International Research Journal in Global Engineering and Sciences. (IRJGES)
ISSN : 2456-172X | Vol. 7 Issue 4 - December 2022 to February 2023| Pages 42-50

SISAL-BASED FIBER-REINFORCED COMPOSITE FABRICATION AND TESTING OF ITS MECHANICAL BEHAVIOR

Dr. N. Abilash[1], Dr.R.Angeline Prabhavathy[2], Dr.Johnny Varghese [3], David Philip Daniel [4]
Professor, Mechanical Engineering, Annai Vailankanni College of Engineering- Pottalkulam
(e-mail: dean-academic@avce.edu.in).
Professor, Civil Engineering, Annai Vailankanni College of Engineering- Pottalkulam,
Asso.Professor, Mechanical Engineering, Annai Vailankanni College of Engineering- Pottalkulam.
Asst.Professor, Mechanical Engineering, Annai Vailankanni College of Engineering- Pottalkulam.

ABSTRACT

New technologies addressing environmental issues have garnered a great deal of attention lately. The continued availability of natural resources, such as natural fiber reinforced polymeric composite, is pushing the emerging industrial sector to look for and evaluate environmentally friendly materials. In the industry as a whole, the use of composites in manufacturing tools and goods is gaining significant traction. Furthermore, when these materials are examined independently of their constituents, they reveal special qualities. Nonetheless, it is well recognized that caution must be exercised throughout their creation due to the importance of fiber adhesion, the employment of suitable processes, and the composition of each component in determining the product's ultimate mechanical strength. Additionally, one should consider whether the composites are ecologically cordial. In order to improve the mechanical behavior of the specific product, a largely ecological composite was created in this work using sisal, a natural fiber with well-known mechanical qualities, as reinforcement in the dispersion phase of the composite in the polypropylene resin.

Keywords: *Natural fibres, FRP, Composites*

INTRODUCTION

Gay (1991) states that a composite is made up of many elements, is homogenous under a microscope, and can contain either long or short fibers, which are used in the material's reinforcing phase. The matrix, which serves as an agglutinant and encourages the reinforcement to operate cohesively to support the mechanical load, is another aspect of the composite (Pardini et al., 2006).Only with the development of structural composites were a number of recent technological advances made possible, especially those pertaining to pertinent applications in the fields of aeronautics, aerospace, petrochemical, shipbuilding, bioengineering, automotive, construction, and sporting goods (Levy, 2006).Numerous studies and efforts in the field of composites have been undertaken in the pursuit of sustainability in order to guarantee environmental preservation and offer a better standard of living to the society. Due to the vast range of potential species that may be studied, there is a growing body of study in this field that looks for ways to apply natural resources in the creation of materials. One such application is the use of natural fibers derived from vegetables. Almost every nation produces a variety of vegetable fibers, which are typically referred to as lignocellulosic materials. While certain fibers are produced naturally, others are cultivated as part of agricultural practices, and yet others are waste products mostly produced by the agro industry (Silva et al., 2009).

However, a number of variables, including age, type of soil, extraction technique, and weather, can have a significant impact on the structure, chemical makeup, and physical characteristics of plant fibers (Sydenstricker et al., 2003). As said, ligno-cellulosic natural fibers are nontoxic, lightweight, and can have high specific strength and elastic modulus. They also cost roughly ten times less than glass fiber and, in contrast to this inorganic fiber, inflict less abrasion damage to molds and equipment (Angrizani, 2006). One stands out among the other natural fibers when it comes to creating composite materials. Utilizing materials with good mechanical properties, such as tensile, impact, and others, in different polymer matrices, such as sisal, jute, hemp, ramie, palm, pineapple, sugarcane bagasse, wood fibers, and coconut fibers (Mochnacz et al., 2002).

Resin transfer molding, extrusion, injection, filament winding, lamination, and other composite forming techniques are only a few of the many ways that sisal fibers can be adapted to enhance their strategic value in the creation of novel composites. In addition to its many benefits, sisal is easy to grow and has the ability to modify the characteristic surface of vegetable fibers. sisal-reinforced composites exhibit a work of fracture resembling that of ultra high molecular weight polyethylene (UHMWPE) composites reinforced by fiber glass, and sisal's hollow helical microstructure accounts for a failure mechanism unique from that of other vegetable fibers (Amico, 2004). The use of natural fiber has drawn attention because it reduces environmental pollution and waste disposal issues, particularly in agricultural settings. As a result, it has a variety of uses in the engineering, electronics, and automotive industries (Goda et al., 2006). Green composites are biodegradable, renewable, sustainable, and kind to the environment. The majority of cellulosic fibers are harvested annually, and their supply ought to be endless in contrast to the restricted availability of other synthetic fibers. Additionally, natural fiber reinforced polymers have demonstrated a host of benefits, including superior electrical resistance, excellent thermal and acoustic insulating qualities, low weight, low cost, low density, high specific properties, and increased fracture resistance (Manfredi et al., 2006). Furthermore, because of their minimal maintenance requirements, natural fiber reinforced composites can reduce machine wear due to its low abrasiveness and absence of health hazardness during processing, application and upon disposal.

FIBRES AND ITS TYPES

Fibres are materials that resemble hair and are elongated, distinct bits that resemble thread. It is possible to spin them into thread. They are a valuable addition to composite materials. Man-made and natural fibers are the two primary categories into which fiber can be divided. In general, man-made fibers can be further classified into synthetic and natural polymers, whereas natural fibers can be further classified according to their source, such as plants, animals, or minerals. Natural fibers including cotton, wool, silk, flax, hemp, and sisal were the earliest materials that humans used. Glass was presumably the earliest material created by humans (Cooke, 1989) [2]. Presently, natural and synthetic fibers are accessible and frequently utilized as fillers to improve the qualities of composite materials. In the last ten years have seen a rise in interest in natural fiber reinforced composites due to its excellent mechanical performance, notable processing benefits, chemical resistance, and cheap cost/low density ratio. Compared to traditional reinforcing fibers, natural fiber offers more environmentally favorable options. Natural fibers offer several advantages over conventional ones, including lower costs, better specific strength characteristics, toughness, low density, reduced tool wear, improved energy recovery, CO_2 neutrality when burned, and biodegradability. Natural fibers have a lower bulk density and function as acoustic and thermal insulators due to their hollow and cellular structure. Three classifications apply to lingo cellulosic fibers: (1) wood flour particulate, which raises the composites' tensile and flexural modulus; (2) fibers with a higher aspect ratio, which, when used in conjunction with appropriate additives to control the stress transfer between the matrix and the fibers, enhance the composites' modulus and strength; and (3) long natural fibers, which are the most effective lignocellulosic reinforcements. Natural fibers with a high cellulose content and a low micro fibril angle—which results in good filament mechanical properties—have been thought to be the most efficient. Depending on their origin, the major classifications of fibres used nowadays are given in Fig 1.

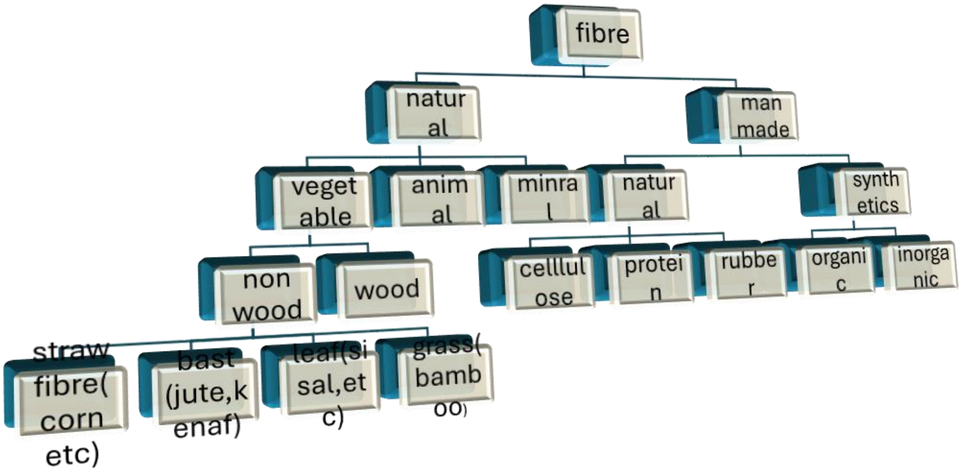

Fig.1 Fibre Classification

The ability of natural fibers to biodegrade increases the use of natural fiber reinforced polymeric materials in our daily lives, even if glass fibers also offer many benefits. Furthermore, the fact that this fiber is recyclable and has no abrasion or hazardous gas emissions demonstrates why NFRP composites have drawn the attention of contemporary businesses and academics.

SISAL

Sisal is highly valued for use in cordage due to its strength, durability, stretchability, affinity for particular dyestuffs, and resistance to degeneration in saltwater. Three grades of sisal are used by the industry. Because the lower grade fiber has a high proportion of cellulose and hemicellulose, it is processed by the paper industry. The medium grade fiber is utilized in the cordage industry to create ropes, balers, and binders twine. Ropes and twines are commonly utilized for seafaring, agricultural, and general industrial uses. The carpet business uses the higher-grade material that has been processed to create strands. Figs. 2 and 3 show the plant from which the leaves were taken and the extracted sisal fiber that was manually retted.

APPLICATIONS OF SISAL

Wall tiles and furnishings are among the many products made with resonant sisal. Recently, the offering was expanded to include auto interior parts.

Fig.2 Sisal fibre

Fig.3 Sisal plant

COMPARISON BETWEEN NATURAL AND SYNTHETIC GLASS FIBRES

Table.1 shows the various parameters that have to be monitored in natural and synthetic fibres, with considerable advantages while considering natural fibres.

Parameter	Natural fibre	Synthetic Glass fibre
Density	Low	High
Cost	Low	High
Renewability	Yes	No
Recyclability	Yes	No
Energy consumption	Low	High
Distribution	Wide	Wide
CO_2 Neutral	Yes	No
Abrasion to machines	No	Yes
Health risk	No	Yes
Disposal	Biodegradable	Not Biodegradable

Table.1 Properties of Natural & Synthetic Fibers

COMPOSITE AND ITS CLASSIFICATION

A composite material is one that combines two or more separate materials to create a material whose qualities are better to those of the individual materials that made up the composite. There are two major classifications of composites; they are (1).Natural composites and (2).Artificial or synthetic composites. Fig.4 and Fig.5 shows an example of natural composite and synthetic composite materials.

Fig.4 Wood

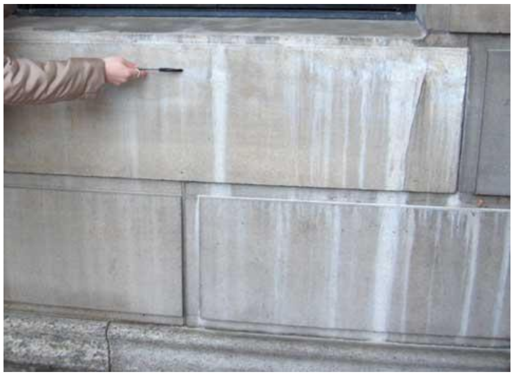

Fig.5 Concrete

BASIC CONSTITUENTS OF COMPOSITES

The two major constituents of composites are

- Matrix phase
- Dispersed phase which is clearly indicated in Fig.6

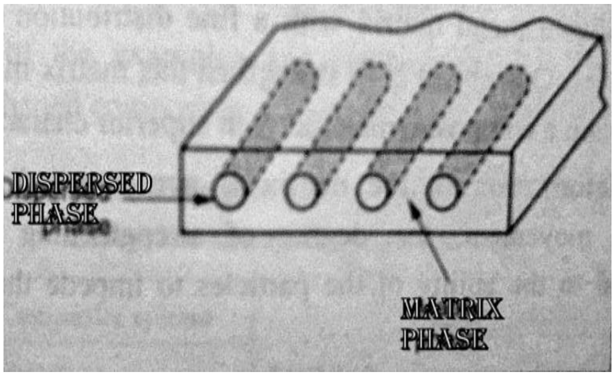

Fig.6 Constituents of composites

POLYMERS

The Greek words "poly," which means numerous, and "mer," which means parts or units, are the source of the word polymer. Therefore, polymers are made up of a huge number of monomers small molecules that repeat of one another.

APPLICATIONS

Typical applications of thermoplastic (PP) composite products in various sectors are listed in the **Table. 2**

ISO ABBREVIATION	POLYMER NAME	TRADE NAME	PROPERTIES	TYPICAL APPLICATION
PP	**Poly Propylene**	**Profax, Tenite, Moplen, Escon, propylux,**	**High strength, Excellent fatigue resistance, Light weight, Low cost**	**Used for buckets, bowls, toys, automotive parts, vacuum cleaner body.**

Table. 2 Applications of Thermoplastic (PP)

FABRICATION OF SISAL FIBRE POLYPROPYLENE COMPOSITE

Natural sisal fibre reinforced polymeric composite is fabricated by closed-mold system. Fig. 7 shows the individual view of male and female mold which is mainly used for composite fabrication. To make sisal fibre composite, the fibres are weighed according to the fibre volume ratio. To maintain homogeneity, the fibres are arranged systematically according to the weight. Firstly, the weighed fibres are divided into two groups and they are knitted together as like a fabric mesh which represents a layer. The procedures are repeated for the second layers. Both layers are separated by polymeric resin placed inside the mold die along with the additives before fabrication as explained below. First, the catalyst is measured for 0.9% of the resin volume, and the resin is measured based on the intended volume. Catalyst and resin are combined, then the mixture is swirled. To make sure the mold surface is wetted, a part of the mixture is poured into the mold. Next, without changing the orientation of the fibers, the first layer of fibers is softly deposited. To soak the fibers, a further quarter of the fluid is then poured. The air is removed with a trowel. The second layer of fibers is laid after another quarter of the liquid has been poured. Using a hydraulic press, the final quarter of the mixture is poured before the mold is closed and screwed. After 24 hours, the composite plate is taken out of the mold. We looked at how employing fiber results in a higher tensile module (E) and how this may be used to using the composite material in the application indicated above. (**Table. 2**), more effectively than the old one. Figure shows the compression molding setup used to fabricate the sisal reinforced polymeric composite.

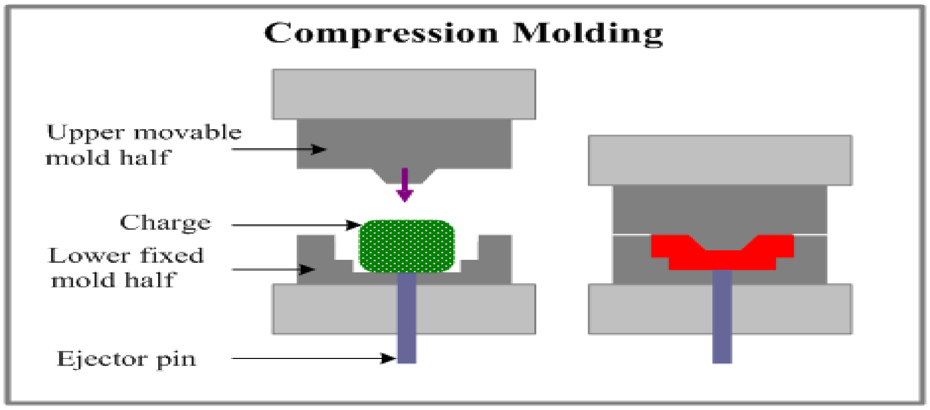

Fig.7 Compression Molding

TENSILE TESTING

A sample is put to uniaxial tension until failure in tensile testing, commonly referred to as tension testing, which is an essential materials science test. Test findings are frequently utilized for quality control, material selection for applications, and material behavior prediction under various stresses.

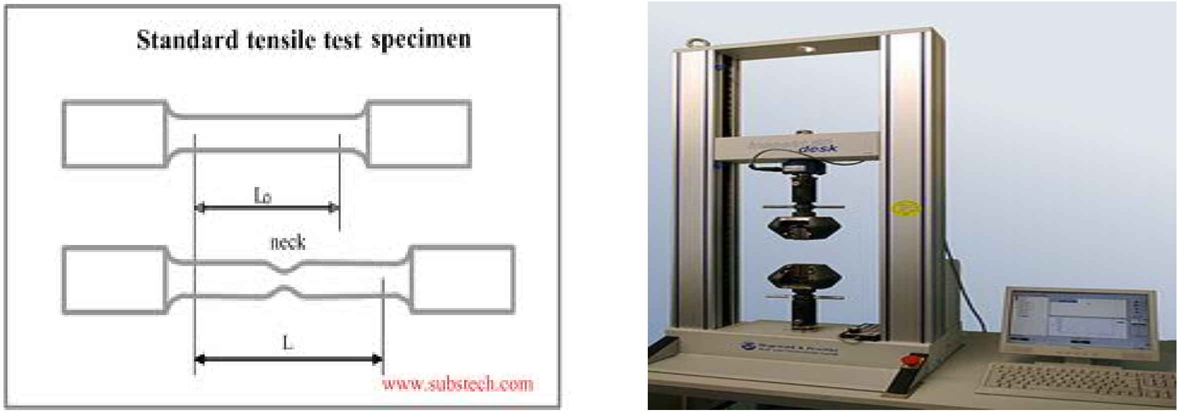

Fig.8 Tensile Specimen and Testing Machine

Tensile specimens composed of an alloy of aluminum. A standardized sample cross-section is called a tensile specimen. It has a gauge segment between each of its two shoulders as shown in Fig.8. While the gauge section has a smaller cross-section to allow for deformation and failure, the shoulders are big enough to be easily grabbed. *The following Table.3 give examples of test specimen dimensions and tolerances per standard ASTM E8.*

Flat test specimen

All values in inches	Plate type (1.5 in. wide)	Sheet type (0.5 in. wide)	Sub-size specimen (0.25 in. wide)
Gage length	**8.00±0.01**	**2.00±0.005**	**1.000±0.003**
Width	**1.5 +0.125 -0.25**	**0.500±0.010**	**0.250±0.005**
Thickness	$0.25 < T < \frac{3}{16}$	$0.005 \leq T \leq 0.25$	$0.005 \leq T \leq 0.25$
Fillet radius (min.)	**1**	**0.25**	**0.25**
Overall length (min.)	**18**	**8**	**4**
Length of reduced section (min.)	**9**	**2.25**	**1.25**
Length of grip section (min.)	**3**	**2**	**1.25**
Width of grip section (approx.)	**2**	**0.75**	**⅜**

Table.3 Test specimen dimensions and tolerances

Figure 9(a) and (b) shows the composites' Young's modulus and ultimate tensile strength as a function of fibre volume fraction, respectively for both L and T tensile samples. The results for randomly oriented composites, reported in a previous work, are also included in this figure for

$$\sigma_t = \frac{F_{max}}{A}$$

comparison. Irrespective of sample orientation, an increasing trend of Young's modulus and tensile strength with fibre content was found. The observed improvement of the ultimate properties suggests that some kind of interaction between the reinforcement and the polymer matrix exists.

Tensile stress

Where, A- cross sectional area in mm2 and Fmax- maximum load in N

Young's modulus $E = \frac{\Delta\sigma}{\Delta\varepsilon}$

Where, Δб= the change in the tensile stress
Δϵ=the change in the tensile strain

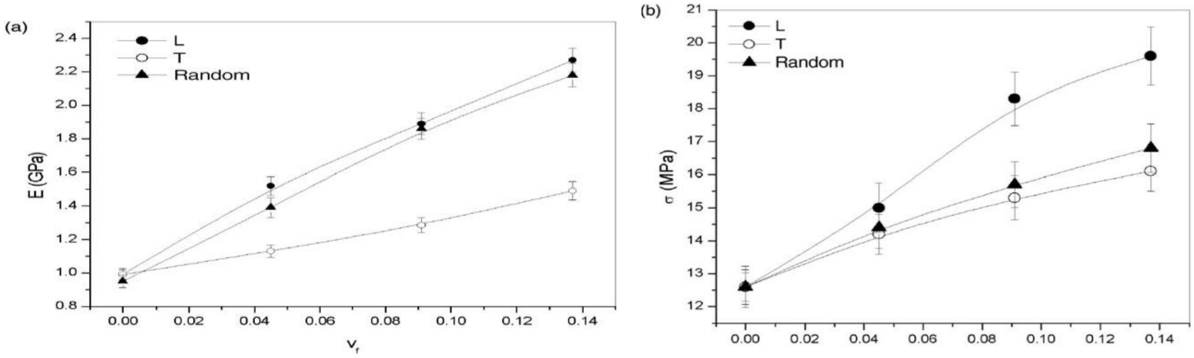

Fig.9 (a) (b) Young's modulus and ultimate tensile strength

L sample gives effective young's modulus and ultimate tensile strength which is shown in the Table 4, so we preferred the L sample for the usage. Figure 10, shows the material which we fabricate for the testing.

Sl.no	Young's modulus (GPa)	Volume fraction Vf	Ultimate tensile (MPa)
1	0.92	0.00	12.5
2	1.5	0.045	15
3	0..9	0.9	18.5
4	22.7	0.137	19.5

Table.4 UTS of L sample
Fig.10 The Fabricated Sample

CONCLUSION

When compared to synthetic fibers, natural fibers appear to have more advantages over man-made fibers, particularly in terms of cost, environmental effects, and high specific modulus. By giving the natural fibers chemical or physical treatments, the disadvantages can be partially mitigated. Over the past few decades, numerous trials and tests have been documented. Thanks to developments in materials science, treated fibers have been successfully included into most composites. By adding the right amount of fiber, the sisal reinforced polymeric composite with the laminates reduces the likelihood of delaminating failures and significantly increases the tensile module. This provides a promising avenue for carrying out additional research in the characterisation of this combination.

SCOPE FOR FUTURE WORK

- A great deal of room remains for further research after this study. It can be expanded to include more recent composites with different reinforcing phases, and the experimental results obtained can then be examined.
- There has been far less research done on the tribological evaluation of coconut fiber reinforced epoxy resin composites. Future researchers have a great deal of room to explore in this field. Further research is needed on a number of additional elements of this issue, including the impact of fiber orientation, loading patterns, and the weight percentage of ceramic fillers on the wear response of such composites.

REFERENCES

[1]. Abilash, N., et al. (2011). Evolution of experimental study on bamboo-based FRP composites. *International Journal of Advances in Science and Technology*, 3, 47-65.

[2]. Grozdanov, A., et al. (2007). Rice straw as an alternative reinforcement in polypropylene composites. *Australian Journal of Crop Science*.

[3]. Rao, K. Murali Mohan, et al. (2010). Extraction and tensile properties of natural fibers Vakka, date, and bamboo. *Materials and Design*, 31, 508-513.

[4]. Herrera-Franco, P.J., et al. (2005). A study of mechanical properties of short natural fiber reinforced composites. *Composites: Part B*, 36, 597-608.

[5]. Ghavami, K. (2005). Bamboo as reinforcement in structural concrete elements. *Concrete Composites*, 27, 637-649.

[6]. Netravali, A.N., et al. (2003). Composites get greener. *Elsevier Science*.

[7]. Valadez-Gonzalez, A., et al. (1999). Effect of fiber surface treatment on the fiber matrix bond strength of natural fiber reinforced composites. *Composites Part B*, 30, 309-320.

[8]. Chand, N., et al. (2007). High stress abrasive wear study on bamboo. *Wear*, 262, 1031-1037.

[9]. Wambua, P., et al. (2003). Natural fibres: can they replace glass in fibre reinforced plastics? *Composites Science and Technology*, 63, 1259-1264.

[10]. Hardin, I.R., et al. (2009). An assessment of validity of claims for bamboo fibers. *AATCC International Conference*.

[11]. Coutts, R.S.P. (1995). Autoclaved bamboo pulp fiber reinforced composites. *Concrete Composites*, 17, 99-106.

[12]. Amada, S., et al. (2001). Fracture properties of bamboo. *Composites: Part B*, 32, 451-459.

[13]. Zhang, J.Y., et al. (2001). Residual properties of reformed bamboo. *Composite Science and Technology*, 61, 1041-1048.