



24th COBEM - 2017



24th ABCM International Congress of Mechanical Engineering  
December 3-8, 2017, Curitiba, PR, Brazil

## COBEM-2017-1334

# MECHANICAL CHARACTERIZATION OF POLYESTER RESIN COMPOUND WITH FIBER OF GLASS AND CAIXETA WOOD

**Antônio Carlos Barbosa Zancanella**

Universidade Federal do Espírito Santo. Rodovia BR101 Norte, Km 58, Bairro Litorâneo – CEP 29.932-900, São Mateus – ES  
antonio\_carlos1505@hotmail.com

**Anderson Guimarães Andrade**

**Douglas Santana Jaegger**

**Hédrick Colona**

**Murilo Rios Barros**

**Rômulo Maziero**

**Davi Pereira Garcia**

**Bruno Corveto Bragança**

**Artur Pratti de Barros**

**Igor Chaves Belisario**

Instituto Federal de Educação, Ciência e Tecnologia do Espírito Santo. Rodovia BR 101 Norte, Km 58, Bairro Litorâneo - CEP

29.932-540, São Mateus – ES

anderson.scout@hotmail.com

jaeggerdouglas@gmail.com

riosb.murilo@gmail.com

maziero.ifes@gmail.com

davi.garcia@ifes.edu.br

bruno.braganca@ifes.edu.br

artur.pratti@ifes.edu.br

igor.belisario@ifes.edu.br

**Abstract.** *Mechanical properties research of new composites allows engineers a greater flexibility during the design of machines, structures or components. In this context, the objective of the work is to characterize the mechanical properties of a composite made of wood and fiberglass with an unsaturated polyester resin matrix, using a tensile and flexural test. Due to the greater supply of wood chips caixeta wood (*Tabebuia cassinoides* (Lam.) DC.), than balsa wood (*Ochroma pyramidale*) in smaller markets, its use, associated with fiberglass in the form of sandwich composite, can become an option in the manufacture of airship aircraft. The results shown the composite elaborated with caixeta wood presents superior mechanical rather the balsa wood.*

**Keywords:** *Hybrid composite, caixeta wood, Mechanical properties, *Tabebuia cassinoides*.*

## 1. INTRODUCTION

Material selection for aeronautical projects needs to be with a careful manner, taking account the properties of each material, as well as the cost. Baúto (2010) states that the aeronautical and aerospace industry, in the search for light materials with higher mechanical properties, have encouraged the preparation of new materials, mainly composites.

One of the methods of composite construction is panel-sandwich, or sandwich-only. Layers of overlapping materials in order to obtain a composite with better mechanical properties rather than the properties of the materials composing it. According to Callister (2008), sandwich panels are used in a wide variety of applications including roofs, floors and walls of buildings; and in the aerospace and aeronautics industry (wings, fuselages and horizontal rudder linings).

As stated by Garcia, Spim and Santos (2010), any engineering project requires, in order to make feasible, a vast knowledge of the characteristics, properties and behavior of the available materials.

In this context, the objective of this work was the survey of the mechanical properties of the composite hybrid of unsaturated polyester resin with glass fiber and caixeta wood (*Tabebuia cassinoides* (Lam.) DC.), through tensile and flexion tests.

## 2. THEORETICAL REFERENCE

According to Callister (2008), composite is any multiphase material that exhibits a significant proportion of the properties of both the constituent phases, so that a better combination of properties is obtained. As Faria (2007) stated, composite materials do not have a universally accepted definition. The word composite derives from compound, that is, anything consisting of different parts (or constituents). In the microstructural scale, several materials can be considered composites, since they are formed by different atomic groupings. In the macrostructural scale, where the constituents are different and can be identified with the naked eye, there is also a diversity of materials considered composite.

Smith (1998) states that there is no single definition that is accepted by all researchers. However, the author says that composite material is a mixture or combination of two or more microconstituents or macro-constituents that differ in chemical form and composition and which, in essence, are insoluble in one another.

According to Callister (2008) composite materials consist of only two phases, one is called matrix, which is continuous and involves the other phase, called the dispersed phase frequency. As stated by Silva (2012), the matrix material acts as a binder, surrounds the other constituents by keeping them in relative position, allows some ductility to the composite, ensures the transmission and distribution of mechanical stresses to the reinforcing material, and also protects their surfaces. With respect to the reinforcing material this may consist of fibers (continuous or discontinuous) and particles, these materials will withstand most of the stresses to which the composite is subject and usually exhibit high strength and stiffness.

According to Silva (2012), the combination of the different materials for the matrix and reinforcement obtains a mutual cooperation, in which the composite material presents better properties and characteristics than those of each constituent separately. Silva (2012) cites two examples of this interaction between naturally occurring materials: wood and bones. Wood consists of cellulose fibers arranged in a matrix of lignin, the bones have a mineral matrix, formed essentially of calcium, to envelop the collagen proteins.

Despite the difficulty of defining the composite material, studies have been done to develop new materials that can replace metallic, ceramic and polymer alloys, in order to meet the new technological demands (Faria, 2007).

Certain features are the focus of the development of composites for the industry leading edge. Faria (2007) states that the high strength and stiffness values continue to be the combination that launches the composite materials into new areas. However, the large damping capacity and the low coefficient of thermal expansion are characteristics that can be adapted for specific applications. Advanced composites reduce fatigue problems and give greater design and manufacturing flexibility, which can significantly reduce the number of parts needed. Another advantage of composite materials is corrosion resistance and wear under high temperature, especially in industrial applications.

Gagliardo and Mascia (2010) analyzed sandwich structures, considering the mechanical behavior and possible applications in civil construction. They conclude that when designing using structures of this type, the designer must keep in mind that he is associating properties of distinct materials for the improvement of the mechanical characteristics of the structure.

The recent work by Vieira *et al.* (2017), presents new laminates of alumina with sisal fiber, prepared by cold compression techniques and tested under the methods of traction, bending and impact. Pristine sisal tissue and composites reinforced with sisal fiber were tested for mechanical performance evaluation of laminates derived therefrom. The new laminates achieved the highest modulus and strength and the highest specific properties. A recent evidence that this type of structure is currently innovation in technological applications in the field of mechanics.

In a journal focused on applied research and communication in the broad area encompassing Metallurgical Engineering, Materials Engineering, Condensed Matter Physics, Chemistry and related areas, Aparecida, Karoline and Motta (2017) emphasize the importance of sandwich panels reinforced with ramie fibers for construction, experimenting mechanically and numerically using finite elements method and microstructural analysis through Scanning Electron Microscopy evidencing a potential utilization of fibers for the sector.

## 3. EXPERIMENTAL PROCEDURE

The present work was carried out in the Test Laboratory of the Instituto Federal do Espírito Santo, Campus São Mateus. The manufacture of the hybrid composite was carried out by means of the compression molding technique, using 1 mm of thickness of caixeta wood (*Tabebuia cassinoides* (Lam.) DC.), fiberglass blanket and pre-accelerated unsaturated terephthalic polyester resin in the ratio of 0.33% per volume.

On a flat surface was placed polypropylene plastic with release wax. Then the resin with catalyst, at the rate of 25 drops of catalyst per 100 g of resin, then it was apply directly to the plastic. The first fiberglass blanket was positioned above the initial resin layer. A new layer of resin was added so that there was complete penetration into the glass fiber. The caixeta wood was then placed on the fiberglass blanket, ending with a layer of resin and fiber. The top was covered with polypropylene plastic with release wax. The whole set with the aid of clamps was pressed in a hydraulic press of capacity 15 ton and, at the end of four hours, the composite was demolded.

Test specimens were prepared for tensile and flexural tests, according to ASTM D638-14 standards for tensile bodies, and ASTM C393/C393M-11, for flexural strength. The sections of the specimens were made parallel to the fibers of the wood.

The tensile test occurred at a speed of 2 mm/min in a universal testing machine. A 50 mm extensometer with an accuracy of 0.001 mm was used. For the three-point flexural test, a speed of 5 mm/min was used on the same test machine. All data were saved in computer, and the stress-strain curves generated by the data acquisition software itself.

#### 4. RESULTS AND DISCUSSION

Figure 1 shows the appearance of the five ruptured specimens after the tensile test and the stress-strain curves obtained in the tests are shown in Fig. 2.



Figure 1. Test specimens subjected to tensile stress.

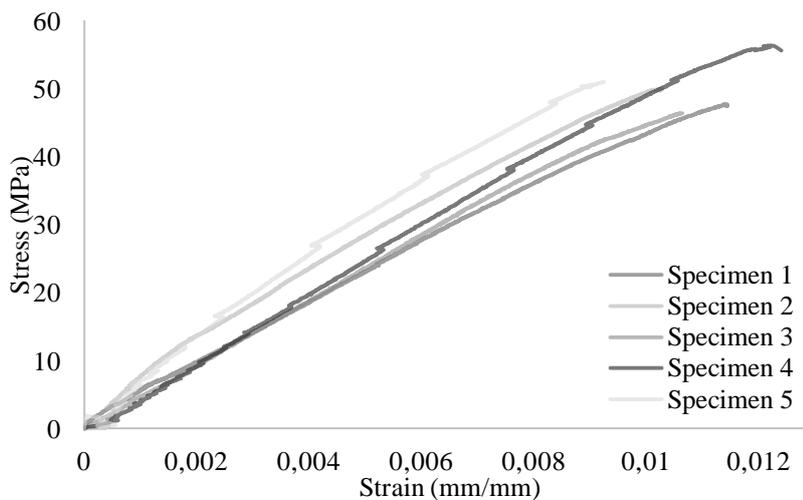


Figure 2. Stress-strain curves in traction of the elaborated composites.

The results of the modulus of elasticity and maximum stress are shown in Table 1.

Table 1. Modulus of elasticity and maximum stress of the specimens.

Specimens	Modulus of elasticity (GPa)	Maximum stress (MPa)
1	4.23	47.71
2	4.74	49.92
3	4.53	46.38
4	4.87	56.37
5	5.36	50.94

The modulus of elasticity averaged 4.75 GPa, with a standard deviation of 0.42 GPa and a 95% confidence interval of 0.52 GPa.

The largest modulus of elasticity found was for test specimen 5 with 5.36 GPa, being about 12% higher than the average. Test specimen 1 has the smallest modulus of elasticity with 4.23 GPa, about 11% lower than the average.

The mean maximum tension was 50.30 MPa, with a standard deviation of 3.90 MPa and a 95% confidence interval of 4.80 MPa. The highest maximum stress was from specimen 4 with 56.37 MPa, approximately 12% higher than the mean. On the other hand, the lowest maximum tension found was of specimen 3 with 46.38 MPa, about 8% lower than the average.

Considering that aerodynamic aircraft currently use balsa wood (*Ochroma pyramidale*) as structural element, studies are carried out to characterize this material, presenting results as maximum tensile strength, with a value of 13.50 MPa (Diab, 2016), and for the modulus of elasticity of 3.71 GPa (Wood-database, 2016). The composite showed modulus of elasticity above 28% and maximum tension about four times higher, compared to balsa wood.

Comparing these results with those of Marinelli *et al.* (2008), the results indicated an average elasticity modulus of 4.75 GPa, smaller than all the natural and conventional fibers of the table that involves, Cotton (5.5-12.6) GPa; Jute 26.5 GPa; Rami (61.4-128) GPa; Flax 27.6 GPa; Sisal (9.4-22) GPa; E-Glass 70.0 GPa; S-Glass 86.0 GPa; Aramide (normal) (63.0-67.0) GPa; Carbon (standard) (230.0-240.0) GPa; Curauá 50,4 GPa, being very close only to the Fiber of coconut (4,0-6,0) GPa.

Figure 3 shows the appearance of the five ruptured specimens after the flexure test and the load-deformation curves obtained are shown in Fig. 4.



Figure 3. Test specimens subjected to bending stress.

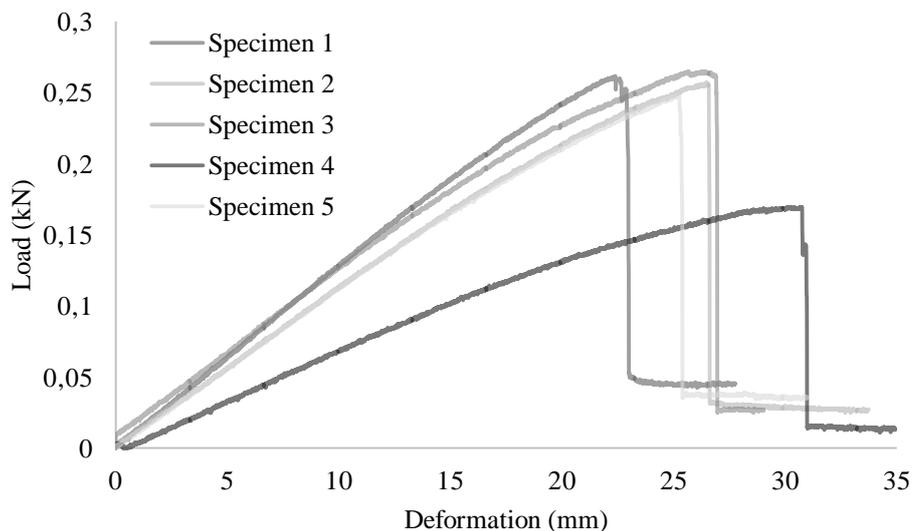


Figure 4. Flexure test of the composites.

The maximum load obtained in the bending tests is shown in Tab. 2.

Table 2. Maximum stress of each test piece.

Specimens	Maximum load (kN)
1	0.2616
2	0.2568
3	0.2648
4	0.1696
5	0.2480

The mean maximum load is 240.2 N, with a standard deviation of 39.9 N. The 95% confidence interval was 49.6 N. The test piece 4 has the lowest maximum load, 169.6 N, being about 70% of the average. The highest maximum load was verified on specimen 3, with 264.8 N, being about 10% higher than the average.

## 5. CONCLUSIONS

The elaborated composite presented superior mechanical properties to balsa wood, which indicates the use of caixeta wood along with fiberglass as a material for the manufacture of aerodesign aircraft.

The applications of composite sandwich material are diverse, including surfboards like those of Powerlight (2017).

In addition sandwich panels have come to be used in the most various applications where the relationships rigidity/weight and resistance/weight are of the greatest importance. The first applications of sandwich panels have been connected to the aerospace industry, having been extended to the automobile and naval industry. Recently, the field of application of the panels has been widening to be extended, which is his emphasis in construction in constant growth.

## 6. REFERENCES

- Aparecida, L., Karoline, L. and Motta, C., 2017. "Painéis sanduíches de poliéster reforçado com fibras de rami para aplicação na Construção Civil". *Revista Matéria*, Vol. 21, n. 3, p. 796-806.
- ASTM C393/C393M-11, 2011 Standard Test Method for Core Shear Properties of Sandwich Constructions by Beam Flexure.
- ASTM D. 638-14, 2014. Standard Test Method for Tensile Properties of Plastic.
- Baúto, M.J.C., 2010. Estudo comparativo do comportamento mecânico de materiais compósitos à base de polímeros líquido-cristalinos. Master thesis, Instituto Superior de Engenharia de Lisboa, Lisboa.
- Callister, W.D., 2008. *Ciência e engenharia de materiais: uma introdução*. LTC, Rio de Janeiro, 7th edition.
- Diab, 2016. Technical Data. In *Probalsa: The high performance sandwich core*.
- Faria, P.E., 2007. Estudo sobre a furacão de compósito de resina epóxi reforçado com fibras de vidro. Ph.D. thesis, Universidade Federal de Minas Gerais, Belo Horizonte.
- Gagliardo, D.P. and Mascia, N.T., 2010. "Análise de estruturas sanduíche: parâmetros de projeto". *Ambiente Construído (Online)*, Vol. 10, n. 4, p. 247-258.
- Garcia, A., Spim, J.A. and Santos, C.A., 2010. *Ensaios dos materiais*. LTC, Rio de Janeiro.
- Marinelli, A.L., Monteiro, M.R., Ambrósio, J.D., Branciforti, M.C., Kobayashi, M. and Nobre, A.D., 2008. "Desenvolvimento de compósitos poliméricos com fibras vegetais naturais da biodiversidade: uma contribuição para a sustentabilidade amazônica". *Polímeros: Ciência e Tecnologia*, Vol. 18, n. 2, p. 92-99.
- PowerLight, available in: <<http://powerlight.com.br/>>, accessed in 15/05/2017.
- Silva, V.Q.C.P., 2012. Avaliação experimental dos deslocamentos e das cargas críticas de "bending-buckling" em placas compósitas. Master thesis, Universidade de Coimbra, Coimbra.
- Smith, W. F., 1998. *Princípios de ciência e engenharia dos materiais*. Mc.Graw-Hill de Portugal Lda, Lisboa.
- Vieira, L.M.G., Santos, J.C., Panzera, T.H., Rubio, J.C.C. and Scarpa, F., 2017. "Novel fibre metal laminate sandwich composite structure with sisal woven core". *Industrial Crops and Products*, Vol. 99, p. 189-195.
- Wood-database, 2016. The Wood Database: Balsa <<http://www.wood-database.com/balsa/>>.

## 7. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.