



25th ABCM International Congress of Mechanical Engineering
October 20-25, 2019, Uberlândia, MG, Brazil

COB-2019-0841

DEVELOPMENT AND EVALUATION OF MECHANICAL PROPERTIES OF COMPENSATED WOOD ENHANCED WITH GLASS FIBER

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Abstract. *In recent years, there has been a marked growth in the development of composite materials. The insertion of a polymer matrix reinforcement has resulted in significant improvements in the mechanical performance of materials commonly used in engineering areas. The composite materials combine the best properties of each material to formulate a new material with different characteristics. Some studies have been developed with plywood, looking for ways to improve the resistance of the same, as well as the addition of reinforcement elements. For this experiment, a layer of epoxy-laminated glass fiber fabric was added on the last panel of the compensated panel for comparison of results with panels without reinforcement. The panels were characterized by physical-mechanical tests proposed by the normative documents of the American Society for Testing and Materials – ASTM.*

Keywords: *composite materials, compensated wood, fiberglass*

1. INTRODUCTION

Callister (2002) defines composite as a material formed from the mixture of two or more immiscible constituents that differ in shape in the chemical composition and must be separated by a distinct interface.

The materials composing the composites are divided into two phases: the matrix, which is a continuous phase and involves the other constituents or the other phase providing some ductility to the composite, and the reinforcement, which is discontinuous and supports the stresses applied to the material (Mota, 2010).

According to Carvalho (2002), the composites have properties significantly different from the properties of the constituents, as they evaluate the individual properties of each constituent, as well as the relative percentage in the composite and the dispersed phase geometry.

The dispersed phase geometry in this context encompasses the shape, size, distribution and orientation of the particles. In this way, the composites are designed to present the combination of the best characteristics of each constituent material (Mota, 2010).

In composite materials, the matrix is generally responsible for the transfer of charge to the reinforcements. In addition, it protects it from abrasion, damage and degradation media, as well as shaping the final product (Juvandes, 2012).

Inside the most common reinforcements is fiberglass. The mixture of glass fiber as a reinforcement together with a polymer matrix forms a composite called Glass Fiber Reinforced Plastic (PRFV), which allows to obtain pieces with increased mechanical properties (Orth et. al., 2012). Fiorelli and Dias (2002) evaluated the behavior of glass fiber reinforced wood beams, obtaining a significant increase in strength and rigidity of reinforced parts.

In mechanics, flexion is a physical effort where deformation occurs perpendicular to the body axis, that is, the longitudinal axis of a body is subjected to perpendicular loads.

The flexure test consists of applying a growing load at certain points of a standardized geometry bar until it breaks due to the traction of the lower part of the specimen. In this test, the value of load versus maximum strain is measured. In ductile materials, when subjected to this type of load, as they are capable of absorbing large deformations, they do not provide qualified quantitative results for the flexural test, so this test should be applied for higher rigidity materials.

There are basically two main types of bending test: the three-point test, where the bar to be tested is supported at the ends and the load is applied at the center of the specimen length; and the four-point test, in which the bar to be tested is biased at the ends and the load is applied at two points in the central region of the length, separated by a standard distance. To obtain the mechanical flexural properties of the composite object of this study, the three-point flexural test was used.

Plywood is a product obtained by gluing overlapping wood veneers with the fibers crossed perpendicularly. These sheets are produced under two main specifications:

- a) for internal use with urea-formaldehyde resin-based bonding, being used primarily in the furniture industry;
- b) for external use with phenol-formaldehyde resin-based bonding and is commonly used in construction.

Plywood cross lamination results in more desirable physical and mechanical properties in biaxial stresses such as beam souls and bracing panels. The resistance of wood in the direction parallel to the fibers is greater than in the perpendicular direction. Cross fibers significantly increase strength and stiffness in the normal fiber direction of plywood compared to solid wood. Therefore, plywood panels have good stiffness and strength in the directions: perpendicular and parallel to the face blade fibers (Olin, 1990).

Currently, glass fibers are applied to more than 35,000 products, with most commonly used are type E (E-glass). Glass fibers are produced from silica (SiO₂) by the addition of calcium oxide, boron, sodium and aluminum. They are amorphous materials and their crystallization occurs after prolonged treatment with high temperatures (Ota et al, 2004).

This material is composed of very thin filaments of glass, which aggregate by application of resins, silicones, phenols and other solvent-soluble compounds Organic (Soares et al, 2007).

Some advantages of using fiberglass in structural reinforcements can be highlighted: low cost, compared to other fibers (carbon and aramid), high impact and corrosion resistance. It can be highlighted as a product that is also made in Brazil (Barcellos, 2009).

Therefore, this research has as objective the study and development of a composite material formed by glass fiber and polymeric resin, used as structural reinforcement in plywood to evaluate some mechanical properties. Through flexural tests of the material, to estimate some important mechanical properties and subsequent analysis with the material without reinforcement.

2. METHODOLOGY

The methodology used in this research is based on the comparison of properties between naval plywood and naval plywood fiberglass reinforced with sandwich construction to evaluate the benefits of using the reinforcement.

From the panels, the specimens were removed for evaluation of the physical-mechanical properties. The dimensions of the specimens (Tab. 1) and the conduction of the tests were based on the requirements of the standards of the American Society for Testing and Materials - ASTM.

Table 1. Dimensions of the specimens.

Dimensions	Specimen
Length (mm)	200.0 ± 0.5
Width (mm)	75.0 ± 0.5
Thickness (mm)	7.30 ± 0.02

The rectangular plywood panels were arranged on an impermeable surface with the glass fiber (Tab. 2) on the top and on the bottom for the application of the adhesive thereon. In this work the epoxy resin was used as the matrix phase, together with the hardener in the proportion 2:1, recommended by the manufacturer.

Table 2. Data of Glass Fiber.

Properties	Glass Fiber
Direction	Warp
Wires/cm warp	4
Wires/cm web	4
Density (kg/m ³)	2.54
Thickness (mm)	1
Gramature (g/m ²)	330

Soon after the specimen was pressed together with the resin for a better compacting of the materials, for later to be tested. After five days of curing, the bodies were cut, measured and numbered as shown in Figure 1.

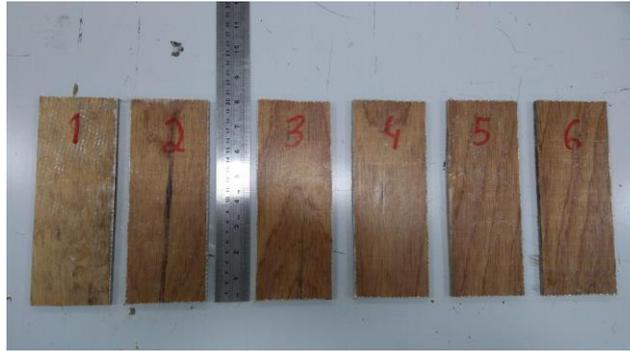


Figure 1. Specimens prepared for the test.

The three point flexural test was performed, according to standard American Society for Testing and Materials - ASTM C393-00. The tests on the specimens were carried out in the universal test machine with a speed of 6 mm/min (Fig. 2 and 3), with the aid of the strain gauge, whose function is to measure deformations in the working area of the specimen.



Figure 2. Specimens on the test machine.



Figure 3. Specimens and after the test.

3. RESULTS

Tests were carried out on six test specimens and a mean of the values obtained. Tab. 3 presents the medium values of the physical-mechanical properties of the specimens of plywood manufactured without the reinforcement and the values for plywood with fiberglass reinforcement. The results are presented in the directions parallel to the fibers of the outer blade.

In this table, we have:

- PF1 represents the non-reinforced test specimens;
- PF2 represents the reinforced specimens;
- τ represents the maximum shear stress;
- σ the modulus of maximum resistance to static bending and
- E the modulus of elasticity to the static bending.

Table 3. Medium results for the bodies of proof with and without reinforcement.

Properties	PF1	PF2
σ (MPa)	40.0 ± 0.4	52.4 ± 0.4
E (GPa)	37.75 ± 0.01	8.37 ± 0.01
τ (MPa)	0.80 ± 0.03	1.27 ± 0.03

In the bending test, the applied load versus strain graph was generated for the material with and without the use of glass fibers in its matrix and the data extracted from the graph reinforce the thesis that the inclusion of the glass fibers increases considerably the resistance of the material. The maximum load considered for the calculations corresponds to the first discontinuity in the graph (Fig. 4) due to the appearance of the first cracks, which weakens the material near 0.40 KN.

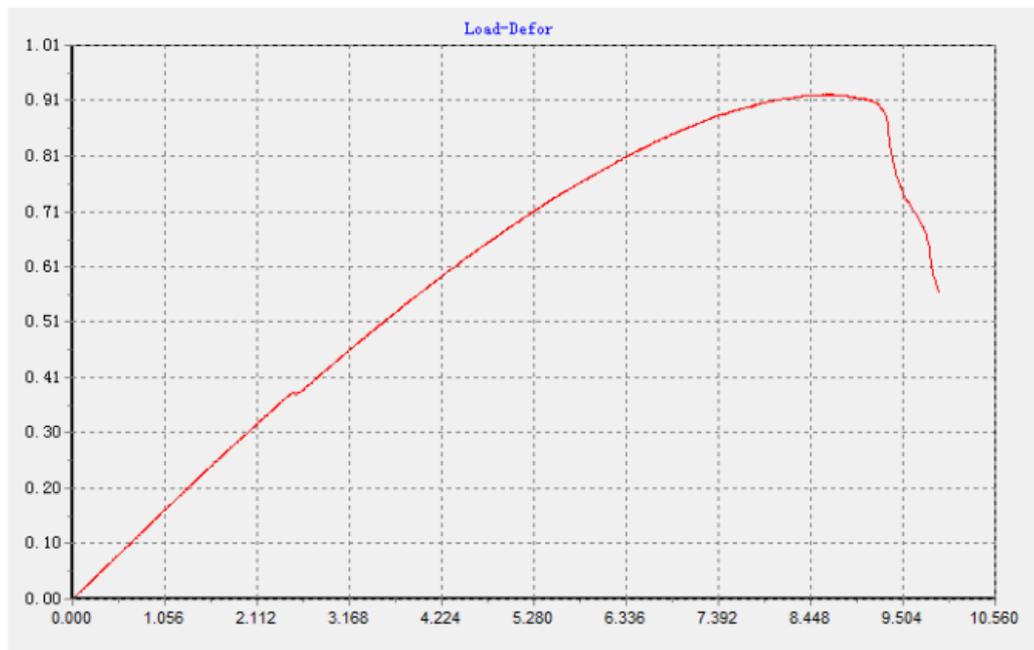


Figure 4. Graph Force (kN) x Deformation (mm) extracted from the bending test. Test piece without reinforcement.

In the graph that represents the reinforced specimen (Fig. 5), the curve is more uniform, without the presence of the discontinuity, emphasizing a better performance of the specimen with reinforcement.

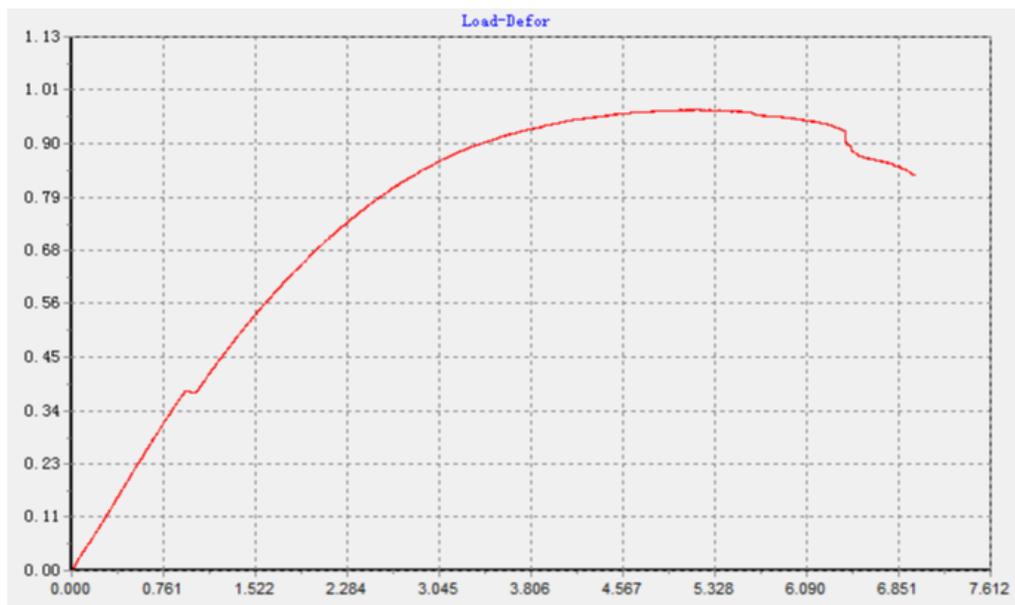


Figure 5. Graph Force (kN) x Deformation (mm) extracted from the bending test - Test piece with reinforcement.

It's noted that the use of glass fiber reinforcement in the plywood sheets increased by about 31% the flexural strength of the sheets. It was also observed an increase in the maximum shear stress of the material and, as a consequence of the increase of resistance, the reinforcement with glass fiber considerably decreased the modulus of elasticity, which was already expected because it is a fragile material.

This result means that this reinforcement can increase the mechanical properties of the material and allow different applications with the possibility of the replacement of noble wood, according to the required specifications.

4. CONCLUSIONS

After conducting the tests on the specimens, it was noted that the combination of the properties extracted from the glass fiber and plywood yields satisfactory results in relation to the specific strength of the composite. The addition of glass fibers in the matrix of the material considerably increased the resistance of the material to flexion, therefore, considering the ease of manufacture of this material, low cost and the improvement of the mechanical properties due to the addition of glass fibers, it is evident that this composite can have diverse applications in substitution to more expensive and noble materials while meeting the requirements that the applications demand.

It should be noted that the addition of glass fiber in the material of this study improves not only the mechanical properties of flexural strength, but also improves properties such as rigidity and tensile strength.

5. ACKNOWLEDGMENTS

The authors thank Federal Institute of Espírito Santo for their support during research.

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