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Characteristics of SFs and SF/Polypropylene (SFPP) Composites Reinforced with Aluminum Trioxide as Filler

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ABSTRACT

Global energy crisis and environmental pollution have compelled the scientists and engineers to develop alternative materials. The composite materials play a vital role as a substitute for the conventional materials. In particular, composites with natural fibre reinforcement will be environmental friendly. In this work, the locally available Sisal fibre (SF) is identified as a new natural fibre reinforcement. The current research has established the fact that SFs have not been characterized and it have not been utilised as reinforcement in composite materials until today. An attempt has been made to study the characteristics of SFs and SF/polypropylene (SFPP) composites reinforced with Aluminum trioxide as a filler. Fibre-reinforced polymer (FRP) composites are becoming popular materials for reinforcing and strengthening of structure. FRPs have high strength, light weight and excellent resistance to aggressive environments. FRPs materials, as is known, are influenced by environmental conditions such as freezing, thawing, moisture, temperature, solar radiation, and aggressive chemical agents that occur during their service life. The degrading effect of environmental actions on the mechanical properties of FRPs reduces the durability of structures. As a consequence, for an efficient use of FRPs as substitutes, an analysis of the durability of FRP materials considering all possible deteriorating conditions is necessary. One of the most important environmental factors affecting the durability of FRP is the moisture condition. The experimental investigations performed include Tensile, Flexural, impact and hardness tests of Sisal, polypropylene, Aluminium tri hydroxide. The mechanical properties tensile strength and bending strength determined from water exposure are compared with those of the unexposed laminated composites. The mechanical degradation is then analysed and discussed.

Keywords: *FRP, GRP***,** *polymer*

INTRODUCTION

Natural Fibre Reinforced Polymer Composite

The usage of natural fibres has found more interest among researchers due to their easy availability, high strength, low cost and more importantly their eco-friendly nature. Several types of natural fibres such as sisal, bamboo, okra, pineapple, jute, banana, coconut, Palmyra, flax, hemp and ramie are used as a reinforcement along with polymer matrix composites as reported by many researchers (Mathura, Saira Taj *et al.*, Alavudeen *et al.* [1]) and many have found their applications in automotive industries. [1-5]

The strength of all natural fibres and the fibre content depend on cellulose and lignin content. Depending on the type of the natural fibre, the cellulose content is in the range of 60–80 wt% and the lignin content is in the range of 5–20 wt%. In addition, the moisture content in natural fibres can be up to 20 wt%. Composite materials have been in use since biblical times when chopped straw was added to brick to' make building materials. The modern composite materials age began with the introduction of particulate or fibrous reinforcement material into thermoset phenolics in the early 1900s. Glass fibre was commercially produced for the first time in the USA in 1937. The first was made in 1942. Since then, there has been tremendous development in terms of new reinforcement materials, matrix materials and production methods. Fibre reinforced plastics (FRP), particular glass fibre reinforced plastics are meeting the demanding techno-economic requirements of various industries.[6-8]

Much of the early impetus to the development of composite materials (FRPs, GRPs) was on account of the needs of military aircraft during World War 11. The USA is the major consumer of coiriposite materials. In 1984, 11 million kg of Natural fibres have received much attention of the international research community over the past decade. Natural fibres are now considered as a serious alternative to glass fibres to be used in composite materials as reinforcing agents.

The advantages of natural fibres over glass fibres are their low cost, low density, high strength-to-weight ratio, resistance to breakage during processing, low energy content and recyclability. Since they are considered as waste, the utilization of such natural fibres as reinforcement for polyester composite is a best eco re-using technique.

A study on the structure, properties of the natural fibres and the fabrication, physical and mechanical properties of polyester-based composites are described in detail. Natural fibres as reinforcements in polymer matrix composites provide positive environmental benefits with respect to ultimate disposability and raw material utilization (Rajeev Karnani *et al.*). A number of thermoplastic and thermoset matrices are used for achieving the above mentioned target (Harikumar *et al.*). The best results have been obtained with polyester and some phenolic resins (Mishra *et al.*) and Singh *et al.*). In recent years, the natural fibres are attractive reinforcement in polymer matrix (Davies *et al.* [9-12]).

Manikandan *et al.* studied the mechanical properties of randomly oriented short palmyra fibre-reinforced composites and identified the critical fibre length and optimum fibre weight percentage of short Palmyra fibre polyester composites as 50 mm and 53%, respectively.

Sapaun *et al.* studied the tensile and flexural strength of treated coconut sheath fibre reinforced epoxy composites to assess this novel reinforcement.

The mechanical properties of randomly oriented short sisal fibre reinforced thermoset and thermoplastic matrix composites are reported based on its fibre length and fibre loading by Joseph *et al*. It is found that all the composites show an increase in mechanical properties with fibre loading. They have suggested that the critical length of the fibre varies with the type of matrix.

Flavio de Andrade Silva *et al* [15] studied the tensile behaviour of high performance natural (sisal) fibres. They extracted sisal fibres from sisal plant leaves by “decortication” process. The tensile fractography of sisal fibres was also performed by them. The properties of natural fibres depend upon the nature of the plant and locality in which it is planted. The age of the plant and the extraction method used are studied by Kuruvilla Joseph *et al*.

MATERIALS USED & DIMENSION

Materials Used

- Sisal Natural Fibre
- Polypropylene
- Aluminium tri hydroxide
- Nano silica
- Epoy Ly556
- HARDNER HY991

Matrix Material

The natural fibres were procured from Go-Green natural fibre, Chennai, India. Matrix material selected is epoxy resin grade LY556 and hardener grade as binder for the resin, composite fabrication and testing specimen's preparation was carried out at B.S. Abdur Raghman University, Chennai, India. Mechanical testing was carried out at METMECH Engineers Chennai, India. From the rule of mixture, it is predicted that the natural woven fibre fabric used in this investigation is 65% and the epoxy resin used is 35%. The pattern of woven fabric is of plain weave type and it offers high fabric integrity and dimensional stability.[13-15]

Composite Preparation

We used hand layup process for composite preparation. The advantage of using this process is that, it is very simple and easy. This process involves the mixture of resin and fiber in different forms as shown in Figure 3. In this study, Woven Sisal, jute and flax fibre were reinforced separately by alternative layers into epoxy resin grade Ly556 and the hardener grade Hy951 was mixed in a ratio of 10:1.

During the mixing of resin and hardener, Proper stirring was carried out. We employed careful attention to disperse the resin and the hardener into matrix. As the first layer, the Woven sisal fibre mat measures 300×300 mm was kept on the epoxy resin film coating on the entire surface of the fibre mat uniformly.

After that, woven flax fibre mat was kept as the second layer with the same dimensions, and the epoxy resin was applied and filled over the entire surface of the fibre mat, As the second layer, the Woven sisal fibre mat measures 300×300 mm was kept on the epoxy resin film coating on the entire surface of the fibre mat uniformly. After that, woven jute fibre mat was kept as the second layer with the same dimensions as shown in Figure 1.

The process was repeated by placing the woven sisal, jute and flax mats alternatively in between each resin coatings until a thickness of 3.2 mm was obtained in the laminates. To remove the air gaps, Rollers are used between the layers. Then the laminates were compressed for a curing of 24 hours.

STEPS INVOLVED TO FABRICATE THE SPECIMEN

- SISAL fiber and polypropylene is placed as layer by layer to form the specimen
- Hardener is mixed with the resin and it is mixed with the SF/polypropylene formatted fibers.
- Apply some wax all over the Polyester sheets to remove the fabricated job easily.
- Then, a coat of resin mixture is applied over the mold.
- The mixed fiber and chemical compositions are spread over the mold.
- Flatten the top surface of mold using a roller.
- Then cover the upper part with polythene sheet and keep the other aluminum sheet on it.
- Keep the counter weight over it.
- After 6 hours remove the plate from the mold by ramming it up.

- Follow the same procedure for fabrication of rest of the composites.
- Below pictures explains in detail,

Fig. 1: *Woven Sisal Fibre.*

SISAL FIBER [Figure 2]

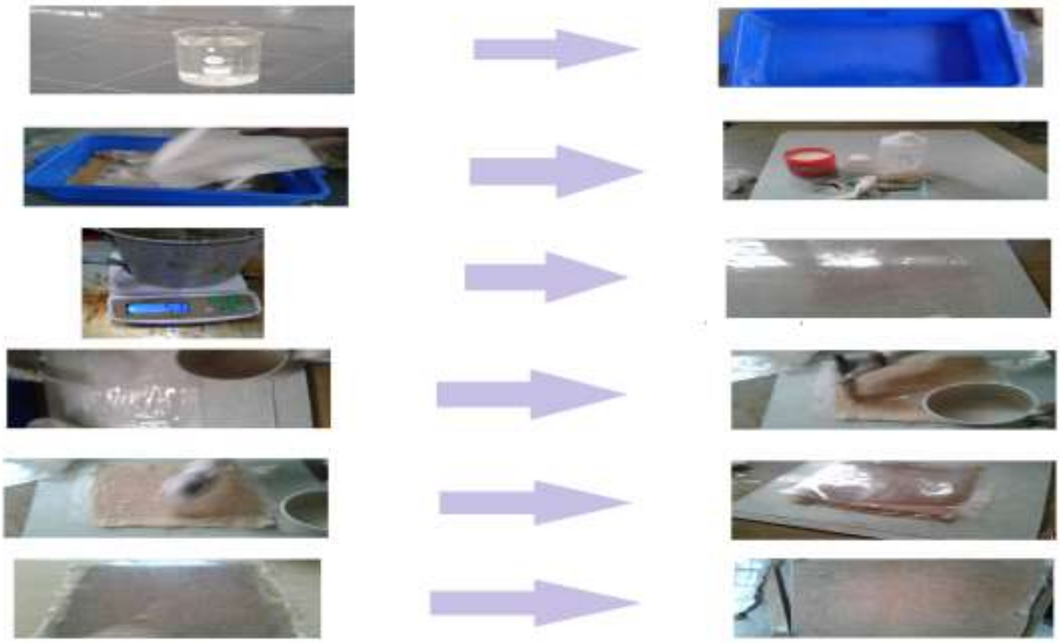

Fig. 2: *Specimen Preparation Steps.*

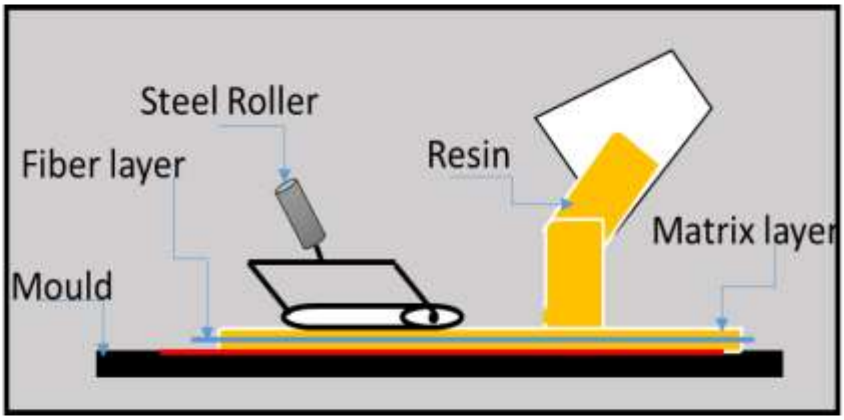

Fig. 3: *Schematic representation of Hand layup process.*

Sample code	**Type**	**Name of the Fiber**	**Reinforcement**	**Laminate Thickness(mm)**
S_1	SPP	1.5pp+ATH1,5+S1.5+nanosilica0.5 +resin95%	S/PP/A/S	3.2
S_2	SPP A1	2.5 pp +ATH2,5+S2.5+nano silica0.5 +resin95%	S/PP/A/S	3.4
S_3	SPP A2	5pp+ATH1,5+S1.5+ +resin95%	S/PP/A/S	3.3
S_4	SPP A3	0,5pp+ATH0.5+S0.5+ +resin95%	S/PP/A/S	3.2

MECHANICAL TESTING

The mechanical testing is carried out to understand the mechanical performance of the composites by using Universal Testing Machine (UTM) and impact tester. It will be explained in detail in this section.

- Tensile Test
- Flexural Test

Tensile Test

- Tensile strength is a measure of a material's ability to resist being pulled apart. The tensile test is generally performed by Universal Testing Machine (UTM) with the capacity-3T which is presented in Figure 4. The tests are done as per ASTM D 3039. Figure 4 shows the tensile test specimen.
- A thickness of 3 mm is maintained. A uni-axial load is applied through the ends. The tension test is performed on all the five samples and the average is taken.

Fig. 4: *Tensile test specimen.*

Flexural Test
The flexural test measures the force required to bend a beam under three point loading conditions.

A three point bend test is conducted for finding out the flexural strength of the specimen. A span of 50 mm is taken and cross head speed is maintained at 2 mm/min.

The attachment of 3-point bending is shown in Figure 5 Flexural tests are done as per ASTM D 790 and the specimens are shown in Figure 6.

The specimen has to be mounted only on the support so that, the centre of the specimen touched the point of application of load on the specimen. Load is applied on the specimen at a particular time as the breaking point of the specimen

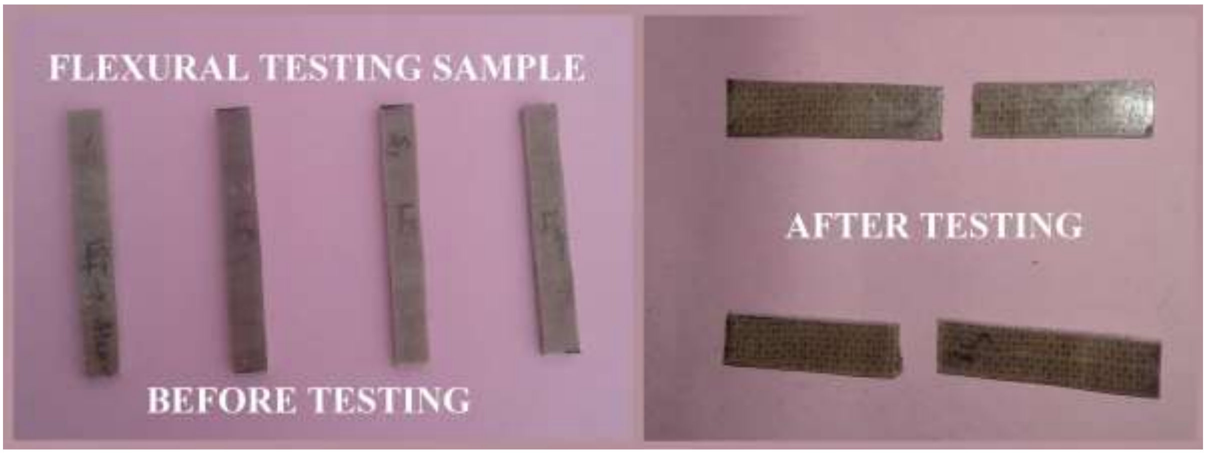

Fig. 5: *Typical flexural test specimens.*

SCANNING ELECTRON MICROSCOPY
The SEM images were collected from Carl Zeiss SUPRA 55 FESEM having resolution of 0.8 nm and the magnification factor ranges from 100 to 1000 k.

Figure 6 shows the SEM images of prepared samples from the tested specimens of the sisal, jute, flax and its hybrid composites which underwent tensile test of magnification factor 100.

The figures representing the fracture takes place in the matrix and fibre materials. As well as it shows the matrix fracture, crack, fibre pull outs and voids in many spots due to the applied tensile load in the composite specimens.

The SEM micrograph of tensile fractured specimen shows poor adhesion between the fibres and re-sin in both fractured and prepared specimens. Hence formation of cavities, voids and less interfacial strength is noted, so stress transfer mechanism will be low.

This affects mechanical properties. Hence the samples fail in fracture well in advance. So enough care must be taken in fabricating the composite by appropriate manufacturing method.

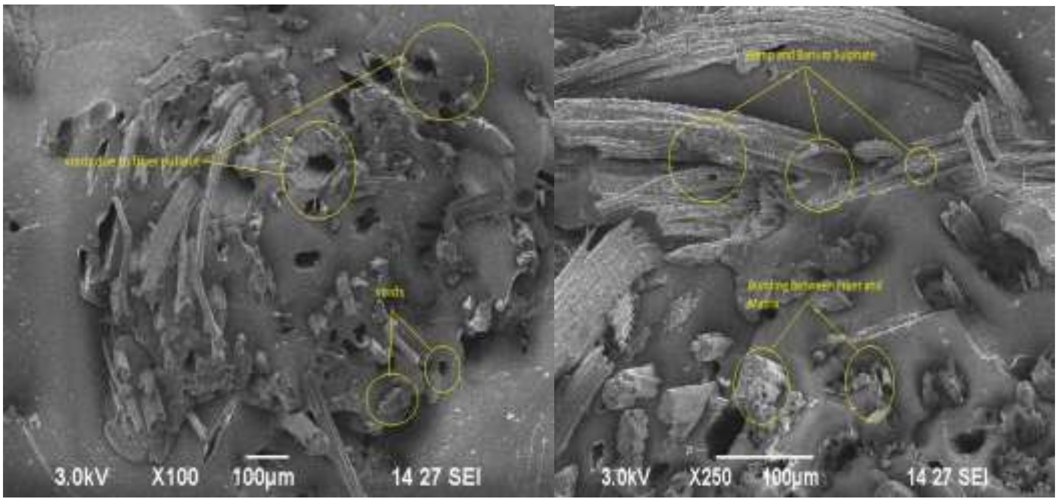

Fig. 6: *SEM images of (a) SF/polypropylene specimens.*

RESULTS AND DISCUSSION

The effect of chemical treatment on tensile strength and modulus of treated sisal/polypropylene fibre reinforced composites fabricated with higher curing temperature is shown in Figure 7 in which sisal/polypropylene fiber is subjected to different chemical treatments like alkalization, permanganate treatment, and silane to modify the surface and to remove the wax, hemicelluloses etc to make it a rough topography.

Among the chemically treated fibre composites fabricated with optimum conditions, $Ca(OH)_2$ treated composites show higher tensile strength of 55 MPa compared to all other treatments followed by $KMnO_4$ treated composites with a tensile strength of 50 MPa.

This may be due to improved polymerized network between the fibre and matrix holding them together compared with other treatments. During $KMnO_4$ treatment, an increase in porous nature of sisal/polypropylene fibre is compared with other treatments. Hence, the matrix tends to penetrate inside the porous of the fibre resulting in less fibre pull out. Manganese is highly reactive with polyester resin and makes good bonding strength between fibre and matrix.

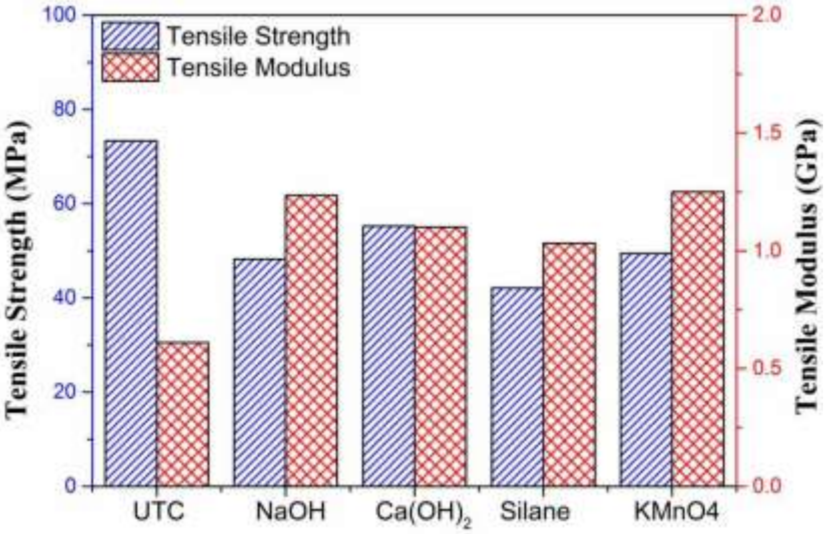

Fig. 7: *Different condition of composite.*

Flexural Strength [Figure 8]
The effect of chemical treatment on flexural strength and modulus of treated sisal, jute, flux fibre reinforced polyester composites fabricated with higher curing temperature. In flexural strength analysis, specimen is subjected to three point bending load. The upper and lower surfaces are subjected to bending stress and perpendicular to the axis of the plane is subjected to shear stress.

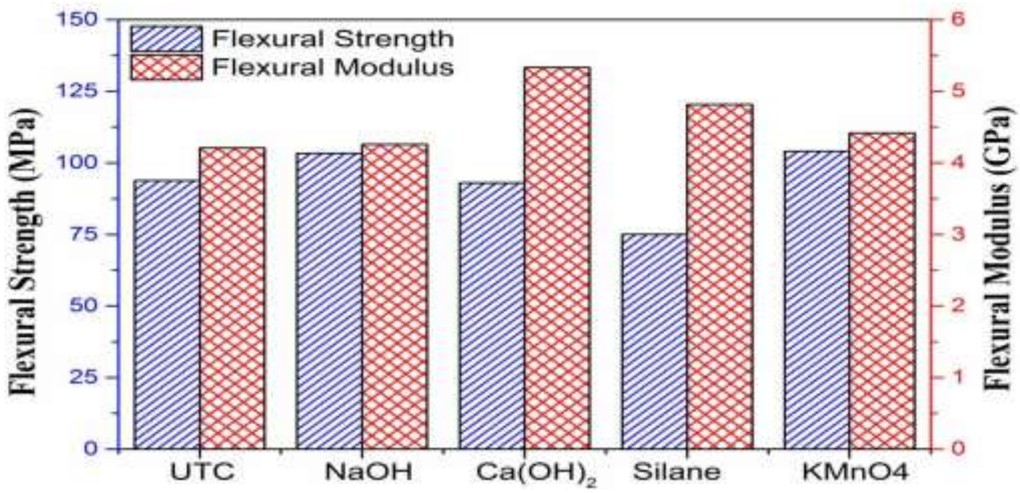

Fig. 8: *Different condition of composite.*

CONCLUSION
This chapter deals with the research findings of this present research work, limitation of the present research work and future scope.

- The SF/polypropylene fibre length, optimum weight percentage and optimum curing temperature are found to be 40 mm, 40 % and 60^0C, respectively.
- Superior SF/polypropylene mechanical properties are obtained for composites fabricated at 60^0C curing temperature for an optimum fibre length and fibre weight percentage of 40 mm and 40% wt.
- High modulus composites can be prepared using chemically treated fibres under optimum curing temperature conditions.
- Higher tensile modulus is exhibited by $KMnO_4$ treated composites and higher flexural modulus is shown by $Ca(OH)_2$ treated composites.
- The change in the magnitude of specific wear rate is observed in all the chemical treatments which could happen due to the improved adhesion and change in the morphology of fibre surface 5% filler of ATH.
- ATH Posses higher in the hybrid composites imparts greater strength to the composite structure.

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