was most commonly used in the manufacture of composite materials. The mechanical behaviour of a fiber-reinforced composite basically depends on the fiber strength and modulus, matrix strength, the chemical stability and the interface bonding between the fiber/matrix to enable stress transfer [2]. Suitable compositions and orientation of fibers made desired properties and functional characteristics of glass fiber reinforced polymer composites was equal to steel, higher range of stiffness than aluminum and the specific gravity was one quarter of the steel [3]. Composite materials have wide range of industrial applications as well as laminated glass fiber-reinforced composite materials are used in marine industry, piping industries because of good environmental resistance, better damage tolerance for impact loading, high specific strength and stiffness [4]. Polyester matrix based composites have been widely used in marine applications, in marine field the water absorption was an important parameter in degradation of polymer composites. The different mechanisms used to identify the degradation of material such as initiation, propagation, branching and termination [6]. Araujo et al investigated the water absorption behavior of fiberglass wastes reinforced polyester matrix composites with different fiber/matrix combination such as Polyester/Fiberglass Wastes (20%), Polyester/Fiberglass Wastes (30%) and Polyester/Fiberglass Wastes (40%). The test specimen immersed in distilled water at different interval of time up to 600 hours, time versus water absorption curve reported that the water sorption decreased with increase of fiber content in composite, the minimum water absorption was found at Polyester/Fiberglass Wastes (40%) composite[7]. Abdullah et al investigated the effects of weathering condition on mechanical properties of glass fiber reinforced thermo setting plastic materials. The mechanical properties were decreased under weathering conditions such as temperature, humidity, ultraviolet radiation, and pollutant [13]. Edson Cocchieri Botelho et al investigated the Environmental behavior of woven mat Glass Fiber reinforced poly ether-imide thermoplastic matrix Composite, the test was conducted at various temperature with the relative humidity of 90% for 60 days under sea water. The moisture absorption behavior was mostly dependent on temperature and relative humidity. The Moisture absorption curve reported that the weight gain was initially increased linearly with respect to time .The maximum moisture absorption 0.18% was found after 25 days [9]. Rahul chhibber et al investigated the environmental degradation of glass fiber reinforced polymer composite with different temperature such as 45°c and 55°c, the test conducted in water and NaOH bath after a time of 1 and 2 months. The percentage weight gain increased with increase of bath time and temperature, NaOH bath found larger weight gain compared with water immersion [13]. Somjai Kajorncheappunngam et al found the Effect of Aging Environment on Degradation of woven fabric E-Glass-Reinforced Epoxy with four different liquid media such as distilled water, a saturated salt solution, 5-molar NaOH solution, and 1-molar hydrochloric acid solution and two separate temperatures. Water immersion had the lower damage than acid or alkali soaking and immersion in brine didn't affect the mechanical properties [10]. Agarwal et al investigated the environmental effects of randomly oriented E glass fiber reinforced polyester matrix composites with different environmental conditions such as acid Brine, and solution, freezing condition, Ganga water and kerosene oil. The test conducted at different interval of time such as 64hours, 128hours and 256hours. The percentage reduction in tensile strength decreased after every interval of time, the maximum percentage reduction was found on NaOH solution and minimum percentage reduction was found on freezer condition [11]. Fernand Ellyin et al investigated the moisture absorption behavior of E-glass reinforced fiber epoxy matrix composite tubes. They were immersed in distilled water at two different temperatures such as 20° C and 50° C. The test was conducted in distilled water for four months. The time versus moisture absorption curve reported that 0.23% weight gain was found at 20°C and 0.29% weight gain was found at 50°C [12]. Abdolkarim Abbsaiet al investigated the environmental behavior of glass fiber reinforced polymer matrix composites with different combinations such as glass fiber/ isophthalic polyester resin, glass fiber/ vinyl ester resin, glass fiber/ urethane modified vinyl ester resin. The test conducted at different temperatures from 20°C to 120°C for 30 days, 120 days and 240 days under water and alkaline environments. The glass fiber strength and modulus were decreased in alkali environment. [14]. Visco et al found the mechanical performance of glass fibre reinforced polyester matrix composites while before and after immersion in seawater. Two different types of polyester resins used such as isophthalic or orthophthalic and two different types of laminates were performed, one laminate was five layers of reinforcement with isophthalic resin and another was obtained by laminating four layers of reinforcement with orthophthalic resin and one external layer with isophthalic. The experimental result reported that Flexural modulus, maximum flexural strength and shear modulus values decreased with increase in immersion time. Isophthalic resin was well bonded to glass fibres so the seawater absorption resistance was higher compared to orthophthalic resin [6].

The ultimate aim of this research is find out the tensile strength of woven natural fiber reinforced polyester resin matrix composite under water environmental conditions

II. MATERIAL

A. Sisal plant

A coarse and strong fiber, sisal is being increasingly used in composite materials for furniture, cars, construction and in plastics and paper products. Sisal fibers are extracted from agave sisalana, a native of Mexico (figure.1). The hardy plant grows well all year round in hot climate and arid regions .Sisal can be cultivated in all soil types except clay and has low tolerance to very moist and saline soil types. Husbandry is simple as it is resilient to disease and its input requirement is low compared with other crops. The Sisal can be harvested from 2-3 years after planting and its productive life will be up to 12 years, producing 180 to 240 leaves depending on location, level of rainfall, altitude, and variety of plant. The leaves contains 90 percent moisture, they are very rigid and the fleshy pulp is very firm. The fibers which lie embedded longitudinally in the leaf and most abundant near the surface of the leaves must be removed from the leaves as soon as they are cut in order to avoid the risk of damage during the cleaning process.

Fig. 1 Sisal plant

B. cotton plant

Fig. 2 Cotton plant

Cotton is a very soft, fluffy staple fiber that grows in protective capsule, and around the seeds of cotton plants of the genus gossypium (Fig.2). The fiber is almost pure cellulose. During natural conditions, the bolls will tend to increase the dispersion of the seeds. The cotton plant is a shrub native to subtropical and tropical regions around the world. SF is one of the most widely used natural fibers. These plants produce rosettes of sword-shaped leaves which start out toothed, and lose their teeth with maturity. Each and every leaf contains a number of long and straight fibers which will be removed by a process known as decortications. During decortications, leaves are crushed and beaten by a rotating wheel set with blunt knives.

Water is used to remove the waste parts of the leaf. The fiber is then dried and brushed. Cotton fiber is commercially available. Hybrid cotton–sisal fiber mat was prepared in power-loom at Gobichetipalayam (Tamilnadu). Wrap direction is made by cotton and the weft by sisal. It is difficult to made pure sisal fiber woven mat (i.e. in both wrap and weft direction) due to the short fiber length. The gap between the two parallel fibers was kept as .5 mm. The properties of natural fibers are shown in Table I

TABLE I
PROPERTIES OF NATURAL FIBERS

Properties	Sisal	Cotton
Density (g/cm^3)	1.33	1.5
Tensile strength (N/mm^2)	600-700	400
Stiffness (KN/mm^2)	38	12
Elongation at break (%)	2-3	3-10
Moisture absorption (%)	11	8-25

C. Polyester resin

Polyester resins are extremely versatile in properties and applications. These resins are resilient, rigid, flexible, weather resistant or flame retardant. They can also be filled, reinforced and pigmented. There are two principle types of polyester resin used widely: orthophthalic polyester resin, isophthalic polyester resin. The properties of the isophthalic resin facilitate its usage more widely for the manufacturing of the composite laminates.

Suitable coupling agent and accelerator used in combination with polyester resin are methyl ethyl ketone peroxide and cobalt naphthalene respectively. Such agents facilitate faster reaction and quicker curing time for the isophthalic polyester resin. The properties of the isophthalic polyester resin are listed out in the following table II.

D. Catalyst

Resins can be cured by using readily available materials called catalysts (peroxides / hardeners). for un-saturated polyesters are unstable, energy rich molecules which decompose into highly reactive molecule fractions - defined as radicals - under the influence of heat, or ultra violet light. These radicals are capable of reacting with the polyester or styrene molecule, forming new radicals, and starting of a chain reaction. Normally methyl ethyl ketone peroxide is used as a catalyst for manufacturing of composite materials. Methyl ethyl ketone peroxide is a colorless liquid, usually supplied at a 50% concentration in a phlegmatizing solution.

MEKP is the most widely used catalyst system. it is used with promoters, usually 6% cobalt naphthenate or 6% or 12% cobalt octate. The MEKP used most often is supplied at 9% active O_2. Water in the catalyst will affect resin cure, but MEKP can be checked for excessive water content by mixing small amounts eith equal parts of styrene

TABLE II
PROPERTIES OF ISOPHTHALIC POLYESTER RESIN

S.no	Properties	Unit	Range
1	specific gravity	no unit	1.1 - 1.46
2	hardness (Rockwell)	no unit	70 - 115
3	tensile strength	MN/mm^2	42 - 91
4	tensile modulus	GN/mm^2	2 - 4.5
5	compressive strength	MN/mm^2	90 - 250
6	specific heat calories	g/ºc	0.3
7	coefficient of linear expansion	/ºc	9.9 - 18x10^{-5}
8	shrinkage	%	0.004 - 0.008
9	water absorption	%	0.15 - 0.60

E. Accelerator

Accelerators are used to speed up and enhance the cure. Resin can be cured with a wide variety of accelerators. Normally cobalt accelerators can be added during curing at room temperature .the proper choice of the curing system depends to a large extent on the application technique and the requirements of the final product. Cobalt solutions are blue or purple liquids and are available on the market with different percentages of active cobalt.

III. COMPOSITE PREPARATION

The simple hand lay-up technique followed by compression molding process was adapted to prepare the composite specimen with various fiber volume fractions (v_f). One percent of catalyst and accelerator were mixed with the isophthallic polyester resin for curing the composites. Steel dies were designed to prepare the composite plate as shown in figure 3. The dimensions of female dies were 330mm × 330mm × 25mm, with 5mm × 5mm key way on top face for fixing the side plate to maintain the dimension of 300mm × 300mm for the composite fabrication. The dimensions of the male die were 300mm × 300mm × 25mm which was the exact size of the composite plate.

The woven mats were placed on the female die and resin was poured on it, and steel rollers were used to entrap all the air bubbles by the continuous rolling process over the fiber in the die. At the time of curing, the closed mould was kept on the hydraulic press and compressive pressure of 1.5 kg/cm^2 was applied for 4h at atmospheric temperature. Finally the fibers were reinforced with the polyester resin within the mold size of dimensions 300mm × 300mm × 3mm

Fig. 3 Die Assembly

Fig. 4 Composite Plate

The prepared composite plate was then post-cured for 1h in oven and the final shape of composite plate was obtained as shown in figure 4.

IV EXPERIMENT

A. Tensile test without water treatment

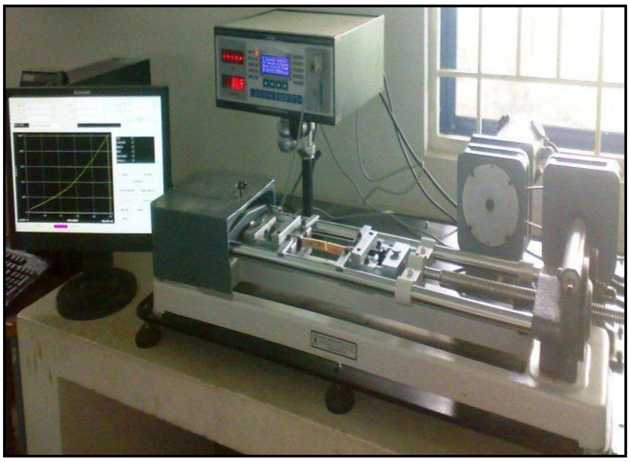

Fig. 5 Tensometer Apparatus with the Specimen

The tensile test were conducted for the prepared composite specimens using tensometer set up as shown in Fig. 5 to evaluate the tensile properties. Composite specimen were prepared according to the ASTM D 638 M-89 standards the specimens were machined to a standard size of 165mm×12.7mm×3mm for a gauge length of 50mm. for this testing, the load cell of 20 KN was utilized in the tensometer with the cross head speed of 1.5 mm/min. five identical test specimens were used for the testing and the average results were utilized. From the tensile test the tensile strength were calculated.

B. Tensile test after the immersion of distilled water

The hybrid natural fiber composites were immersed in distilled water in the time interval of 16 hrs. The total immersion of specimen in a bath of the test liquid under controlled room temperature conditions. After immersion of the specimens, the tensile test was conducted immediately by using tensometer setup. In order to prevent the infiltration of solution via the ends of the test specimens during immersion process, therefore the both ends were coated with polyester resin.

V RESULT

A. Tensile Properties without Water Treatment

The tensile properties were measured in various volume fractions such as 10, 20, 30 and 40% respectively; the tensile strength increases with increasing the fiber volume fraction up to 30% after increasing fiber content the tensile strength were reduced. The tensile strength versus volume fraction curve indicated that the maximum tensile strength was found at 30% volume fraction. Fig.5 shows the tensile strength of hybrid natural fiber reinforced composites. From this figure maximum tensile strength was 62.11 MPa at 30% of fiber volume fraction.

B. Tensile properties after the immersion of distilled water

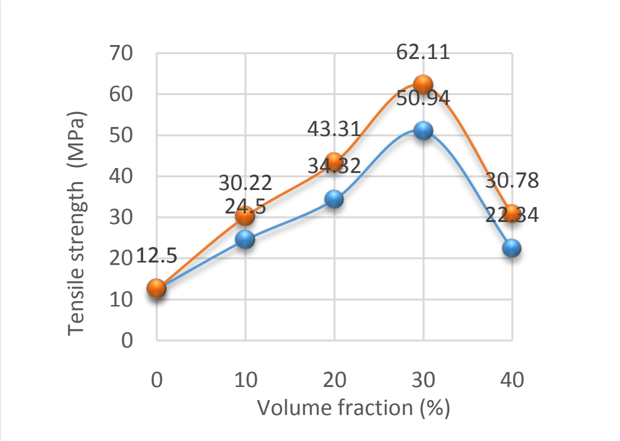

Fig. 6 Tensile Strength versus Different Fiber Volume Fraction Dry Condition

Dry condition

After water absorptions

Abbreviations

SF= Sisal fiber

MEKP= Methyl Ethyl Ketone Peroxide

After expose to distilled water the composite specimen tensile strength was decreased, initially up to 25% of original sample tensile strength has been reduced and it increases on further exposure to distilled water. The reason would be accounted that in the water environment, the water molecules have been enter rapidly into the inter phase of the capillary action. The fiber and matrix inter phase would be degraded by hydrolysis reaction of unsaturated groups within the resin. Deboning may be occurring at fiber and matrix inter phase, during that initial reduction of tensile strength take place. After some period of time the saturation stage was reached where upon no more water seeps into the composite. All the cracks and voids of the composites can be filled with water, which acts as a plasticizer and it can be favor of the tensile strength.

VI CONCLUSION

The hybrid natural fiber reinforced polymer composites have been prepared and the effect of water absorption was studied.

- The tensile properties were investigated on hybrid cotton/sisal fiber reinforced polyester composites by applying a tensile load on the specimen in electronic tensometer. During the tensile test the load versus displacement data was recorded for calculating the tensile strength of the composites.

- While increasing the volume fraction of the fiber the tensile strength and modulus gets increased upto 30% Vf . The maximum tensile strength value and modulus were found at 30% Vf that is the critical volume fraction of the composite.

- After water immersion, the tensile strength initially reduced up to 25% of original value, then increases on further exposure to distilled water.
- The experimental investigation reported that distilled water environment characterization of materials like composite was essential for their wide spread applications in engineering fields.
- Adding various additives in polymer matrix composites, which resist the various environmental conditions and that were important area of research.

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