COMPARATIVE ANALYSIS OF BIO-BASED RESINS FOR POTENTIAL USE AS MATRICES IN COMPOSITE MATERIALS

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Abstract *This study explores the potential of natural resins to be used as components in the development of new bio-based resins suitable for composite material matrices. The initial form of the natural resin is first described, followed by the processing steps required to make it suitable for composite fabrication. After polymerization, test specimens are prepared and evaluated in order to assess their mechanical properties.*

Keywords: natural resin, bio-based resin, mechanical properties, strength

1. INTRODUCTION

It is well known that a bio-based resin suitable for use as a matrix in composite materials can be formulated from two main components: a natural component (such as plant- or animal-derived resin) and a synthetic one. In this study, dammar resin is used as the natural component for the development of bio-based resins with potential as matrices, which can be further employed in the fabrication of composite materials.

Dammar resin is a natural resin obtained from trees belonging to the Dipterocarpaceae family, primarily found in India. The resin forms on the surface of the tree bark and, following oxidation and the evaporation of volatile compounds, hardens and is collected directly in the form of solid lumps or “stones”. In this solid form, however, the resin cannot be used directly as a component in bio-based resins, so it first needs to be brought into a liquid state to allow proper mixing. In this regard, it can be mixed with a solvent (such as turpentine derived from pine buds or ethanol), which facilitates its dissolution [1-3].

All these aspects are schematically presented in Figure 1. One of the main drawbacks of natural resins is their long curing time or their tendency to cure incompletely, meaning they do not always form a fully crosslinked network [4-6]. For this reason, in order to obtain a solid material, the natural resin was combined with a proportion of synthetic resin (Resoltech 1050 epoxy resin in this study).

The dammar resin, previously brought into a liquid state, was mixed with the synthetic epoxy resin in a container and then poured into a mold (see the schematic in Figure 2) [4].

In this study, ratios of 50:50 and 60:40 (dammar resin: epoxy resin) were used. These formulations are hereafter referred to as BBR 50 and BBR 60.

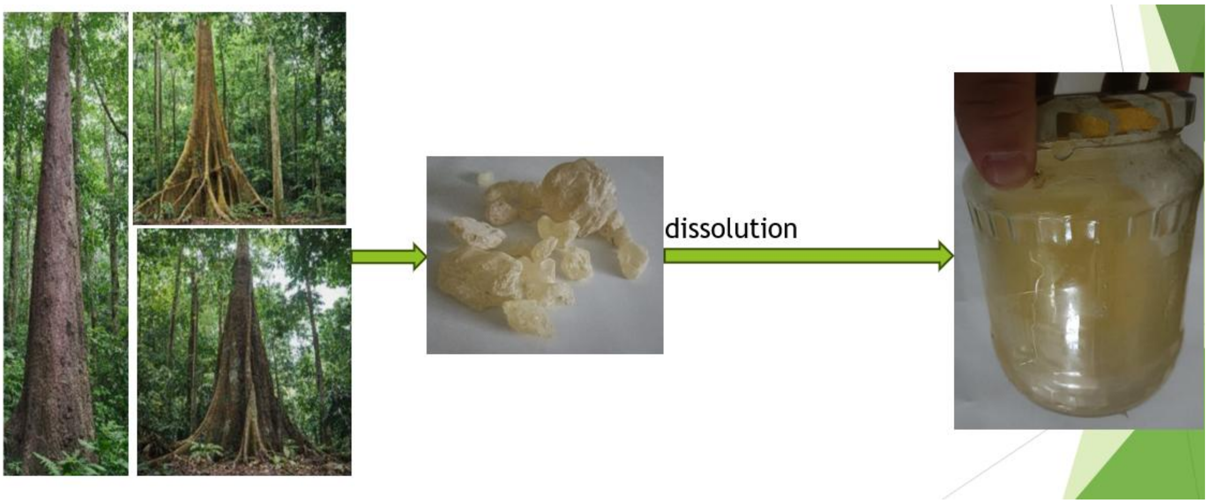


Fig. 1. Schematic representation of bringing dammar resin into a liquid state

Fig. 2. Schematic representation of the preparation of a bio-based dammar–epoxy resin in a 50:50 ratio

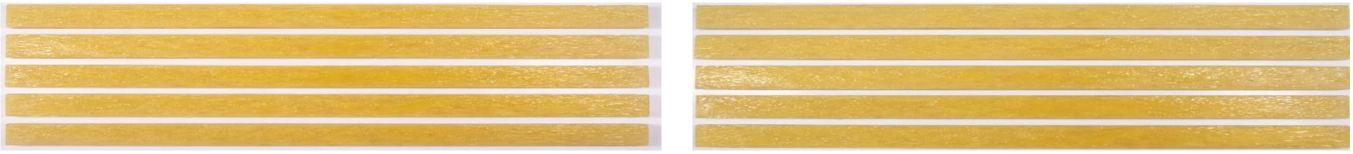


Fig. 3. Samples used for tensile or Shore D hardness test (50:50 ratio)

2. MATERIALS AND METHODS

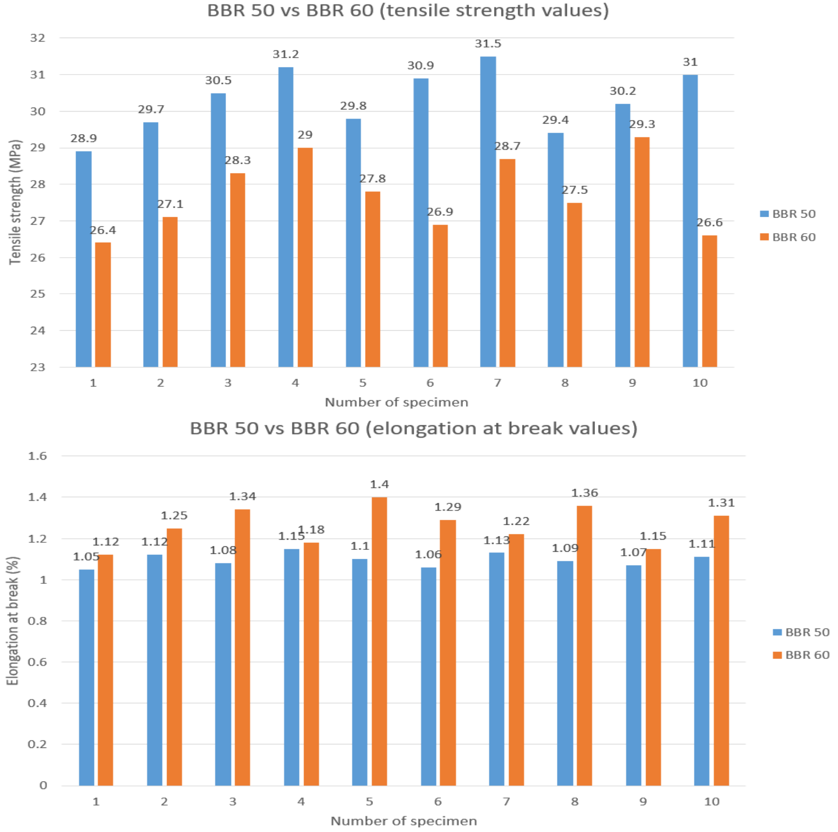
Specimens for tensile, Shore D hardness and compressive testing were cut from the obtained plates. An overview of the specimens used for tensile testing is presented in Figure 3. Similar specimens were used for Shore D hardness.

The compression specimens, shown in Figure 4, are significantly shorter, as this geometry was chosen to avoid the occurrence of buckling. It is well known that short specimens tend to fail by compression rather than by buckling. The ASTM D3039 standard was used for tensile testing, ASTM D695 for compression, and ASTM D2240 for Shore D hardness measurements. Destructive tests were carried out using a Laryee universal testing machine. For each type of destructive test, ten specimens were used (see Figures 3 and 4).

Fig. 4. Samples used for compression test (50:50 ratio)

3. RESULTS

In the case of the BBR60 formulation, the mechanical properties showed average values of 27.76 ± 1.03 MPa for the tensile breaking strength, 1789.4 ± 16.2 MPa for the Young's modulus, 0.490 ± 0.005 for the Poisson's ratio, and 1.26 ± 0.09% for the elongation at break. For the BBR50 formulation, the average values obtained were 31.07 ± 0.93 MPa for the breaking strength, 1864.6 ± 13.6 MPa for the Young's modulus, 0.483 ± 0.004 for the Poisson's ratio, and 1.10 ± 0.03% for the elongation at break. A comparison between the two types of materials is given in Figure 5.



BBR 50 vs BBR 60 (tensile strength values)

BBR 50 vs BBR 60 (elongation at break values)

Fig. 5. Comparison of tensile strength and elongation at break for BBR50 and BBR60 formulations.

Compared to BBR60, the BBR50 formulation exhibits higher breaking strength and Young's modulus, along with a reduction in elongation at break, suggesting increased stiffness and reduced ductility.

In the case of compression test, for the BBR50 formulation, the shortening at fracture was 1.518 ± 0.023 mm. The compressive breaking force reached 5736.5 ± 148.7 N, while the corresponding compressive strength was 33.55 ± 0.72 MPa. For the BBR60 formulation, the shortening at fracture was 1.586 ± 0.022 mm. The compressive breaking force reached 5441.0 ± 101.4 N, while the corresponding compressive strength was 31.81 ± 0.61 MPa. Compared to BBR50, the BBR60 formulation showed a slightly higher shortening at fracture, while both the maximum compressive breaking force and compressive strength were lower. This suggests a less rigid behavior under compression, probably due to the higher proportion of dammar resin.

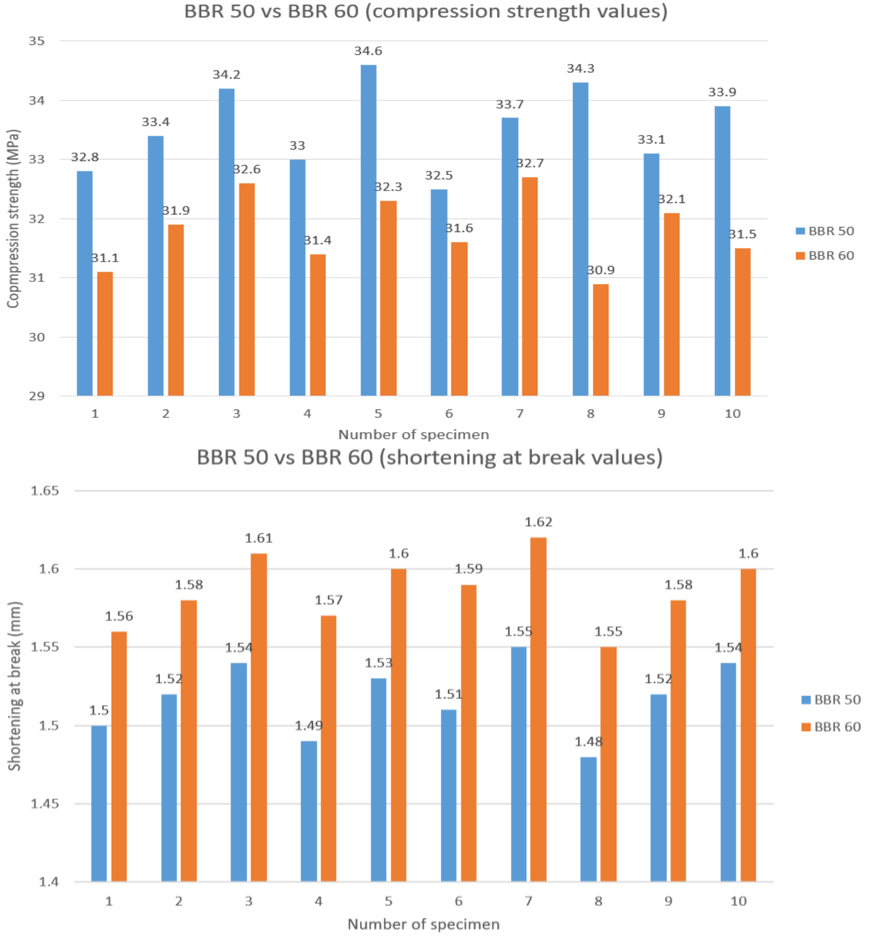


Fig. 6. Comparison of compression strength and shortening at break for BBR50 and BBR60 formulations.

Shore D hardness was evaluated on one specimen for each material type (BBR50 and BBR60). Measurements were taken at five points along the specimen length, at mid-width.

This number of measurements was considered adequate due to the good consistency of the results and is in line with the minimum requirement specified by the ASTM standard. The Shore D hardness values indicate that the BBR50 formulation exhibits higher hardness (64.4 ± 0.89) compared to BBR60 (59.3 ± 0.84) (see Figure 7). This suggests that the increased proportion of epoxy resin leads to a stiffer and harder material. The relatively low standard deviation values in both cases indicate good repeatability and uniformity of the tested specimens. The decrease in hardness for BBR60 is consistent with its higher elongation at break, confirming a more compliant and less rigid material behavior.

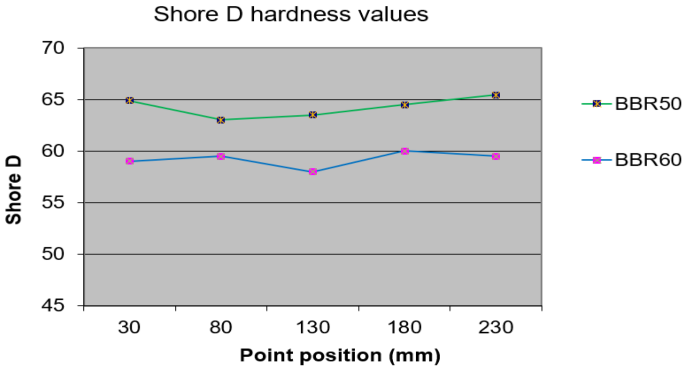


Fig. 7. Comparison of Shore D hardness for BBR50 and BBR60 formulations.

4. CONCLUSIONS

The results obtained in this study confirm the potential of natural resins, such as dammar, to be used in combination with synthetic resins for the development of bio-based composite matrices.

The experimental data showed that the resin composition has a significant influence on the mechanical behavior of the material. Increasing the proportion of epoxy resin (BBR50) led to higher tensile strength, Young's modulus, compressive strength, and Shore D hardness, indicating a stiffer and stronger material. On the other hand, a higher content of natural resin (BBR60) resulted in increased elongation at break and higher shortening at fracture, suggesting a more compliant and less rigid behavior. These findings highlight a clear trade-off between stiffness/strength and ductility, depending on the ratio between natural and synthetic components. Overall, the developed bio-based resins show promising properties and can be considered viable candidates for use as matrices in composite materials, especially in applications where a balance between mechanical performance and sustainability is required.

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