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TENSILE AND FLEXURAL PROPERTIES OF POLYMER COMPOSITE SANDWICH BEAMS

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ABSTRACT

This work is concerned with the study of the mechanical behavior of polymer composite sandwich beams. The skins consist of glass and carbon reinforced epoxy composites. The core is made from balsa wood and Divinycell H45 (48 kg m^{-3}) foam. The main goal is to evaluate the best composite system considering the ultimate tensile strength (σ_u), the elastic modulus (E), flexural strength (σ_f) and flexural modulus (E_f). Tensile tests according to standard ASTM D 3039 and bending tests according to standard ASTM D 790 were performed. The mechanical properties were analyzed and compared, in order to present the composite laminate with finest properties.

Keywords: Mechanical properties, Sandwich beams, Tensile test, Flexural Test

1 INTRODUCTION

Laminated polymer matrix composite materials have been excelling in the industry in recent decades. Widely applied to the areas of aviation, spacecraft, automotive and petrochemical structures, composite laminates must have appropriate properties to mechanical stress. Specifically, for the aerospace engineering knowledge of the mechanical properties are treated especially for performing as one of the main factors for projects in such areas of industry [1-3].

Distinctively of metals, which characteristics previously cited have been widely studied, composite materials lack the amount of information available on those aspects. Because it is formed by the material composition of two or more constituents which have distinct properties, the polymer matrix will present special features from their composition [2,3].

For years, the laminated composites have been studied for its high mechanical strength and low weight. However, in order to propose new mechanical characteristics, the hybrid composites have been developed. Formed by two or more types of compounds they have mechanical properties of both [4]. Hybrid composites can be produced for various settings, such as intra-ply, inter-ply and sandwiches. In this way, the mechanical properties of the hybrids can be quantified by the law of mixtures [5].

Typical studies conducted by [6-9] show that the hybrid composites under flexural loads, traction, fatigue and impact feature improvements in relation to properties, composites with high mechanical strength and low displacement as carbon fiber and reinforced glass.

Among the hybrid composites the sandwich type, consisting of two thin layers of rigid skins of low thickness with a core of greater thickness, less dense material and less resistance. Thus, a composite with the strength of its external skin is obtained, which is consistent with traction and compression characteristics as well as its core with high flexural strength and low weight [10].

For [11-13] the tensile behavior in the sandwich composites does not change, therefore, the yield strength of the core is smaller than the skin, which is predominant. However, for flexural strength the core distributes tensions through the body, minimizing the shear and traction effects which are concentrated in the skins.

Other studies evaluate the composition of the core and its geometry under flexion. For [14] the effects of shear and bending can be predicted by the composition of the sandwich and its thickness. For [15, 16] PVC cores (usually applied) can be replaced by natural composites and metals in order to guarantee greater or less stiffness, whereas for [17, 18] resin columns in the core or honeycomb geometry can produce the same effect.

With these aspects in view, this paper aims to evaluate and compare sandwich composites and laminated composites. To this end, it was performed tensile tests according to standard ASTM D 3039 [19] with five specimens and bending tests according to standard ASTM D 790 [20] with three specimens of each polymer/matrix combination. The proposed mechanical properties were analyzed and compared, obtaining from them the composite laminate with finest properties.

2 MATERIALS AND EXPERIMENTAL PROCEDURES

The apparatus and procedures used to obtain the tensile and flexural properties are described below.

Tensile and flexural tests were performed according to ASTM D3039 [20] and ASTM D790 [21]. The test specimens were cut from hand lay-up sheets. The glass and carbon composites were a cross-ply plain weave [0/90°] with eight layers of glass and carbon. The sandwich beam specimens are composed of two layers of glass or carbon fiber with balsa wood or divinycell H45® (PVC foam) core. Table 1 and Table 2 shows the properties of fibers and cores used in the specimens. The epoxy resin system used was LY 5052 from Araldite® with a mix ratio of 2:1. The resin system properties provided by manufacturers are presented in Table 3.

The specimens were cut 250 mm x 25 mm, leaving a gauge section of 200 mm. The tensile tests were performed on a Shimadzu AG-X tensile test machine at a rate of 2,0 mm/min. The flexural tests were performed on an EMIC DL test machine at different rates according to the thickness of each specimens as the ASTM D790 suggests. Five specimens of each combination of layer and core

have been used for tensile tests, and three specimens such as used in tensile, have been tested in flexural tests.

Table 1 Layer Properties

PROPERTIES	Glass fiber	Carbon fiber
WIRES/CM WARP	4,0	5,0
WIRES/CM WEB	4,0	5,0
DENSITY (g/m ²)	330	200
THICKNESS (mm)	0,30	0,30

Table 2 Core Properties

PROPERTIES	Divinycell H45®	Madeira Balsa
TENSILE STRENGTH (MPa)	1,4	19,9
ELASTICITY MODULUS (MPa)	55,0	900,0
DENSITY (Kg/m ³)	48,0	140,0

Table 3 Properties of Epoxy Resin

PROPERTIES	Araldite® LY 5052
DENSITY @ 25°C (g/cm ³)	1,16 - 1,18
VISCOSITY @ 25°C (mPas)	1000 - 1500
TENSILE STRENGTH (MPa)	80 - 83
FLEXURAL STRENGTH (MPa)	126 - 126
MAXIMUM ELONGATION (%)	8,5 - 13,4

3 RESULTS AND DISCUSSION

3.1 Tensile Tests

Figure 1 present the curve stress (σ) x strain (ϵ) obtained in tensile tests for each composite combination. The carbon fiber reinforced matrix has higher tensile strength (582,94 MPa) and elasticity modulus (36,81 GPa) as expected. In another way, glass fiber reinforced matrix did no show the same aspect compared to sandwich composites. In fact, it has a higher tensile strength than sandwich beam composites, but the elasticity modulus is practically the same compared to carbon fiber/balsa wood and carbon fiber/divinycell composites.

Sandwich beams with balsa wood core presented a slight stress drop as the core start to crack, this behavior is not surprising since balsa wood is a natural composite with large fibers. Composites with divinycell core revealed to be more reliable due to the pattern that tensile tests generated.

Figure 2 presents three different bar graphics that show the average value of tensile strength (σ_u), elasticity modulus (E) and the mass (m) of specimens. The blue bars are related to sandwich composites with carbon fiber layers and orange bars are to sandwich with glass fiber. As commented before, sandwiches with a carbon fiber layer has better properties in those parameters since carbon fiber is more strength and less heavy than glass fiber.

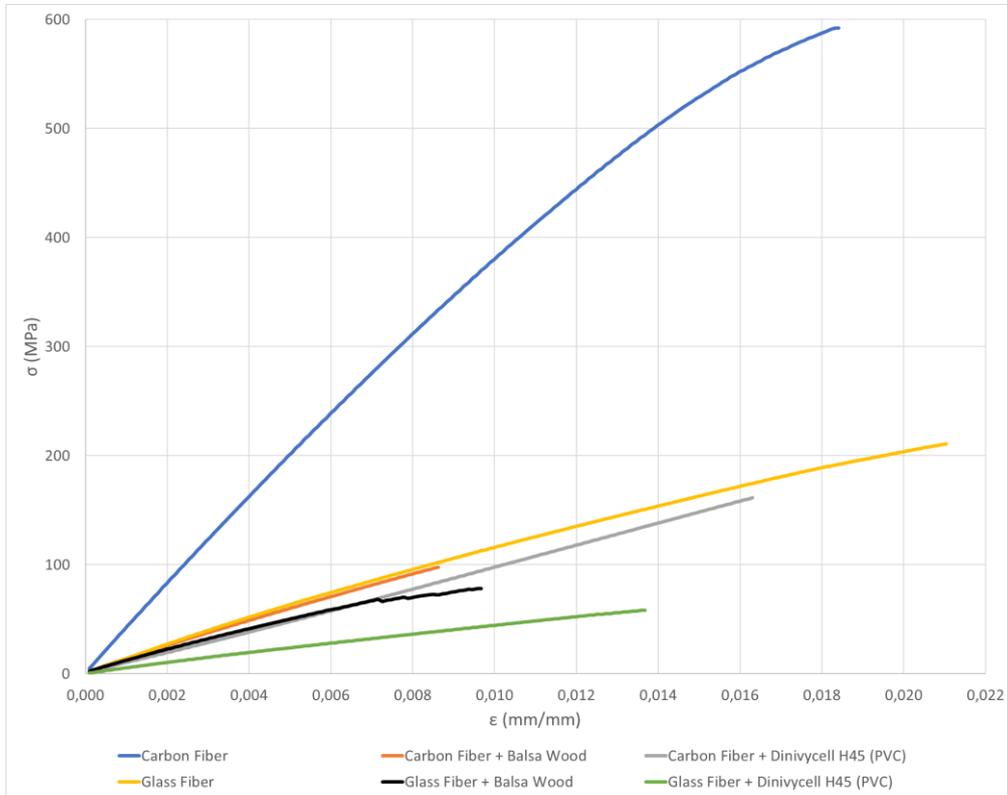


Figure 1: Stress x Strain Comparison in Tensile Tests

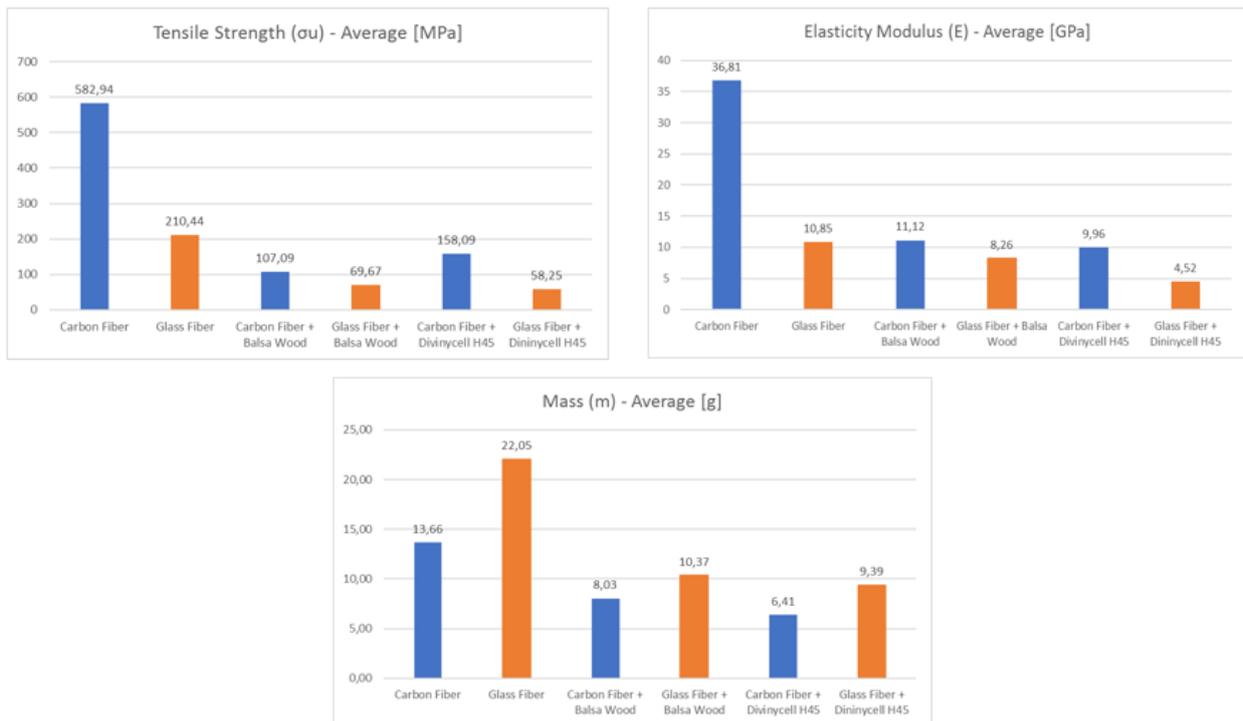


Figure 2: Properties Comparison in Tensile Tests

3.2 Flexural Tests

Figures 3 and 4 presents the curve flexural stress (σ_f) x strain (ϵ) obtained in flexural tests for each composite combination. Carbon fiber reinforced matrix has the highest flexural strength (751,43 MPa) and flexural modulus (47,28 GPa) as expected. Besides the lower value of flexural strength obtained in glass fiber reinforced matrix (284,79 MPa), the strain behavior in relation to carbon fiber reinforced matrix were same.

For sandwich beams composites, it can be verified the difference between the core and skin that was used in specimens. In fact, the flexural strength and flexural modulus is strongly dependent on the stiffness of the core and the skin that the sandwich was composed. Composites with balsa wood cores presents a higher flexural strength and flexural modulus in comparison with divinycell cores due to stiffness of the core, in the same way, sandwich beams with carbon fiber skin shows the same patter in comparison with the glass fiber skin. Those properties comparisons are presented in Figure 5.

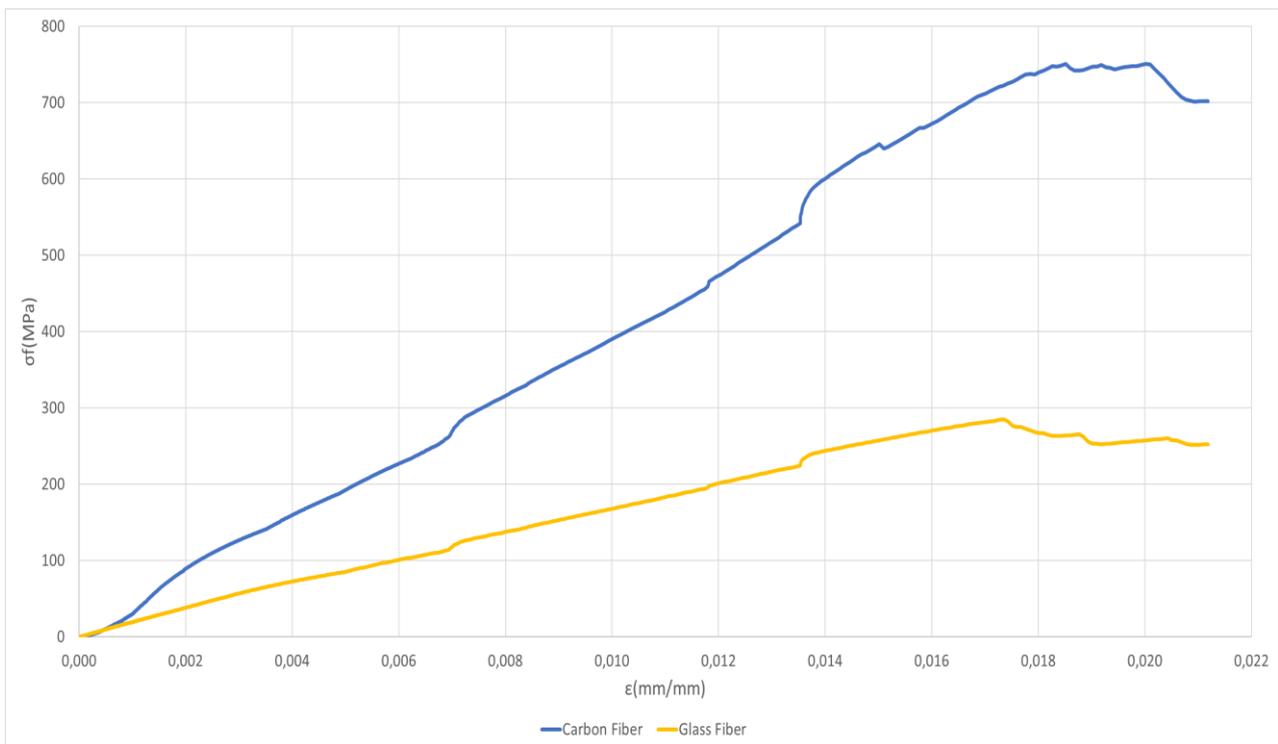


Figure 3: Stress x Strain Carbon and Glass Fiber Comparison of Flexural Tests

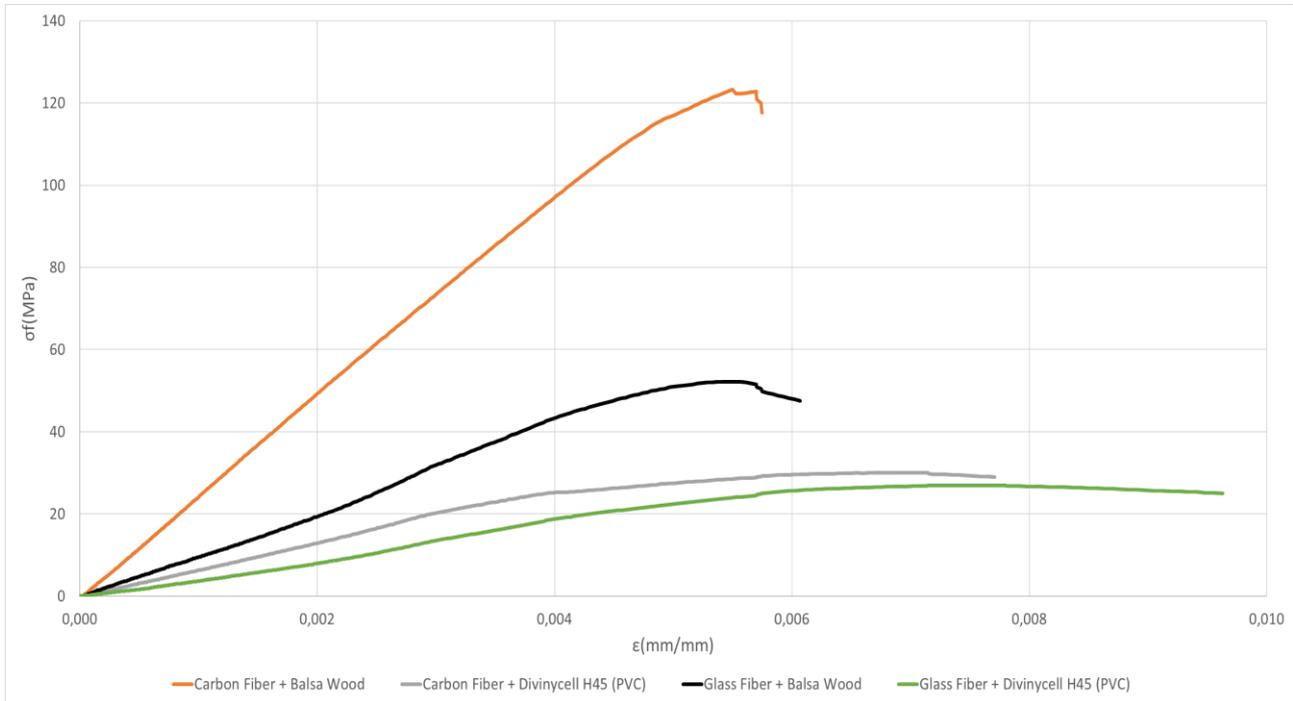


Figure 4: Stress x Strain Sandwich Beams Comparison of Flexural Tests

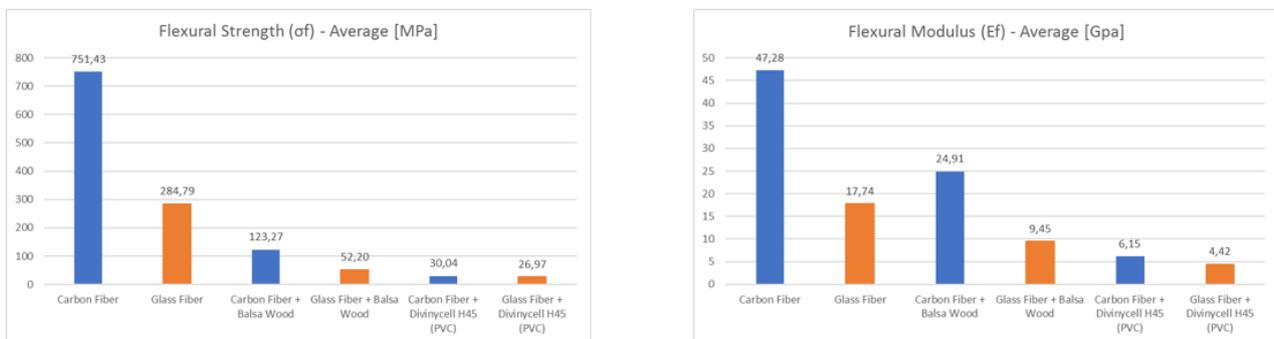


Figure 5: Properties Comparison of Flexural Tests

4 CONCLUSION

Tensile and flexural tests are so far the most important techniques used to estimate the relation of stress/strain of composite materials.

The purpose of this work was to evaluate and compare laminated and sandwich beams composites in order to identify the composite with finest properties by tensile and flexural tests. The main idea was to use carbon and glass fiber reinforced matrix as control specimens and compare with sandwich beams made of balsa wood and divinycell H45 core with carbon fiber and glass fiber skins evaluating tensile and flexural strength, tensile and flexural modulus as well the mass of each specimen.

Assuming the properties mentioned before the carbon fiber reinforced matrix has the finest properties of all, but mass, in this case, is an important property because the aim of this paper is aerospace engineering. So, by the mass, and other properties showed in this paper, the sandwich beam composed by Divinycell H45 core and carbon fiber skin is the composite laminated with the finest properties.

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