

Experimental Research into the Mechanical Behaviour of Dammar and Sandarac - Based Bio Resins

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In this paper, we examine two types of Dammar-based bio resins. In the first type, Dammar alone is used as natural resin, while in the second type a mixture of 70% Dammar and 30% Sandarac is used. Three sample sets were made of each of these resins with a bio resin volume proportion of 55, 65 and 75% respectively, the rest being epoxy resin (used, together with the associated reinforcing material, to generate a quick polymerization process). A SEM analysis is carried out and the surface roughness of each of the studied materials. A series of mechanical properties, determined by tensile testing, are presented. We have determined the characteristic curves, tensile strength and modulus of elasticity and the influence of the epoxy resin volume proportion on the mechanical behaviour of bio resins.

Keywords: *bio resin, mechanical properties, roughness*

In the last decades great attention has been paid to composite materials, the components of which, whether matrix or reinforcing material, come from nature. The main advantages of using green composites are given by the fact that both the fibers and the bio resins are abundantly produced by nature, consequently they have a low cost of manufacture compared to synthetic composites. Moreover, they are totally biodegradable and have relatively good mechanical properties. Most composite materials that have been studied so far have focused on natural fibers as reinforcing materials, only in combinations with thermoplastic matrix (polypropylene, polyethylene and vinyl polychloride) or with a thermo-rigid (phenolic, epoxy and polyester resins) (see example [1]). Synthetic resins have the disadvantage of a processing limit due to the high viscosity at meltdown, phenomenon appearing when cast by injection, and the final product is hard to recycle. This disadvantage may be eliminated by using biological thermo-rigid matrices based on vegetable-oil resins since the latter are bio-degradable and, therefore, the polymerization process is not necessary [2-4]. Bio resins are resins derived from a biological source and, consequently, can be biodegradable and compostable, thus, hypothetically, they can be decomposed after use. Natural resins can be fossil (amber), vegetable (Sandarac, Copal, Dammar), or animal Shellac). Natural resins are insoluble in water, however, they are slightly soluble in oil, slightly soluble in oil, alcohol and, partly, in petrol. They form solutions with certain organic solvents, solutions that can be used as covering lacquers. Turpentine, colophony, mastic is products resulted from the distillation of conifer resins. A study concerning the chemical composition of the properties of these resins is carried out in [5], and the applications are shown in [6].

The studies conducted on these resins have focused mainly on their chemical composition and their chemical properties and less on their mechanical properties. Thus, work [7] was intended to broaden the knowledge about

microbiological biodegradation of the lacquers based on Dammar in works of art subject to unsuitable protection conditions, particularly to long exposures to relative humidity. In [8] a new binder is introduced, modified from silicon and Dammar, which can reduce the use of the synthetic binder and which has improved, especially ecological, properties. The optimal composition of this binder, which ensures the best properties for impact, hardness, traction and adherence stresses, was determined. The way in which Dammar addition contributed to improve the rigidity, the modulus of elasticity and the hardness of modified silicon was studied in the work [9].

In [10] the Dammar gum is examined as supplementary material used for improving thermal conductivity and performance in preparing the material for changing the composite phase, while the possibility of using bee wax, tallow and Dammar as PCM (phase change materials) in concrete buildings is investigated in [11]. The effect of polymethyl-methacrylate (PMMA) on Dammar's physical properties for the application of covering lacquers was analysed in [12].

A model with free particles used for numerical simulation of charpy impact test of plastic materials is studied in [13].

Sandarac is presented in [14], as well as its uses and chemical composition in comparison with other very similar resins. An identification of Sandarac's main chemical components is performed in [15] and in [16] there is a qualitative and quantitative study on some Sandarac resin types with different origins.

The Young modulus for composite material constituent was obtained based on numerical analysis [17].

Still, there are not enough studies on the mechanical behaviour of natural resins. The mechanical characteristics (the tensile strength, percentage elongation and Young's modulus), the characteristics of water vapour transmission and the characteristics of moisture absorption of Dammar

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films containing softening agent were studied in the work [18]. The reaction to the compression stress of palm tree trunk treated with different amounts of Dammar resin was analysed in [19]. There are also few studies concerning composites with both their matrix and reinforcing material made of natural material. The mechanical behaviour of some composite materials with a bio resin matrix based on Dammar and with reinforcement made with cotton, flax, silk and hemp fabric is studied in [20] and [21].

Experimental part

To make the studied materials we used natural resins, namely Dammar and Sandarac. The first type of material was made by dissolving Dammar by turpentine. For the second type we dissolved a mixture of 70% Dammar and 30% Sandarac by turpentine too. We cast three plates of each these resins where the volume proportion of natural resin was 55, 65, 75% respectively. The difference up to 100% was made of Resoltech 1050-type epoxy resin together with its associated reinforcing material because natural resins dissolved in turpentine have a very long hardening time and the synthetic component generates points of quick activation of the polymerization process. We also made a specified epoxy resin plate, necessary for assessing the way in which natural resins influence mechanical behaviour. We made three sets of samples of the cast plates, which were submitted to experimental determinations. We will use the following symbols:

- DA 55- resin with a 55% volume Dammar proportion;
- DA 65- resin with a 65% Dammar volume proportion;
- DA 75- resin with a 75% Dammar volume proportion;
- DS 55- resin with a 55% volume proportion of a mixture, composed of 70% Dammar and 30% Sandarac;
- DS 65- resin with a 65% volume proportion made of a mixture of 70% Dammar and 30% Sandarac;

- DS 75- resin with a 75% proportion made of a mixture of 70% Dammar and 30% Sandarac.

Samples of each of the materials mentioned above here submitted to a SEM analysis that was performed by an electron microscope - Hitachi model S3400N/type II, having the following specifications:

- SE image resolution: minimum 3 nm at 3kV (100.000X, WD = 5mm, high vacuum mode);
- BSE image resolution: minimum 4.0 nm at 30kV (60.000X, WD = 5mm, low vacuum mode);
- Magnification Range: 5x to 300.000x;
- Accelerating Voltage: 0.3 kV to 30 kV.

As for the presented materials we measured the roughness of the representative samples. In order to do this we used a portable profilometer (Taylor Hobson Surtronic 3+) in which the analysed length varied between 0.25 mm and 25.4 mm, with a sensor speed of 1 mm/s (fig.1).

The examined samples underwent a tensile test, which was carried out according to the ASTM D3019 and ISO 527-4:1997 provisions. The elements obtained from this trial were: the characteristic curve, tensile strength R_m [MPa], percentage elongation after fracture A [%] and elasticity modulus E [MPa]. We used the LRX Plus testing machine from LLOYD Instruments with the following specifications:

- Force range: 2.5 kN;
- Travel: 1 to 735 mm;
- Crosshead speed: 0.1 to 500 mm / min;
- Analysis software: NEXYGEN.

Results and discussions

Figure 2 shows images obtained on the basis of the SEM analysis of the epoxy resin (fig. 2.1), the bio resin made of Dammar only (fig. 2.2) and the bio resin with 70% Dammar and 30% Sandarac (fig. 2.3).



Fig. 1. Portable profilometer (Taylor Hobson Surtronic 3+)

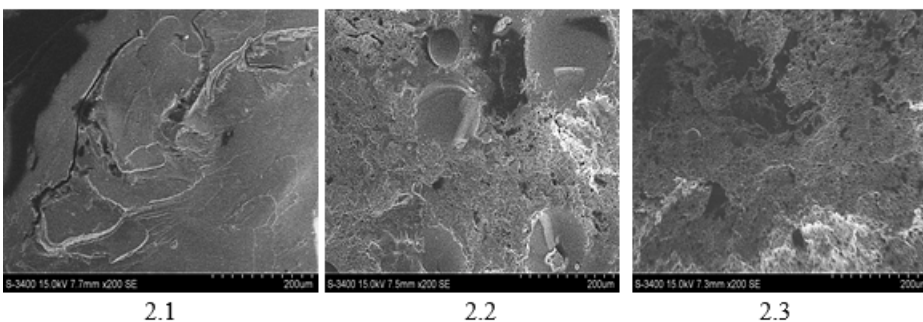


Fig.2. Images obtained by SEM analysis of the three resin types

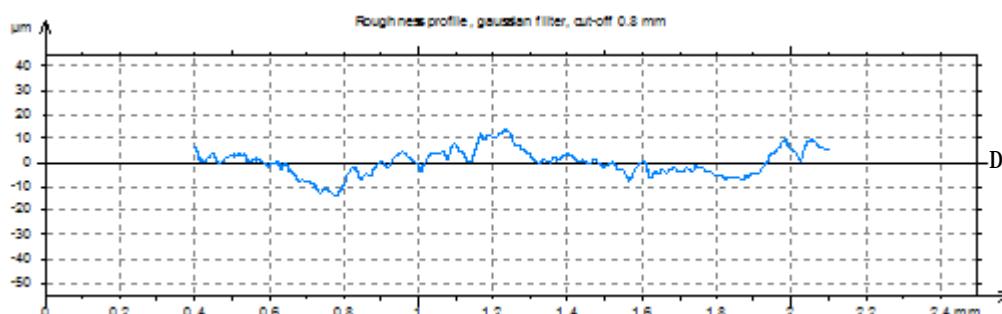


Fig. 3. Roughness diagram of a Dammar natural resin with a volume proportion of 55%

We can see that in the case of the bio resins there is a significant amount of air pockets. This can be explained by the fact that the polymerization takes place more slowly, the hardening of the resin takes a longer time and it is no longer possible to eliminate the air pockets.

In figure 3 we show the roughness diagram obtained for a Dammar natural resin with a volume proportion of 55%.

Table 1 presents the results of the arithmetic mean deviation of the evaluated profile R_a , in μm (the arithmetic mean of the profile absolute values of the profile ordinates), of the studied materials.

Table 1

THE ARITHMETIC MEAN DEVIATION OF THE EVALUATED PROFILE

R_a , in μm

Resin type	The arithmetic mean deviation of the evaluated profile R_a [μm]
DA 55	3.38
DA 65	2.84
DA 75	2.48
DS 55	1.94
DS 65	2.12
DS 75	1.42
epoxy	1.76

We observe an increase in porosity, compared with the epoxy resin, for all the samples containing natural resin. An explanation may be the polymerization time necessary for resin hardening. Thus, in the case of the epoxy resin the hardener produces a quick reaction, the air pockets being eliminated shortly, before the complete hardening of the resin, which happened in less than 24 h. In the case of the mixtures of synthetic and natural resins the reaction time is longer, the hardening taking place in 72 - 96 h. Since the reaction is longer, the viscosity has gradually increased until complete hardening. We can see an increase in the surface roughness of the natural resin plates in comparison with the plate obtained from epoxy resin.

Henceforward, by representative sample of a set we understand the sample with the medium values of the studied mechanical properties.

The characteristic curves of each representative sample of the three sets made of Dammar-based resin are shown in figures 4 - 6.

Figures 7 - 9 show the characteristic curves of one representative sample of each of the three sets, made on the basis of the mixture of 70% Dammar and 30% Sandarac.

Fig. 7. Characteristic curve of a DS 55 resin sample

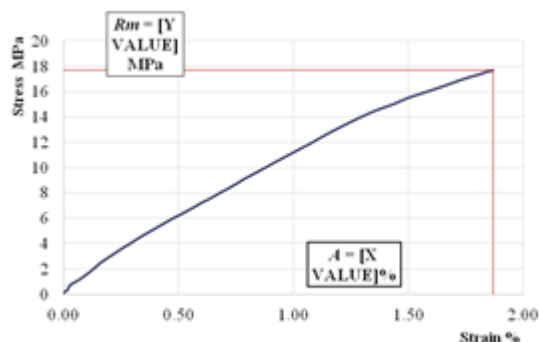
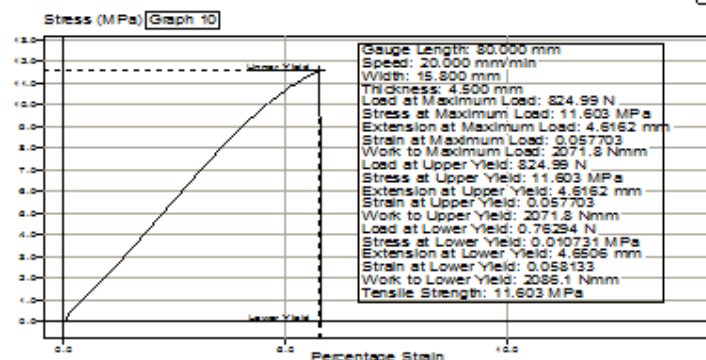


Fig. 4. Characteristic curve of DA 55 resin sample

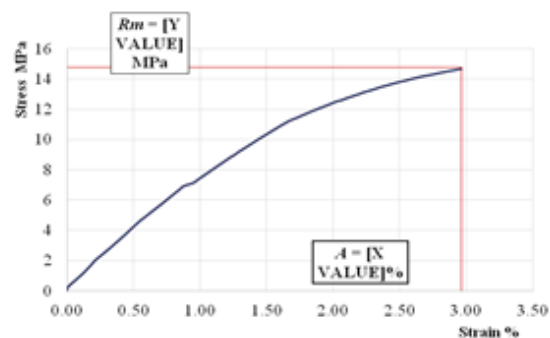


Fig. 5. Characteristic curve of DA 65 resin sample

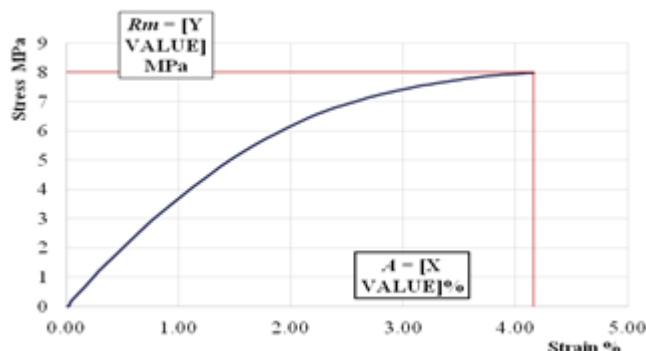


Fig. 6. Characteristic curve of DA 75 resin sample

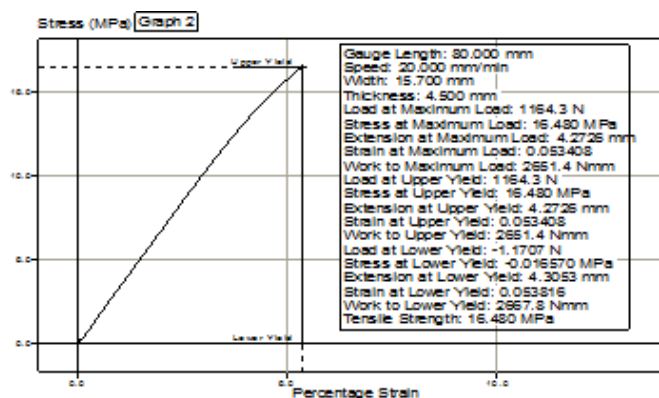


Fig. 8. Characteristic curve of a DS 65 resin sample

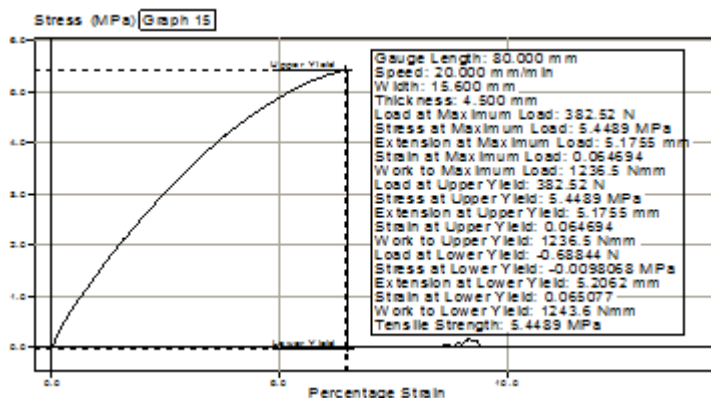


Fig. 9. Characteristic curve of a DS 75 resin sample

Resin	Tensile strength R_m [MPa]	Elongation at break A [%]	Modulus of elasticity E [MPa]
DA 55	17.2-18.3	1.87-2.18	1550-1660
DA 65	13.9-14.8	2.68-3.04	1140-1230
DA 75	7.60-8.20	4.16-4.92	590-720
DS 55	15.90-17.18	4.73-5.34	800-850
DS 65	11.60-12.31	5.45-5.77	560-610
DS 75	5.44-5.90	6.46-7.30	290-310
Epoxy	47.8-51.8	1.52-1.81	3230-3470

Table 2
EXPERIMENTAL RESULTS OF THE TENSILE TESTS

Table 2 shows the results obtained after tensile tests. The highest values of the mechanical properties are obtained for the mixture with 55 % Dammar (DA 55). In comparison with the epoxy resin, the tensile strength is 36% and the modulus of elasticity is 71%. In the case of the mixture with 65% Dammar (DA 65) the tensile strength is 29% and the modulus of elasticity is 71%. In the case of the mixture with 75 % Dammar the tensile strength is 16% and the modulus of elasticity is 29%. An even more important decrease in properties appears in the case of the resin based on the mixture of Dammar and Sandarac. Comparing with the Dammar-based resin with the same proportion of epoxy resin, the tensile strength went down by 7 % in the DS 55 resin, by 17 % in the DS 65 resin and by around 28 % in the DS 75. Moreover, the moduli of elasticity of the resins based on the mixture of Dammar and Sandarac are half in comparison with the resins based on Dammar only. The increase in the air volume in bio resin, at the same time with the increase in the volume proportion of Dammar or Dammar and Sandarac, may explain this decrease.

Conclusions

The use of natural resins for the manufacture of composite materials can be influenced by the resin properties and the capacity to create a synergetic effect together with the reinforcing materials. The analysis of the results we obtained show an important variation of the properties depending on the proportion between the natural and the synthetic resin.

Comparing the experimental results shows a significant modification of the mechanical properties when changing the proportion between epoxy resin and natural resins. We notice a decrease in the values of the tensile strength and the modulus of elasticity as the natural resin proportion is increased in the mixture. Although the mixtures with a higher amount of epoxy resin have superior mechanical properties, we cannot say that there is proportionality between tensile strength, or modulus of elasticity and the volume proportion of epoxy resin.

There are the modifications in the forms of the characteristic curves. If in the DA 55 and DS 55 resins, where the natural resin proportion is 55 %, the characteristic curve is almost linear, in the DA 75 and DS 75 resins, where

the natural resin proportion is 75 %, there is an obvious nonlinearity of the characteristic curve which points out, in these cases, a plastic behaviour.

There are also modifications of the elongation at break, the latter increasing as the natural resin in the mixture is increased. The elongation at break is higher in the resins based on the mixture of Dammar and Sandarac than in the resins based on Dammar only. As a result, the Sandarac presence leads to an increase in the ductility of the obtained materials. This can be used to control the mechanical properties of the composite materials with a matrix of bio resins based on Dammar and Sandarac.

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