Abyss. J. Engg. & Comput. Vol. 1, No. 2, 2021, 47-53


Abyssinia Journal of Engineering & Computing

# Ethiopian Sisal fiber and Unsaturated Polyester Composite Panel Fabrication to Characterize Flexural Properties for Future Opportunities in Car Body Applications

**[a*]Hailay Kidane**

[a]*Department of Textile Engineering, Kombolcha Institute of Technology, Wollo University Kombolcha, P.O. Box 208, Kombolcha, Ethiopia*

**ABSTRACT**

Ethiopian Sisal fibers were extracted manually and treated with alkali to enhance fiber and matrix adhesion. Sisal fibre reinforced unsaturated polyester composites were devolved by hand lay-up techniques. Sisal fibers bundle strength has been tested by pressley strength tester machine. Average bundle strength of the fiber was 67.12g/ tex. The fibers maturity % was 15.82. Sisal fibers have been oriented by using mini card machine, where it's aligned in parallel way and stitched by using conventional sewing machine. The sisal fiber reinforced unsaturated polyester composites have been made with different ply arrangements such as unidirectional arrangement ($0^o{}_4$), ($90^o{}_4$), and cross ply orientations ($0^o/90^o$) $_{s.}$ All the test samples were prepared as per the ASTM standards. The experimental results showed that the flexural strength of 57/43 % by volume ratio of sisal fiber reinforced polymer composites with axial directional arrangement ($0^o{}_4$) gives better results, which is 37 N/mm$^2$. Sisal reinforced unsaturated polyester resin composite shows better mechanical properties applicable for car body applications.

***Keywords:*** Sisal fiber; Unsaturated polyester; Composite; Unidirectional; Flexural strength

## INTRODUCTION

Land Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix) [1].

There are a number of advantages of using sisal fibers in bio-composites, among which are: a) sisal fiber will make the material partially biodegradable; b) glass fiber is relatively expensive to make; c) sisal fiber is currently cheap and most available; and d) sisal has high tensile strength [2].

The scientific name of sisal plant is Agave. This plant is belonging to southern Mexico, but nowadays it is cultivated all over the world. The fiber is obtained from its leaves. In terms of production, sisal occupies the 6$^{th}$ place among fiber plants, Sisal fiber Representing 2% of the world's production of plant fibers, and it accounts for about 70% of the world's hard fibers.

***Corresponding author: hailaykidane@gmail.com**

The main producers are in Africa: Angola, Ethiopia, Kenya, Madagascar, Mozambique, South Africa and Tanzania; and in Latin America: Brazil, Haiti, Jamaica, Venezuela; and in China [3].

Chopped sisal fiber with epoxy composite were fabricated using different weight ratios and studied effect of orientation on flexural, hardness and physical properties. Diameters range from 5 mm (0.0002 in.) to 20 mm (0.0008 in.). The diameter of a glass fiber is in the range of 5mm to 25mm [2].

Among most natural fibers, the sisal fiber has the special properties such as Low density, light weight structures, high energy absorption; comparatively high modulus can be used in car body applications (Table 1). They are very well resistant against heat. Sisal short fibres delay restrained plastic shrinkage controlling crack development at early ages [3 & 4].

Sisal fiber is an important agricultural product used in the manufacture of ropes, rugs and also as a reinforcement of polymeric or cement-based composites [5].

**Table1. Chemical composition of sisal fiber[3]**

| Chemical Property | % |
|---|---|
| Moisture | 11 |
| Ash | 0.8 |
| Lignin | 10 |
| Hemi cellulose | 11.2 |
| Cellulose | 56 |
| Wax | 2 |
| Pectin | 9 |

The sisal plant has a 7–10-year life-span and typically produces 200-250 commercially usable leaves. Each leaf contains an average of around 1000 fibres. The fibre element shown in figure 2, which [2] accounts for only about 4% of the plant by weight, is extracted by a process known as decortications [6].

A matrix material fulfills several functions in a composite structure, most of which are vital to the satisfactory performance of the structure. Fibers in and of themselves are of little use without the presence of a matrix material or binder.

The most common resin materials used in thermo set composites are epoxy, polyester, vinyl ester, phenolics, cyanate esters, bismal eimides, and polyamides.

Several types of polymers have been used as matrices for natural fiber composites. Most commonly used thermoset polymers are epoxy resins and other resins (Unsaturated polyester resins (as in fiberglass) [2].

Polyester resin is durable, comparatively inexpensive, has superior corrosion resistance, has good range of mechanical properties, 4413, which is a general-purpose polyester resin is used as matrix material. Resin ECMALON 4413 is of pale yellow color of 500-600 CPS Viscosity (Brookfield Viscometer) 1.13 grams/c.c. of Specific Gravity [1].

A hand lay-up process is carried out by manual laying the performs and thickness of the composite part is built up by applying a series of reinforcing layers and liquid resin layers.[7] .glass-sisal composite was fabricated by hand layup process and their shear, de lamination and hardness are tested and result shows that composite with 50:50 E-glass and sisal has good mechanical properties [8].

A roller can be used to squeeze out excess resin and create uniform distribution of the resin throughout the surface. By the squeezing action of the roller, homogeneous wetting is obtained. The composite is then cured mostly at room temperature and, once solidified; it is removed from the mold.

Hardness increases with increase in the ratio of glass-sisal fibre content in the glass-sisal hybrid composite [8].

Since the fibers come from stem, less energy is required to process the leaves to get the fibers.[10].Sisal fibre agave American fibre has the ff Chemical composition [10].

The application of natural fiber reinforced polymer composites and natural-based re- sins for replacing existing synthetic polymer or glass fiber reinforced materials in huge [11 & 12].

New materials that would be cheaper and at the same time offer equal or better properties have to be developed. We have enough natural resources and we must keep on researching on these natural resources. Development of plant fiber composites has only begun. Among the various natural fibers such as, sisal fibers, bamboo fibers, coir fibers and jute fibers are of particular interest as these composites have high impact strength besides having moderate tensile and flexural properties [3].

Among the various natural fibers, sisal fiber reinforced composite, is selected to this study due to its availability.

## MATERIALS AND METHODOLOGY

### Unsaturated polyester Resin (GP resin)

The resin used for this study is GP Resin with product name of OCPOL-711N (GP RESIN) which is purchased from Addis Ababa, Ethiopia.

### Hardener (catalyst) of unsaturated polyester

Polyester resin is cured by adding a catalyst, which causes a chemical reaction without changing resin. The catalyst initiates the chemical reaction of the resin and monomer ingredient from liquid to a solid state the curing agent applied in this work for the liquid Gp resin is hardener with brand name of MEKP (MetthlEthyl Keton Peroxide) purchased from Addis Ababa, Ethiopia.

### Sisal fibre

Suitable quantity of sisal plant leaves was collected, after cutting at their base from the harvest. The fibers are extracted through hand extraction with knife. Initially the leaves trimmed in longitudinal direction into strips for ease of fiber extraction. The peel is clamped between the wood plank and knife and hand-pulled through in longitudinal direction gently, removing the resinous material (Fig 1).

**Fig 1. Sisal fiber extracted**

**Sisal fiber treatment with alkali**

The extracted fibers were washed with pure water in order to loosen, and separate the fiber until individual fibers are obtained and extracted fibers are sun-dried which whitens the fiber. Once dried, the sisal fibers are again treated by NaOH at PH 11.4 for betterment of fiber matrix bonding and finally ready for fabrication of test pieces.

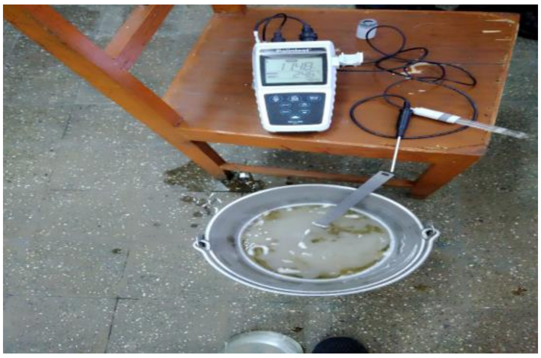

**Fig 2. Surface modification process**

In this research, 1:10 solution is prepared by normal water by adding 11 ml of sequestering agent to the water solution at temperature of 25ºC and a 1:1 MLR of NaOH solution was used to treat the raw Sisal fibers, in order to modify their fiber structures. During this process sisal fibers were taken in tray, to these trays 5.38 ml of NaOH solution was added, the fibers were soaked in for 2 hours, at room temperature to remove fatty impurities (Fig 2). The fibers were then washed thoroughly with water to remove the excess of NaOH sticking to the fibers. Lastly, the fibers were allowed to dry.

**Sisal fiber mat preparation**

Sisal fibers is washed, and dried in sun light then individually aligned by using mini card. According the mass fraction, and prepared the mat form. $0^o/0^o/0^o/0^o$ means that( $0^o)_4$ similarly for all other systems is denoted. four layer of the mat is used to fabricate one sample (Fig 3).

**Mold preparation**

ASTM D 5687/D 5687M – 95 was used as a guide line composite fabrication process. The mold is made up of mild steel of 250 mm X 250mm area. The plate is very thick plate which is placed bottom and top which sandwiched the composite inside. Polypropylene sheet plastic is laid on the female mould (bottom plate) then little resin was spread overall then place the sisal preformed mat according to each degree of orientation in 4 layers for one sample. Then pour small quantity of mixture between each layer of the sisal perform. Then we press the mold on press machine for consolidation and the sample is then left for 24 hours. The composite gets dried up in 24 hours in which the sisal fiber and the polymers adheres itself tightly in the presence of hardener. After a day we put out the mould from the press machine. Then the mold steel lower attachment (plate) is slowly and gently hammered on the boundary of its attachment when the top plate and the composite separate out. Then carefully plastics are removed from the steel mold.

**Fig 3. Fiber alignment and mat making process**

**Table 2. Sisal fibre reinforced unsaturated polyester composite with different ply orientation**

| Orientation of laminates | Volume fraction | | Volume($cm^3$) | | Total Volume($cm^3$) | Thickness (mm) |
|---|---|---|---|---|---|---|
| | GP resin (%) | Sisal (%) | Sisal | GP resin | | |
| $(0^o)_4$ | 42.49 | 57.5 | 108.27 | 79.22 | 187.5 | 3 |
| $(90^o)_4$ | 42.49 | 57.5 | 108.27 | 79.22 | 187.5 | 3 |
| $(0/90)_4$ | 42.49 | 57.5 | 108.27 | 79.22 | 187.5 | 3 |

### Matrix preparation

GP resin is mixed with hardener called MEKP (Metthl Ethyl Keton Peroxide) is used to prepare the composite plate. The weight ratio for mixing ***unsaturated polyester*** and hardener is 10:1. The mixer is strewed with stirrer for about one minute continuously. The mixing is performed in the mixing containers (Bowl) the bowl is made of Nickel to unsaturated polyester resin composites. The composite specimens were prepared in a mold cold compression method. Unidirectional and bidirectional performs were used to prepare the samples. Gp resin and hardener were taken in a steel bowl then mixed well and made ready for layup reinforced sisal fiber. The composite samples were fabricated by hand lay-up technique (Table 2).

### Compression and curing

5 Mpa of force was kept above the mold and it requires 24 hours for curing at room temperature. After curing period, the sisal fiber polymer matrix was removed from the moulds (Fig 4). The prepared composite ceiling boards were post cured and performed for its mechanical properties.

### Flexural stress (ASTM D790)

Flexural strength is defined as a materials ability to resist deformation under load. Flexural test is measured by Zwick Roll tester. It is a 3-point bend test, which generally promotes failure by inter-laminar shear. Test is conducted as per ASTM D790 standard. The loading arrangement is shown in *figure below*. The dimension of the specimen was (250x50x3) mm. The flexural strength is expressed as modulus of rupture (MR) $N/mm^2$ or Mpa.

### Sisal fiber fineness tester

This instrument works by electronic way and it helps to determine the fiber micronier value and maturity %. 2.5 gram of sisal fibre is feed to the instrument and the result will print out in this instrument. Higher the micronier value shows the fiber is mature and strong. Five samples were taken for the test. Micronier is a measure of fiber fineness and maturity. An air flow instrument is used to measure the air permeability of a constant mass of the fiber.

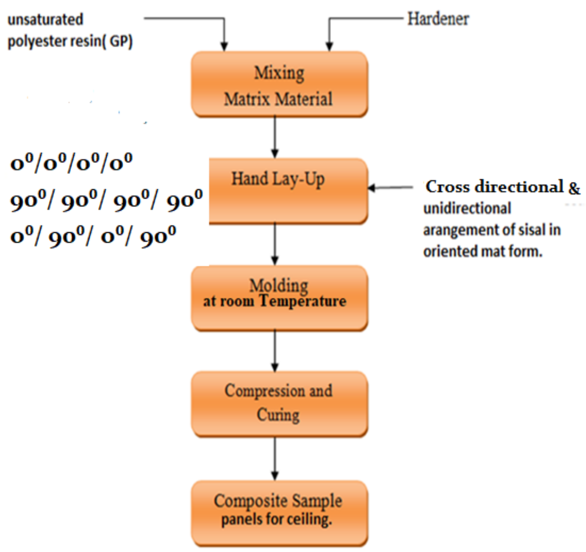


**Fig 4. Schematic diagram composite development**

## RESULTS AND DISCUSSIONS

### Sisal fiber bundle strength and fineness test

After sisal fiber are extracted and treated with NaOH the sisal fibre was tested its fineness value and bundle strength by using WIRA Tester machine and Preslay fibre strength tester respectively in Kombolcha Textile Share Company. The tests were conducted at a standard laboratory atmosphere of $23^0C$ and 50% relative humidity.

From Table 3 the sisal fiber has initially higher strength and very mature. The overall composite property is then depending on the strength of the sisal fiber and the properties of the matrix we used. That is why the final composite strength is good enough to resist about 37 Mpa.

**Table 3. Sisal fiber bundle strength and fineness test result**

| Test | Bundle strength | | | Fineness of sisal fibre | |
|---|---|---|---|---|---|
| | Force(N) | Wight (mg) | Breaking strength (g/Tex) | Micronier | Maturity % |
| 1 | 18.5 | 2.58 | 71 | 15.82 | 10.75 |
| 2 | 19.1 | 2.78 | 68.27 | 16.71 | 10.96 |
| 3 | 17.9 | 2.13 | 83 | 15.78 | 10.65 |
| 4 | 19.6 | 2.88 | 67.6 | 15.40 | 10.32 |
| 5 | 18.8 | 2.6 | 71.8 | 16.66 | 10.81 |
| Average | 18.78 | 2.59 | 72.05 | 16.06 | 10.70 |

**Flexural test (Three Point Bending Test)**

The flexural test measures the force required to bend a beam under three-point loading situations. The data is often used to select elements for parts that will support loads without inflection Flexural modulus is used as an indication of a material's stiffness when inflection. Average flexural stress value of the design for $0^0/0^0$,$90^0/90^0$, and $0^0/90^0$ sisal and unsaturated polyester resin composite panel were tested. It is observed that, the sisal composite with unidirectional arrangement were higher flexural strength than the other orientation direction. The sample graph of flexural strength observed for the sisal–unsaturated polyester composites. The result indicated that the maximum applied load up to around 37 N/mm$^2$, after that it tends to decrease. The load for different composites tested. The specimen of flexural test size was 2505x50x3mm and the span of flexural test is 80mm.

**Effect of orientation on flexural strength**

37,34,29 and 14 N/mm$^2$ flexural stress is observed from in 0°/0°/0°/0°, $0^0/90^0/0^0/90^0$, $90^0/90^0/90^0/90^0$ and existing panels respectively. The results indicated that from sisal–unsaturated polyester resin composites the maximum flexural stress is obtained in the longitudinal arrangement of fibers (Fig 5, Fig 6 & Fig 7).

Although the 0°/0°/0°/0° and $90^0/90^0/90^0/90^0$ are both unidirectional arrangements in 0°/0°/0°/0° arrangement the result is higher. This is due to the long sisal fibers were kept uncut and contribute to the strength of the specimen. Since it is known that long fibers have higher strength than short fibers.

The $0^0/90^0/0^0/90^0$ arrangement shows moderate result. The lower flexural stress in existing ceiling could be the bond b/n the wood particles is less. The existing ceiling is made up of particle board with the mixture of PVA as binding agent. The wood is converted to powder form and allow mixing it with binding agent and finally drying.

- This is may be due to good adhesion of fiber in unidirectional way than bidirectional arrangement.
- The second reason could be fiber is good strength if we measure length wise. The force is distributed in the fiber surface equally and enables to resist the break.
- High flexural stress in the new composite than the Existing maybe due to chemical treatment of sisal fiber.


**Fig 5. Flexural strength of the unidirectional system composites**

$0^0/90^0/0^0/90^0$ orientation of the composite mat form for flexural modulus response moderate value which is 34 this may be due to the 50% of the unidirectional composition in the specimen. For the orientation of the fibers, it was observed that the composite orientation of $90^0/90^0/90^0/90^0$ provided a lower flexural strength than the $0^0/0^0/0^0/0^0$ and due to the fibres at 90° are not positioned at the loading direction, chemical treatment enhances the flexural property of the fiber the treatment clears all the impurities that are adjoining the fiber and stabilize the molecular orientation [5].

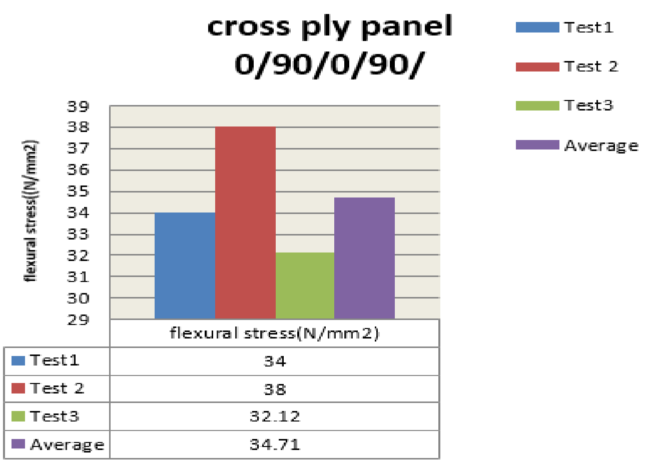


**Fig 6. Flexural strength of the bidirectional system composites**

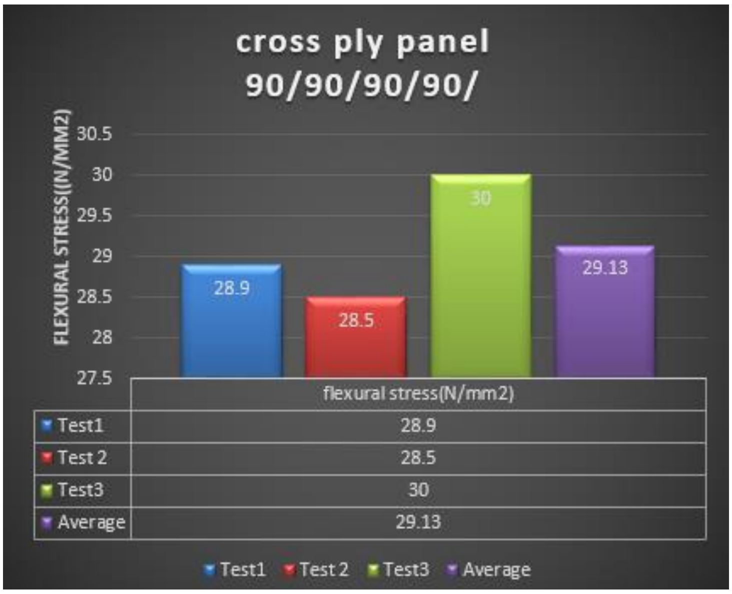


**Fig 7. Flexural strength of the bidirectional system composites**

The properties like flexural strength and inter-laminar shear strength are greatly influenced by the void content of the composites. It has been found that these properties reduced from 0 wt.% to 12 wt.% fiber loading and with the reduction in the void content from 12 wt.% to 48 wt.% the properties are improved [13].

Good adhesion between the fiber and matrix is responsible for the good resistance to crack propagation during impact test. The increased fiber content will increase the contact area between the fiber and matrix, if there is good impregnation of fibers in the resin. At higher fiber loading the impact transfer should be more efficient [6].

Alkali treatment responsible for the increased in flexural property. This is due to the fact that alkali treatment improves the adhesive characteristics of sisal fiber surface by removing hemi cellulose, thereby producing rough surface topography. This topography offers better fiber matrix interface adhesion and an increase in mechanical properties [2]. Developed sample in Fig 7.

**Fig 7. Developed composite**

**CONCLUSIONS**

Sisal fiber reinforced unsaturated resin composite material was successfully manufactured using hand lay-up technique. Sisal fibers bundle strength and maturity values were 72.05g/Tex and 10.70 % respectively. In the mechanical characterization tests, it observed that the sisal fibre reinforced composite material in unidirectional or in length wise direction ($0_4$) composite have a good mechanical performance (modulus rupture). However, Transverse directional (($90_4$)) composites have moderate mechanical properties. The graph of the bending strength shows some interrupted lines indicate elasticity nature of the composites. This shows that very good future applications for car body applications.

**REFERENCES**


[1] G. R Arpitha, M. R. Sanjay, P.Senthamarai kannan, C. Barile, and B. Yogesha, “Hybridization effect of sisal/glass/epoxy/filler based woven fabric reinforced composites,” Experimental Techniques, vol. 41, no. 6, pp.577-584. 2017.

[2] P. N. Khanam and H. P. S. A. Khalil, “Sisal / Carbon Fibre Reinforced Hybrid Composites: Tensile, Flexural and Chemical Resistance Properties,” Journal of Polymers and the Environment, vol. 18, no. 4, pp. 727–733, 2010.

[3] T. Sen and H. N. J. Reddy, “Application of Sisal, Bamboo, Coir and Jute Natural Composites in Structural Upgradation,” Int. J. Innov. Manag. Technol., vol. 2, no. 3, 2011.

[4] S. Mazumdar, “Composite manufacturing: materials,” product, and process engineering. CrC press. 2001.

[5] P.R. Lima, R.J. Santos, S.R. Ferreira and R.D. Toledo Filho, “Characterization and treatment of sisal fiber residues for cement-based composite application,”. *Engenharia* Agrícola, vol. 34, no. 5, pp.812-825, 2014.

[6] C.B. SBVJ, K. Arun and B. Eswaraiah, “Fabrication and testing of natural (sisal) fibre reinforced polymer composites material,”. International Journal, vol. 3, no. 5, 2015.

[7] V. Fiore, T. Scalici, L. Calabrese, A. Valenza and E. Proverbio, “Effect of external basalt layers on durability behaviour of flax reinforced composites. Composites Part B: Engineering,” Vol. 84, pp.258-265, 2016.

[8] G. Y. B. V. Ramnath, A. Abinash, B. Srivasan, and R. V. Nair, “Investigation of Mechanical Behaviour of Sisal Epoxy Hybrid Composites,” Indian Journal of Science and Technology, vol. 9, 2016.

[9] J.I.P. Singh, V. Dhawan, S. Singh and K. Jangid, “Study of effect of surface treatment on mechanical properties of natural fiber reinforced composites,” Materials today: proceedings, vol. 4, no. 2, pp.2793-2799, 2017.

[10] M. Kumaresan, S. Sathish, and N. Karthi, “Effect of fiber orientation on mechanical properties of sisal fiber reinforced epoxy composites. Journal of Applied Science and Engineering,” vol. 18, no. 3, pp.289-294, 2015.

[11] M. R. Sanjay, G. R. Arpitha, L. L. Naik, K. Gopalakrisha, and B. Yogesha, “Applications of natural fibers and its composites: An overview,” Natural Resources, vol. 7, no. 3, pp.108-114, 2016.

[12] V.Arikan and O. Sayman, “Comparative study on repeated impact response of E-glass fiber reinforced polypropylene & epoxy matrix composites,” Composites Part B: Engineering, vol. 83, pp.1-6, 2015.

[13] V. Mishra and S. Biswas, “Physical and Mechanical Properties of Bi-directional Jute Fiber Epoxy Composites,” Procedia engineering, vol. 51, pp. 561–566, 2013.


**Conflict of Interest**

The author declares no conflict of interest.