

Mechanical properties of sisal/ fiberglass reinforced composites

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Abstract—The use of plant fibers to replace artificial fibers such as carbon fiber or glass fiber is the subject of studies by many researchers today. Vegetable fibers are considered for their renewability, degradability, low toxicity and low cost. In this work, the mechanical properties of tensile and flexural strength and modulus of elasticity of hybrid composites of sisal fibers with glass fiber in an epoxy polymer matrix were evaluated. The fibers were treated in a 10% by weight sodium hydroxide solution and subjected to tensile tests in a universal testing machine according to the ASTM D3039 and D790 standards. The best performing composites were the sisal + fiberglass hybrids, at 86% for the tensile strength and 64% for the elastic modulus. In the bending tests the results showed a performance of 119% for the maximum stress and 138% in the greater breaking stress for the hybrid composites.

Keywords— sisal, composites, mechanical Properties, vegetal fibers.

I. INTRODUCTION

Natural fibers have been used in composites as substitutes for materials such as glass and carbon fiber for providing advantages such as low price, renewability, recyclability, low abrasiveness, biodegradability and low cost, low density (Bisaria, Gupta, Shandilya, & Srivastava, 2015; Braga & Magalhaes, 2015; Pickering, Efendy, & Le, 2016; F. M. R. do. Santos, Souza, Barquete, & Amado, 2016).

In addition, vegetable fibers are environmentally friendly and have less risk to humans during handling (Misra, Saw, & Datta, 2011).

Several natural fibers such as kenaf, jute, linen, sisal, have been studied for use as potential substitutes for synthetic fibers (Senthilkumar, Saba, Chandrasekar, Jawaaid, & Siengchin, 2018).

The main constituents of vegetable fibers are cellulose (C₆ H₁₀ O₅)_n classified as polysaccharide, lignin and pectin, in addition to other constituents to a lesser extent. Cellulose is a polymer composed of numerous glucose units (C₆H₁₂O₆)_n.

Composites are hybrid materials formed by combining components with different characteristics giving rise to a

new substance with different properties of the constituent materials (Cunha, Filho, Carlos, & Mota, 2018). In this composition, two distinct phases are evident. A matrix phase and a reinforcement phase, which is embedded in the matrix (Arpitha & Yogesha, 2017). Vegetable fiber-containing composites have been widely used in various applications in the automotive, marine and sports industries (Gopinath, Senthil Kumar, & Elayaperumal, 2014).

However, this combination is not always successful and to improve the compatibility between the compounds in a composite, treatments are needed to improve the adhesion between the polymer matrix and the reinforcement (Joseph, Thomas, & Pavithran, 1996).

In this work, they evaluate sisal fibers in a polymeric epoxy matrix, evaluating their mechanical properties of tensile and flexural strength.

II. THE SISAL FIBER

The fiber of sisal is obtained from the variety agave sisalana. Many studies have been carried out to improve the performance of sisal fiber in polymeric matrix composites. Rana et al (Rana, Ashish, Rana, & Purohit,

2017) analyzed varied levels of sisal in an epoxy matrix (0%, 2%, 4%, 6%) and the tensile strength improves above 4%.

Composites of sisal and epoxy, with fiber treatment with NaOH (18%), showed 110% improvement in tensile strength property (Padmavathi, Venkata Naidu, & Rao, 2012).

Fibers treated with sodium bicarbonate (10%) were used in epoxy matrix composites and showed better results in a 120 h treatment with better interfacial adhesion between the fiber and the resin (Fiore, et al., 2016).

III. MATERIALS AND METHODS

A medium viscosity epoxy resin code 969 MVORGIBX and epoxy hardener code 289 ORGBACMIBX, purchased from IBEX Químicos e Composites. As reinforcement, sisal fibers in the form of mesh purchased from the company SisalSul, fiberglass in the form of mesh and grass of 300 g / m², purchased from the company IBEX were used. For the treatment of fibers, sodium hydroxide (NaOH) J T Baker was used. The manufacturing and testing procedures will be discussed below.

3.1 Fiber treatment

The sisal tissue was washed with distilled water, dried in an oven for 24 hours, at 40°C. Then, it was immersed in a solution of 10% by weight of sodium bicarbonate in distilled water for 5 days at room temperature. After that, they were washed to remove excess solution and placed for drying for 24 hours (Fiore, et al., 2016). The next step was the preparation of the Composite. This treatment was applied to remove lignins, waxes and resins that covering the external surface of the fiber walls and to expose (better access) the hydroxyl groups (Essabir, XIa, Garcia, & Shi, 2018)

3.2 Preparation of composites

Composites were manufactured molded in a flat plate format in an epoxy matrix in the proportion 2: 1 resin / hardener with dimensions 250mmx20mmx4mm. composed with a layer of sisal fiber in bidirectional mesh.

In the hybrid composites, a layer of sisal mesh and two layers of fiberglass mesh were used, in the form of a sandwich, with the sisal in the middle of the reinforcement.

For the manufacture of the composite, the resin / hardener mixture was poured into a glass plate mold, a layer of fiberglass, then a layer of sisal fiber and then

another layer of fiberglass, again, resin / hardener for complete fiber coverage.

After molding, the composites remained at rest in the air for 24 h, when they were demoulded and later cut to make the specimens. Fig. 1 shows the composite ready to be cut.



Fig.1: Sisal fiber composite

3.3 Characterization

3.3.1 Mechanical tests

The tensile and flexion tests were conducted in a Time Group universal testing machine, model WDWEB according to ASTM D3039 and ASTM D790 standards. For the tensile test, the velocity of 2 mm / min was used and for the flexion tests, the three point flexion test speed was 2 mm / min, with a distance of 50 mm between the points.

3.3.2 Density

After being cut and sanded, the specimens were measured for dimensions of width and thickness, the masses were measured at a temperature of 24°C and the average densities of the specimens were calculated. Densities were calculated from measurements of dimensions of width, thickness and length. The width and thickness were measured with a pachymeter in three positions on the specimen defined at the ends and in the middle. The mass of each specimen was measured on a semi-analytical balance. The density was calculated according to the equation

$$D = \frac{m}{V} \quad (1)$$

where D is the density (g / cm³), m (kg) the mass of the and V (cm³) the volume of the specimen respectively.

IV. RESULTS AND DISCUSSIONS

4.1 Average densities

The average densities of the manufactured specimens are shown in Table 1

Table 1: Average density o specimens

	Sisal	Sisal+ Fiber Glass	Fiber Glass
Average density ρ (g/c m ³)	1.129±0.02	1,214±0.06	1.300±0.070

The average densities were obtained by calculating the ratio between the mass of the specimens and the dimensions of height, width and thickness of each of the tested specimens.

4.2 Tensile tests

The average results of the tensile tests are shown in Table 2. The values of maximum force applied to the traction (FM), maximum stress (TM), breaking stress (TR) and module (E) are shown.

Table 2: Average results of tensile tests

	FM (kN)	TM (MPa)	TR (MPa)	E (GPa)
Sisal	1.939±0.096	25.756±1.005	22,384±3.392	2,270±0.275
Sisal+Fiber glass	3.712±0.392	44,847±8.718	41,718±8.748	3,733±0.958

The tests showed that hybrid sisal fibers with glass fiber performed better than composites with only sisal fiber in the polymeric matrix. The maximum force supported by the hybrid specimen was 91.4% greater than the non-hybrid

The maximum stress was 74% higher in the hybrid specimen.

Breaking stress was 86.4% higher in hybrid specimens. The module was 64.4% higher in the hybrid composite of sisal + fiberglass.

Fig. 2 shows the graph of average tensile stresses versus strain for composites of sisal and hybrid sisal with fiberglass and composites with only fiberglass.

The graph shows that the hybrid composites had greater tensile strength

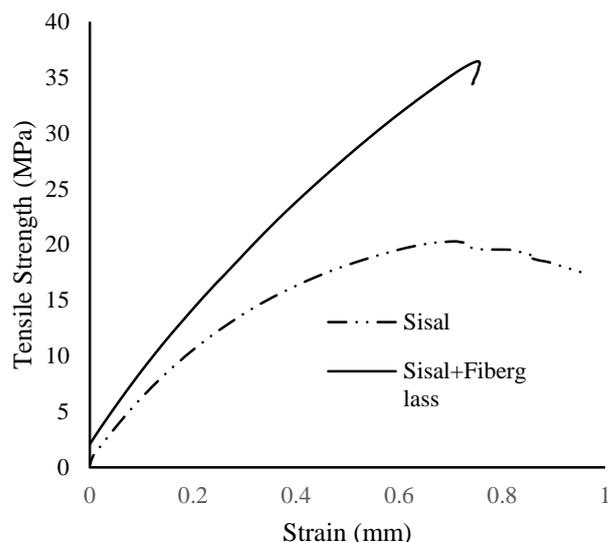


Fig.2: Stress x deformation of the tests of sisa and sisal fiber + glass fiber composites.

4.3 Bending tests

The average results of the flexion tests are shown in Table 3 below:

The results show that hybrid specimens performed better than non-hybrid composites. The maximum strength (FM) for the fiberglass composite had an increase of 148%, while in the maximum stress (RM) the increase was 119%. The tensile strength was 138% higher than non-hybrid composites.

Table 3: Average bending test results

	FM (kN)	RM (MPa)	RP (MPa)
Sisal	0.165±0.029	1.926±0.280	1.143±0.187
Sisal+Fiberglass	0.410±0.020	4,236±0.270	2,722±0.186

In Fig. 3, the graph of the average bending stresses is presented for the composites of sisal, sisal with fiberglass and composites with only fiberglass. It is observed that, in the case of bending stresses, composites with sisal hybrids with fiberglass performed better than other types of composites.

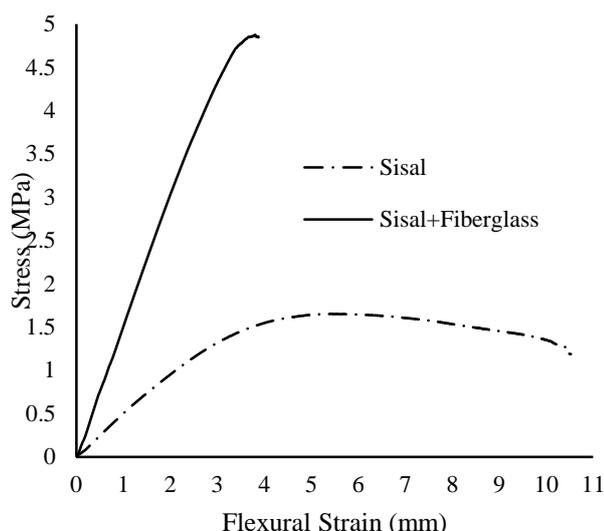


Fig.3: Resultados dos ensaios de flexão de corpos-de-prova compostos com sisal, sisal + fibra de vidro.

V. CONCLUSIONS

Vegetable fibers have reappeared as important substitutes for fiberglass and carbon in several economic sectors. This work aimed to analyze the mechanical properties of composites containing sisal fiber in a polymeric epoxy matrix, compared with a hybrid composite containing sisal fiber with glass fiber. The results showed that hybrid composites containing sisal and fiberglass performed better in the tensile and flexion tests and modulus of elasticity than composites with only sisal fibers in an epoxy polymer matrix. Further studies addressing percentage variations of plant fibers to assess the mechanical behavior of fibers in the composite are needed. In addition, studies are needed to evaluate the inclusion of sisal fibers from an economic point of view.

REFERENCES

- [1] Arpitha, G., & Yogesta, B. (2017). An Overview on Mechanical Property Evaluation of Natural Fiber Reinforced Polymers. *Materials Today*, 4(2):2755-60. doi:<http://dx.doi.org/10.1016/j.matpr.2017.02.153>
- [2] Badrinath, R., & Senthilvelan, T. (2014). Comparative Investigation on Mechanical Properties of Banana and Sisal Reinforced Polymer Based Composites. *Procedia Materials Science*, 2263-2272. Acesso em 20 de Fevereiro de 2020
- [3] Belaaadi, a., Bezazi, A., Maache, M., & Scarpa, F. (2014). Fatigue in Sisal Fiber Reinforced Polyester Composites: Hysteresis and Energy Dissipation. *Procedia Engineering*, 325-328. doi:doi: 10.1016/j.proeng.2014.06.272
- [4] Bisaria, H., Gupta, M., Shandilya, P., & Srivastava, R. (2015). Effect of Fibre Length on Mechanical Properties of Randomly Oriented Shor Jute Fibre Reinforced Epoxy Composite. *Materials Today: Proceedings [Internet]*. 2015:1193-9, 1193-1199. doi:<http://dx.doi.org/10.1016/j.matpr.2015.07.031>
- [5] Braga, R., & Magalhães, P. (2015). Analysis of the mechanical and thermal properties of jute as reinforcement epoxy hybrid composites. *Materials Science and Engineering C*, 269-273. doi:<http://10.1016/j.msec.2015.06.031>
- [6] Cunha, G., Filho, D., Carlos, R., & Mota, D. (2018). Effects of hybridization on the mechanical properties of composites reinforced by piassava fibers tissue. *Composites Part B*, 73-79. doi:<http://dx.doi.org/10.1016/j.compositesb.2018.10.050>
- [7] D., J., Maggiato Jr., Silva, C., Rosa, D., & Frolline, E. (2008). Sisal chemically modified with lignins: Correlation between fibers and Sisal chemically modified with lignins: Correlation between fibers and. *Polymer Degradation and Stability*, 1109-1121. doi:doi:10.1016/j.polymdegradstab.2008.03.011
- [8] Essabir, Y., Xia, C., Garcia, A., & Shi, S. (2018). Development of Natural Fiber-Reinforced Composite With Comparable Mechanical Properties and reduced Energy Consumption and Environment Impacts for replacing Automotive Glass-Fiber Sheet Molding Compound. *Journal of Cleaner Production*, 184:92-100. Fonte: https://ac.els-cdn.com/S0959652618305894/1-s2.0S2959652618305864-main.pdf?_tid=40dbbb6b-9460-48c1-a63d-26bfd7668217&acdnat=1520601245_e8c7b455d5d2c9aff20036b116c216a8
- [9] Fiore, V., Scalici, T., Nocoletti, F., Vitale, G., Prestipino, M., & Valenza, A. (2016). A new eco-friendly chemical treatment of natural fibres: Effect of sodium bicarbonate on properties of sisal fibre and its epoxy composites. *Composites Part B*, 85 (2016) 150-160. doi:<http://dx.doi.org/10.1016/j.compositesb.2015.09.028>
- [10] Gopinath, A., Senthil Kumar, M., & Elayaperumal, A. (2014). Experimental investigations on Mechanical Properties of Jute Fiber Reinforced Composites With Polyester and Epoxy Resin Matrices. *Procedia Engineering*, 97:2052-63. doi:<http://dx.doi.org/10.1016/j.proeng.2014.12.448>
- [11] Joseph, K., Thomas, S., & Pavithran, C. (1996). Effect of Chemical Treatment on Tensile Properties of Short Sisal fire-reinforced Polyethylene Composites. *Polymer*, 37(23):5139-49.
- [12] Kumrre, A., Rana, R., & Purohit, R. (2017). A Review on Mechanical Property of Sisal Glass Fiber Reinforced Polymer Composites. *Materials Today: Proceedings*, 4(2):3466-76. doi:<http://dx.doi.org/10.1016/j.matpr.2017.02.236>
- [13] Misra, R., Saw, S., & Datta, C. (2011). The Influence of Fiber Treatment on Mechanical Behavior of Jute-Coir Reinforced epoxy resin hybrid composite plate.

- Mechanics of Advanced Materials and Structures*, 431-445.
- [14] Mohan, T., & Kanny, K. (2012). Chemical treatment of sisal fiber using alkali and clay method. *Composites: Part A*, 1989-1998.
- [15] Padmavathi, T., Venkata Naidu, S., & Rao, R. (2012). Studies on Mechanical Behavior of Surface Modified Sisal Fibre - Epoxy Composites. *Journal of Reinforced Plastics & Composites*, 31(8)519-532. doi:10.1177/0731684412438954jrp.sagepub.com
- [16] Pickering, K., Efendy, M., & Le, T. (2016). A Review of recent developments in natural fibre composites and their mechanical performance. *Composites Part A: Applied Science And Manufacturing*, 98-112.
- [17] Prasad, G., Gowda, B., & Velmurugan, R. (2017). A Study on Impact Strength Characteristics of Coir Polyester Composites. *Procedia Engineering*, 173:771-7. doi:http://dx.doi.org/10.1016/j.proeng.2016.12.091
- [18] Ramesh, M., Palanikumar, K., & Reddy, K. H. (2013). Comparative Evaluation on Properties of Hybrid Glass Fiber- Sisal/Jute Reinforced Epoxy Composites. *Procedia Engineering*, 51 (2013) 745 – 750. doi:doi: 10.1016/j.proeng.2013.01.106
- [19] Rana, R., Ashish, K., Rana, S., & Purohit, R. (2017). Characterization of Properties of Epoxy sisal/Glass Fiber Reinforce Hybrid Composite. *Materials Today: Proceedings*, 4(2017)5445-5451.
- [20] Ratna Prasad, A., & Mohana Rao, K. (2011). Mechanical properties of natural fibre reinforced polyester composites: Jowar, sisal and bamboo. *Materials and Design*, 4658-4663. doi:doi:10.1016/j.matdes.2011.03.015
- [21] Santos, F., Souza, T., Barquete, D., & Amado, F. (2016). Comparative analysis of the sisal and piassava fibers as reinforcements in light weight cementitious composites with EVA waste. *Construction and Building Materials*, 315-323. doi:http://dx.doi.org/10.1016/j.conbuildmat
- [22] Senthilkumar, K., Saba, N., Chandrasekar, M., Jawaid, M., & Siengchin, S. (2018). Mechanical Properties Evaluation of Sisal Fibre Reinforced Polymer Composites: A Review. *Construction And Building Materials*, 147(2018)713-729. doi:http://doi.org/10.1016/j.conbuildmar.2018.04.143
- [23] Wambua, P., Ivens, J., & Verpoest, I. (2003). Natural Fibers: Can They replace glass in fibre reinforced plastics? *Composites Science and Technology*, 63(9)1589-64.