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Composite Material Based on a Matrix of Resin Polyester Reinforced With Cabuya and Paja Toquilla Fibers

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Abstract

This paper contains the tension analysis of a new composite material based on a mixture of polyester resin reinforced by vegetal fiber, and its comparison with the pure polyester resin tension resistance. The analysis was made on mixtures with fiber weight percent of 5, 12, 15, and 20; the specimens were built using a cold compress process; and ASTM standard test methods were used for analysis.

Keywords: composite material, polyester resin, Cabuya (fourcroia mercadilla) fiber, Paja Toquilla (Carloduvica palmata) fiber, biodegradable

1. Introduction

This investigation was focused on the use of natural fibers as reinforcement for transparent unsaturated polyester resin RPDT 2350; particularly Cabuya and Paja Toquilla fibers that grows in the Ecuadorian region. This paper attempts to make a contribution to the world tendency of creating new materials based on polymer matrix reinforced by vegetal fiber (Jasso, Hernández, San-Juan, Gonzalez, & Mendizábal, n.d.).

Taking into consideration the increased contamination caused by industrial rubbish usually built with fiberglass, aluminum, or plastic materials (Grimm, Bonelli, & Cukierman, 2001); the creation of new materials friendly with the ecosystem but with similar mechanical characteristics becomes relevant.

Vegetal fiber is characterized by a fast biodegradation, due to microorganisms, under solar radiation and rain, this feature make them a suitable choice to be used as reinforcing material (Quesada, Alvarado, Sibaja, & Vega, 2005). Resin polyester was used as base material because of its cost, weight, hardness and resistance (Gómez, Jarones, & Gañan, 1998; Guerrero, Pontón, Tamayo, Villacís, Delgado, & Galeas, n.d.), as well as optimal final condition and easiness of handling.

The Paja Toquilla fiber used has 1.5 mm diameter while the Cabuya fiber has 0.9 mm, the fibers did not undergo drying or chemical treatment, as it tries to use the raw material as is produced by farmers in Ecuador. The specimen has a length of 300 mm, a width of 25 mm, and a thickness of 2.5 mm as shown in the norm ASTM D3039/D3039M – 95a.

Pure resin polyester and composite material specimens containing different concentration of vegetal fiber were assembled. Later, a strain-stress test to define the maximum resistance of the specimens was performed. Finally, the optimal concentration of vegetal fiber to reinforce the resin polyester material was established.

2. Specimens Preparation

The transparent polyester resin RPDT 2350 was set with Methyl Ethyl Ketone (Mek) Peroxide, as the catalyzer; also cobalt (with a 12% concentration) was used to accelerate the reaction, and industrial grade S styrene to improve the material mechanical properties and to reduce the bubbles that could appear in the mixture. The mixture was introduced in the matrix and then compacted by a 10 tons pressure during three hours obtaining a 1.28 (g/cm^3) density resin. The mixture was prepared with 41% of styrene 0.6% of cobalt, 5 % of mek peroxide, and resin as the remaining part. The percentages were calculated for the resin weight.

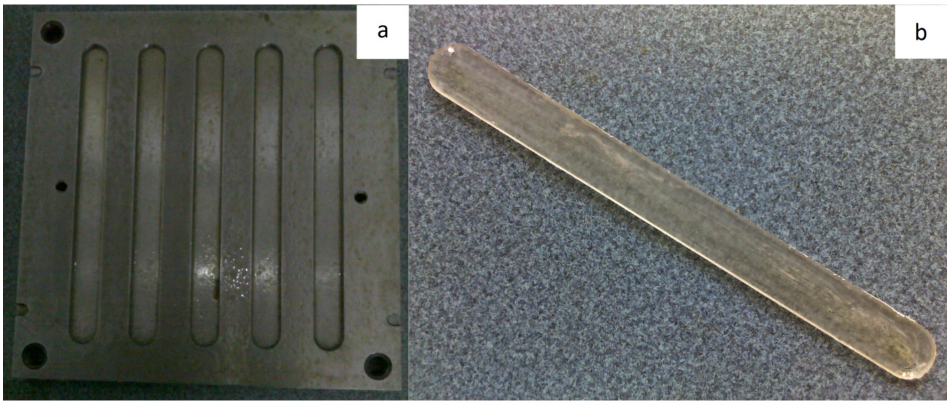

Figure 1. (a) Matrix specimen and (b) Pure resin specimen

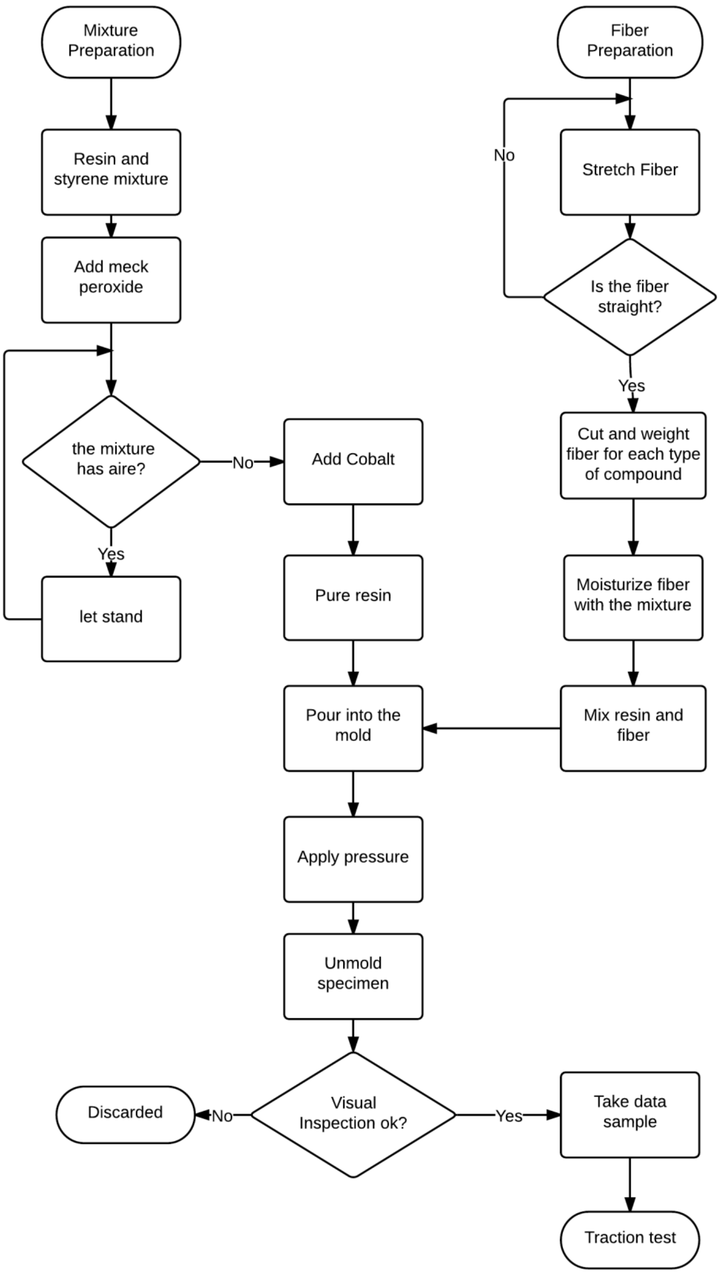

Figure 2. Specimen preparation process

The composite material was reinforced in two different ways and using two different vegetal fibers. First, long pieces of vegetal fiber were added longitudinally; second, small pieces of vegetal fiber were added randomly but uniformly. Specimens with different concentration of vegetal fiber (fiber weight percent of 5, 12, 15, and 20%) were elaborated on both cases.

To reinforce material with Paja Toquilla fiber, pieces of 300 mm long (matrix dimension) were cut. The pieces were added to the mixture uniformly in such a way that they were kept stretched. To reinforce the material in a random way, pieces of 10 mm long were cut and add to the mixture uniformly.

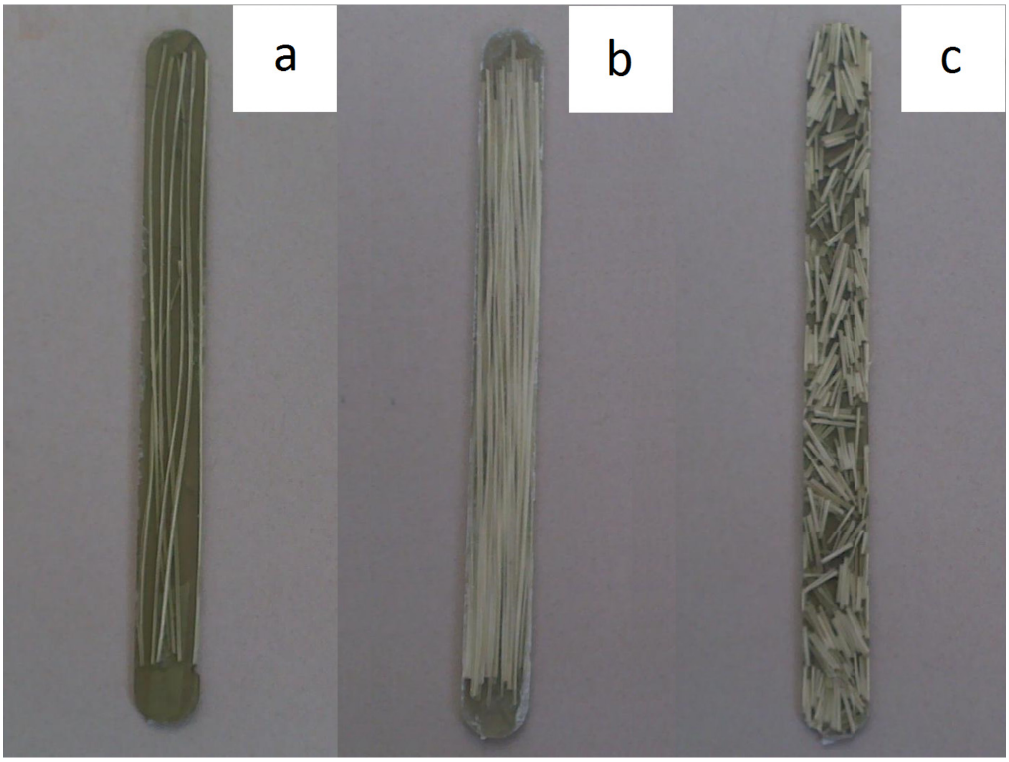

Figure 3. (a) Reinforced Specimen with 5% Paja Toquilla fiber,
(b) Reinforced Specimen with 20% unidirectional distribution Paja Toquilla fiber and
(c) Reinforced Specimen with 20% Paja Toquilla fiber and random distribution

To reinforce the material with Cabuya fiber, pieces of 300 mm long were cut and maintained stretch for four days to avoid bending when introducing to the matrix. Additionally the fiber was introduced into the resin mixture before adding it to the matrix. To reinforce the material in a random way, pieces of 10 mm long were prepared and add to the mixture uniformly. The Cabuya fiber density is 1.24 (g/cm^3).

The specimens were prepared according to technical specifications ASTM D3039/D3039M – 14, "Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials" (ASTM) (ASTM International, n.d.).

The tensile stress test was performed on 10 specimens of each one of the 5 kinds of materials. It is important to underline that were used only specimens that did not present air bubbles or fissures, and the dimensions corresponding to the ASTM D3039/D3039M – 95^a standard. The tests were performed in the universal machine WAW– 600C.

The minimal and maximal values were eliminated from the results according to the sampling theory.

3. Results

Tensile stress tests for the resin polyester specimens were performed. The maximal strain-stress was established to be 19.65 MPa (σmax=19.65 MPa) and a maximal force of 1282.5 N. The value agrees with the provider information which affirms a maximal strain-stress value of 17MPa $\leq \sigma \leq$21MPa. Then tensile stress test was performed for the composite material specimens reinforced with vegetal fiber. Results are presented in Figure 4.

The dependence of maximal tensile stress on the percentage of vegetal fiber in the composite is represented in Figure 4. A comparison of the maximal tensile stress of the composite materials and the pure resin polyester is represented in Figure 5.

The Paja Toquilla fiber random distribution specimens broke at the beginning of tensile test, only the value for the 12% reinforced specimen was obtained as shown on Figure 4.

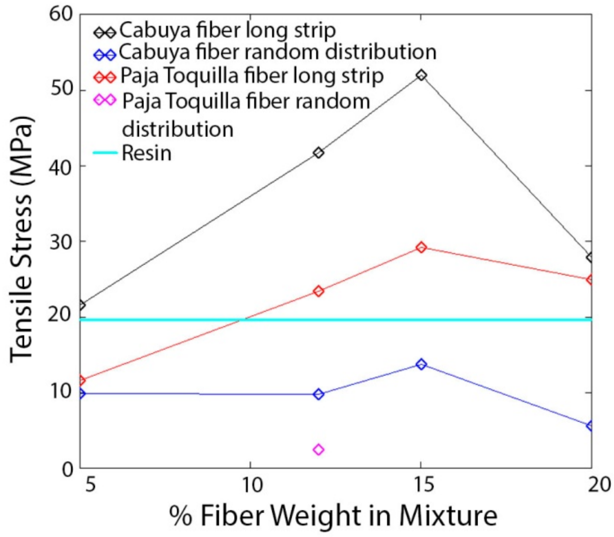

Figure 4. Tensile Stress vs Fiber percent weight

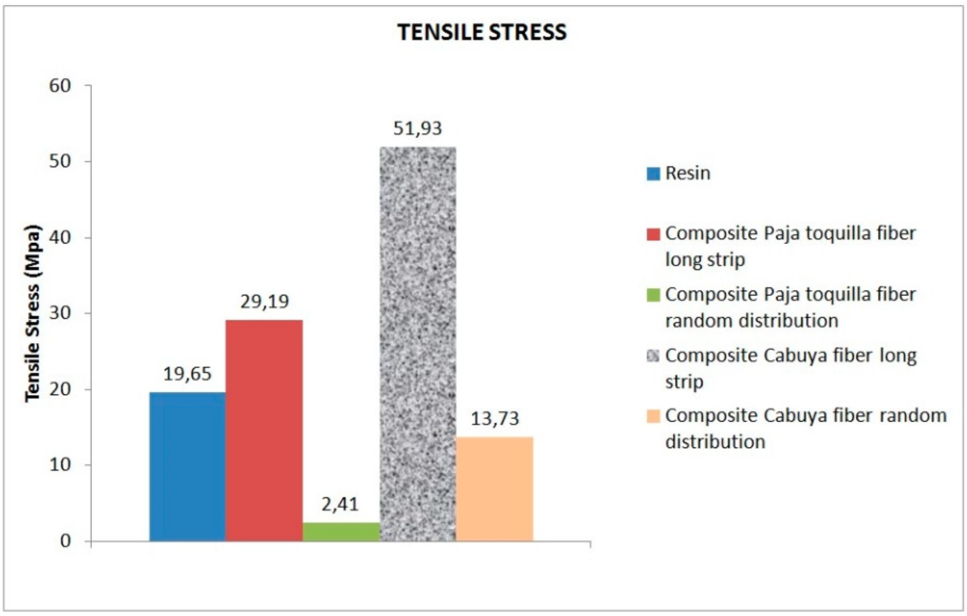

Figure 5. Tensile stress maximum values

3.1 Discussion

The maximal tensile stress of the composite material reinforced by Cabuya fiber is almost 3 times bigger than the tensile stress of pure resin Polyester with a 15% fiber concentration. This is related to the fact that Cabuya fiber adheres with resin polyester in a proper way because of its high cellulose percentage and its fluid absorption around 60% which improves the adhesion between phases (Hidalgo, Muñoz, & Quintana, 2012).

The optimal concentration of vegetal fiber was established to be 15%, over this value the resin polyester does not cover all the fiber creating empty spaces that reduce the material resistance.

It is possible to observe that the tensile stress curve for the composite material reinforced by the Paja Toquilla fiber in a random way is represented by a point in Figure 4. The small Paja Toquilla pieces decrease the material resistance considerably, due to the high moisture on the fiber, around 5.33%, involving problems on adherence between the matrix and the fiber, on this kind of application a moisture smaller than 1% is required (López, Sarmiento, Fajardo, Valarezo, & Zuluaga, 2013).

Furthermore, the Paja Toquilla fiber is classified as hard fiber that together with the poor adherence causes stress concentrator in the form of micro cracks weakening the matrix.

4. Conclusions

- The Cabuya fiber and Paja Toquilla fiber increase the mechanical resistance of resin polyester at 164% and at 48% respectively.

- The new material can be used in industrial appliances if the tensile stress does not exceed 50MPa.

- The Mechanical Resistance could be improved using the Paja Toquilla fiber with a previous drying treatment that could eliminate 75% of the moisture (Boero, & Duque, 2008), also it could be convenient decreasing the fiber diameter from 1.5 mm to 0.9 mm.

- It is not recommended any chemical treatment to fibers because it will reduce the traction resistance (Jasso, Hernández, San-Juan, Gonzalez, & Mendizábal, n.d.), instead, the fiber should be moistened with the same matrix compound.

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