COMPARATIVE ANALYSIS OF BIO-BASED COMPOSITES REINFORCED WITH COTTON FIBER

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Abstract: *Within this paper, starting from two bio-based matrices, composite materials reinforced with cotton fibers will be manufactured. The hand lay-up technique will be used, and the final composite will be obtained by casting. After producing a composite plate, specimens will be cut and subjected to both destructive and non-destructive testing in order to determine the mechanical properties. The influence of the bio-based matrices on the mechanical properties will be discussed.*

Keywords: cotton fiber, bio-based composite, mechanical properties, strength

1. INTRODUCTION

The concept of a bio-based composite is introduced as a material consisting of two main components: a bio-based matrix (which itself is composed of two parts, one natural and one synthetic) and a natural reinforcement, the fiber selected for this study being cotton. In the specialized literature, the concept of a bio-based composite can also be encountered under the following terms: bio-composite, green composite, hybrid composite, eco-composites, sustainable composites, and so on.

Cotton is a naturally occurring lignocellulosic fiber whose structure is predominantly based on cellulose macromolecules composed of carbon, hydrogen, and oxygen. At the molecular level, the material consists of highly ordered linear chains containing thousands of repeating units, interconnected through strong intermolecular interactions, which contribute to its relatively good mechanical performance within typical application limits. The geometry of the fiber, characterized by a very high aspect ratio, provides enhanced flexibility, facilitates processing, and supports satisfactory durability in service [1].

From a dimensional standpoint, cotton fibers generally exhibit lengths in the range of approximately 22.9 to 38.1 mm, while their fineness typically falls between 100 and 200 millitex. In terms of mechanical behavior, the tensile strength of fiber bundles is commonly situated between 245–343 MPa, with extra-long staple varieties reaching values close to 392 MPa. The elongation at break is usually limited, with values ranging from 4% to 6% [1-3].

Owing to its natural origin and favorable aesthetic characteristics, cotton remains one of the most widely used fibers in conventional textile applications, particularly in the manufacture of garments. Additionally, it is extensively employed in domestic and interior products, including towels, bedding materials, and upholstery. More recently, attention has been directed toward its integration into technical applications, such as fire-resistant textiles and flooring systems. In these cases, performance improvements are achieved through chemical modifications, including treatments with compounds such as Proban or Pyrovatex, which enhance flame resistance. Furthermore, cotton can be combined with other fibers, such as wool or low-melting-point polyester, enabling its use in composite textile structures without requiring additional finishing treatments [2-4].

Within this study, two types of composite materials will be manufactured, maintaining the same natural reinforcement (cotton fiber) while varying the type of bio-based matrix. The first type consists of 50% dammar and 50% Resoltech epoxy resin, while the second type consists of 60% dammar and 40% Resoltech epoxy resin. The materials will be abbreviated as BBR50 and BBR60 (according to the dammar resin content), followed by the letter C, which denotes the cotton fiber reinforcement. For the fabrication stage, the hand lay-up technique was employed, consisting of applying resin over the first reinforcement layer, followed by placing a second reinforcement layer and applying resin again. This process was repeated for a total of 24 layers. The final assembly was then pressed and removed from the mold after 5 days.

2. MATERIALS AND METHODS

Specimens for tensile, flexural and shore D hardness testing were cut from the obtained plates. An overview of the specimens used for tensile testing is presented in Figure 3. The ASTM D3039 standard was used for tensile testing, ASTM D790 for bending test, and ASTM D2240 for Shore D hardness measurements [5]. Destructive tests were carried out using an Instron universal testing machine. For each type of destructive test, ten specimens were used (see Figure 1).

3. RESULTS

For the BBR60C composite, the tensile behavior was characterized by an average breaking strength of 52.9 ± 2.28 MPa, a Young’s modulus of 4820 ± 133 MPa, a Poisson’s ratio of 0.355 ± 0.030, and an elongation at break of 3.36 ± 0.12

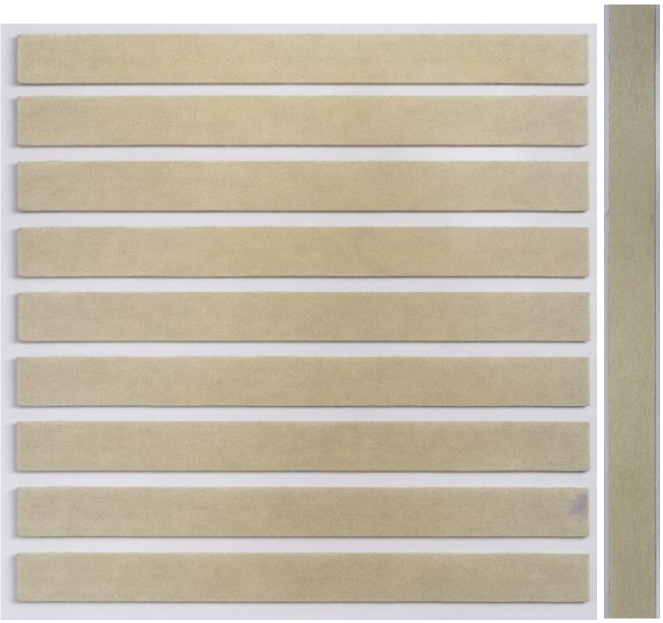

Fig. 1. Samples used for the tensile test (50:50 ratio)

%. In contrast, the BBR50C formulation exhibited improved mechanical performance, with average values of 57.8 ± 1.32 MPa for tensile strength, 5270 ± 106 MPa for Young’s modulus, 0.354 ± 0.022 for Poisson's ratio, and 2.96 ± 0.11% for elongation at break. A comparative overview of these results is presented in Figure 2. The comparison highlights that the BBR50C material demonstrates superior strength and stiffness relative to BBR60C, accompanied by a decrease in elongation at break. This behavior indicates a transition toward a more rigid and less ductile material as the epoxy resin content increases.

Under bending loading, the BBR50C composite (containing a bio-based matrix composed of 50% dammar and 50% Resoltech 1050 epoxy resin) exhibited deformation values ranging from 12.1 to 12.6 mm, with an average of 12.3 ± 0.18 mm. The corresponding maximum loads at failure were between 321.4 and 335.8 N, yielding a mean value of 328.2 ± 4.5 N. These values translated into flexural strengths within the interval of 75.2 to 79.6 MPa, with an average of 77.2 ± 1.39 MPa.

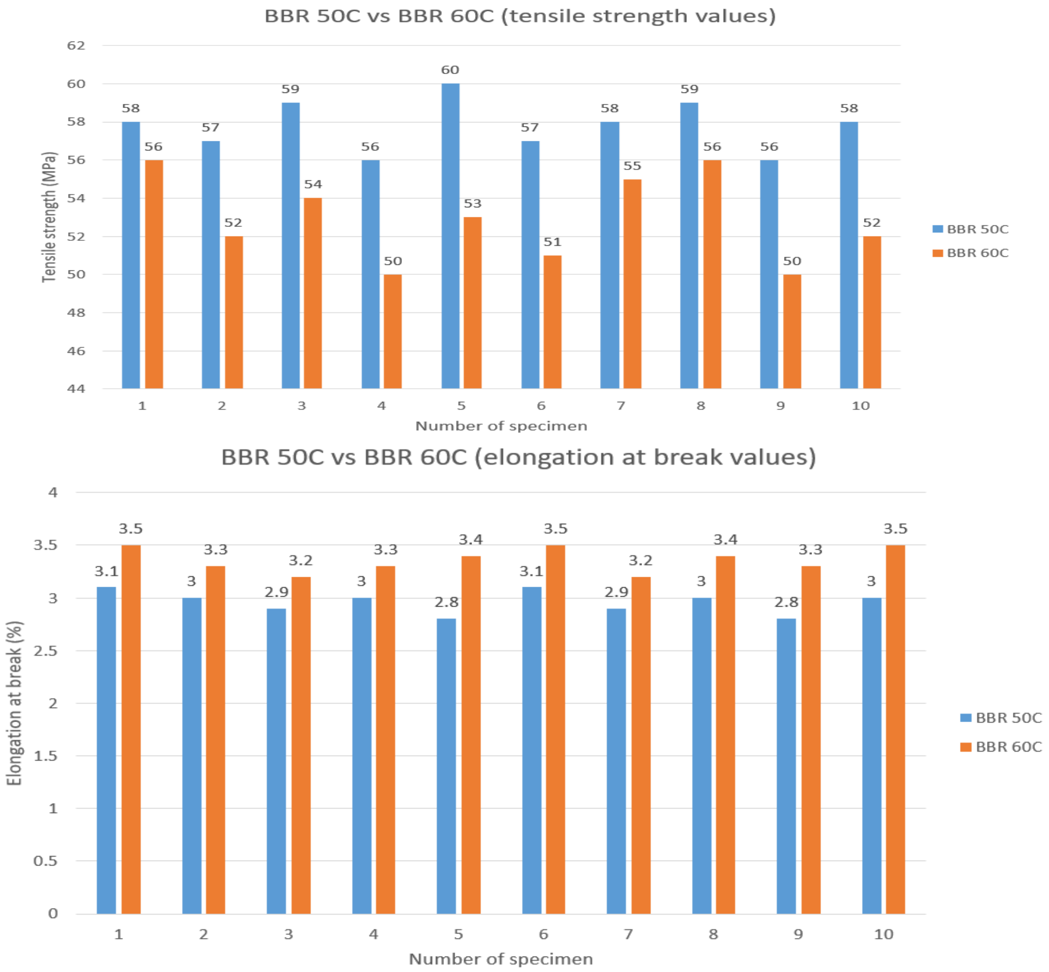

Fig. 2. Comparison of tensile strength and elongation at break for BBR50C and BBR60C formulations.

In comparison, the BBR60C formulation (based on 60% dammar and 40% Resoltech 1050 epoxy resin) showed slightly higher deformation values, ranging from 12.4 to 12.9 mm, with a mean of 12.65 ± 0.16 mm. At the same time, lower maximum loads were recorded, varying between 305.6 and 316.3 N, with an average of 310.9 ± 3.48 N (Figure 3). Consequently, the flexural strength values were reduced, falling within the range of 70.8 to 73.5 MPa, with a mean value of 72.1 ± 0.9 MPa. Overall, the results indicate that increasing the dammar content leads to a slight increase in deformation capacity, accompanied by a decrease in load-bearing capability and flexural strength.

Shore D hardness was determined using a single specimen for each composite variant (BBR50C and BBR60C). Five measurements were performed along the longitudinal direction of the specimen, at its mid-width. This sampling approach was deemed sufficient due to the high consistency of the obtained values and complies with the minimum requirements imposed by the ASTM standard. The results reveal that the BBR50C formulation presents higher hardness values (64.4 ± 0.89) in comparison with BBR60 (59.3 ± 0.84) (Figure 4). This behavior indicates that a higher epoxy resin content contributes to an increase in material rigidity and surface hardness. Moreover, the relatively small standard deviation observed for both materials highlights the good reproducibility of the measurements and the uniform structure of the specimens. The lower hardness recorded for BBR60C correlates with its higher elongation at break, supporting the conclusion that this material exhibits a more flexible and less stiff mechanical response.

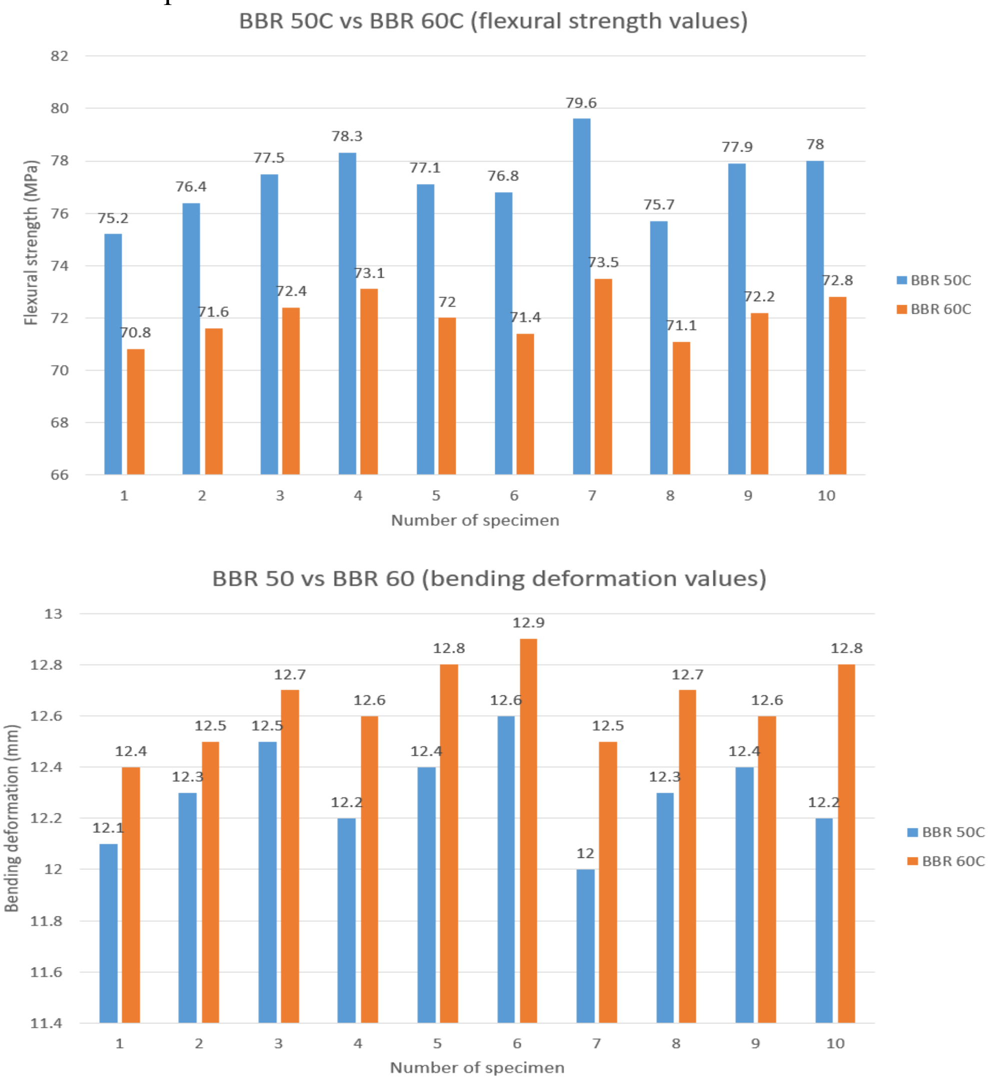

Fig. 3. Comparison of flexural strength and bending deformation for BBR50C and BBR60C formulations.

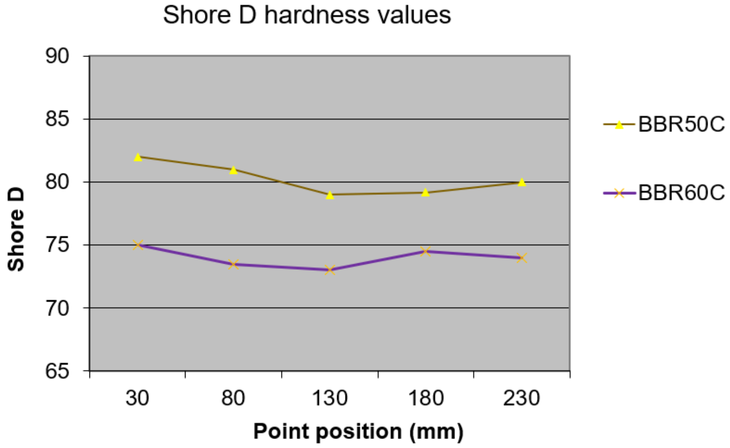

Fig. 4. Comparison of shore D hardness for BBR50C and BBR60C formulations.

4. CONCLUSIONS

The results highlight that the mechanical behavior of the investigated composites is strongly influenced by the bio-based matrix composition. The BBR50C formulation, with a higher epoxy content, exhibited superior tensile strength, Young's modulus, flexural strength, and Shore D hardness, indicating increased stiffness and load-bearing capacity. In contrast, the BBR60C composite showed higher elongation at break and bending deformation, reflecting a more compliant and ductile response. The low standard deviation values confirm the good repeatability of the experimental results and the uniformity of the material structure. Overall, adjusting the dammar-to-epoxy ratio allows tailoring the balance between stiffness and flexibility, depending on the intended application.

5. REFERENCES

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