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Studies Regarding Some Mechanical Properties for a Hybrid Resin Used to Build Composites Reinforced with Corn Cob Powder

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Abstract: *In this paper some mechanical characteristics of a composite made from a hybrid resin and reinforced with corn cob powder are presented. The hybrid resin was made with a combination between the natural dammar resin combined with a small percentage of acrylic one. The synthetic resin was inserted in order to increase the polymerization process which was produced in about 24 h. In the fist part of the investigation, from the compression test, some mechanical characteristics are determined, such as: breaking strength or maximum force obtained at breaking. Then, by using the SEM analysis and EDS spectrometry, some samples with 50% dammar and 60% dammar were investigated. The last hybrid resin test was Shore D hardness and it was found out that the hardness decreases with the increase of dammar percentage. In the last part of the study, some composites by using the poposed hybrid resin reinforced with corn cob powder were manufactured. It has been found out that the proposed composite reinforced with corn cob powder has increased compression mechanical properties compared other composites that have the same reinforcement.*

Keywords*: dammar resin, acrylic resin, corn cob, powder, mechanical properties*

1. Introduction

In the engineering literature there is usually refered as partially bio-resin or hybrid one, the resin that has two distinct components: an organic component that comes from the natural resin and the other which is inorganic that comes from the synthetic part. All the resins that are mostly stuied in the engineering literature and only partially bio because they have a small percentage of a synthetic part [1-3].

Most of the researches related to natural dammar resin concentrate on its chemical properties and less on its mechanical ones. It is known that the dammar resin has a polymeric part which is called polycanniene, and two parts that are soluble and insoluble in alcohol called α and β -resene. This information can be found out by reading the papers [4,5]. The lacquers made from dammar that are exposed to increased stages of relative humidity have a microbiological deterioration, fact presented in [6].

Some properties like the mechanical, moisture absorption or water vapor transmission ones are investigated in the paper [7]. Those results were determined by implementing the method of solvent evaporation from solutions. In [8] the method of nanoindentation test was used to determine some results related to creep behaviour, the stiffness, Young modulus and hardness for improved dammar-silicon. It was concluded that the elastic behaviour increased with the insertion of dammar. In [9] there was studied the antioxidant properties of some bio-resins and it was concluded that the dammar resin increases the speed of sunflower oil oxidation no matter of the concentration percentage.

The dammar resin was applied as a covering layer in [10] for laminated steel in combination with polymethyl methacrylate. Dammar was also applied as a phase change material in combination with

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beeswax for concrete buildings in [11]. It was concluded that dammar with beeswax can be used as a phase change material for concrete with good thermal properties.

In this paper, the authors have created a hybrid resin based on the dammar one which is bio-degradable. The dammar resin was brought in a liquid state by dilution with turpentine and it was kept in closed containers. In order to accelerate the polymerization process, a small quantity of acrylic resin was inserted. There were determined some mechanical properties for this hybrid resin and in the end, it was used to manufacture a composite material with corn cob powder as reinforcement.

2. Materials and methods

In this research we have obtained a hybrid resin from a combination of dammar and acrylic ones. The dammar resin has the disadvantage that it cures in a very long time. In order to reduce this time, a small percentage of acrylic resin ClaroCit (combined with its liquid hardener) has been used in the samples. The samples were obtained by lay-up technique casting at the room temperature. This research is a continuation of the studies performed by the authors in papers like [1, 12, 13]. The difference and the novelty are that they have replaced the epoxy resin with an acrylic one and the hardening time was reduced from 7 days up to 24 h.

2.1. Compression test for hybrid resin samples

Five samples have been built from each type marked in this way: dammar 50% acrylic resin 50% abbreviated as DA50 and dammar 60% acrylic resin 40% abbreviated as DA60.

The samples were tested to compression and had the dimensions according to ASTM D695-15 [14]. It was used an LBG universal testing machine with the maximum force of 100 kN with the general characteristics presented in [15]. A general view with the used samples (one from each DA50 and DA60 type) is presented in Figure 1.

Figure 1. Representative samples from DA50 and DA60 type

2.2. Scanning electron microscopy (SEM) and element identification for the hybrid resin samples

For the two studied samples type, scanning electron microscopy and element identification has been made by using the PHENOM PURE PRO X apparatus [16].

2.3. Shore hardness for the hybrid resin samples

Two samples were casted from each DA50 and DA60 cathegory with the dimensions: 280 mm length, thickness 8mm and width 20 mm. For each sample, 5 points were chosen where the Shore hardness was measured according to the scheme from Figure 2 and standard ASTM D 2240 [17].

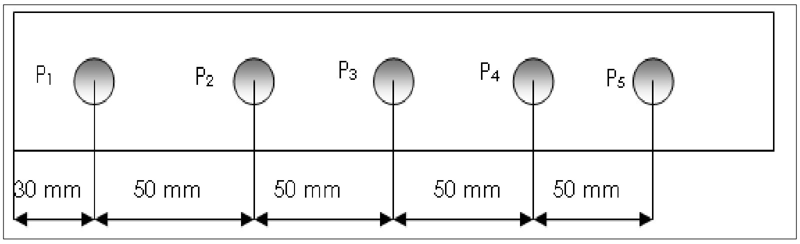

Figure 2. The points chosen to determine the Shore hardness

2.4. Compression test for composite samples reinforced with corn cob powder

In this part of the study, a bio-composite was created, having the matrix from the proposed hybrid bio-resin reinforced with corn cob powder. The samples were tested to compression and had the dimensions according to ASTM D695-15 [14]. It was used an LBG universal testing machine with the maximum force of 100 kN with the general characteristics presented in [15]. For compression, the next samples were built (five samples have been built from each type): 50% corn powder and 50% hybrid bio-resin (made from 50% dammar and 50% acrylic resin), abbreviated as CDA50; 55% corn powder and 45% hybrid bio-resin (made from 50% dammar and 50% acrylic resin), abbreviated as CDA55.

A general view with the used samples (one from each CDA50 and CDA55 type) is presented in Figure 3.

Figure 3. Representative samples from CDA50 and CDA55 type

2.5. Shore D hardness for composites reinforced with corn cob powder

For the Shore D hardness similar samples were casted, as specified in subchapter 2.3 from this research and the points were chosen as specified in Figure 2.

3. Results and discussions

3.1. Compression test results for hybrid resin samples

The load-traverse stroak curve, for a representative sample of DA 50 type, is presented in Figure 4. All the results are written in Table 1.

Table 1. Compression test values for hybrid resin

Sample type	Maximum force of break (kN)	Breaking strength (Mpa)
DA 50	37 ± 1.5	29.5 ± 1.6
DA 60	30.5 ± 1.3	24.3 ± 2.6

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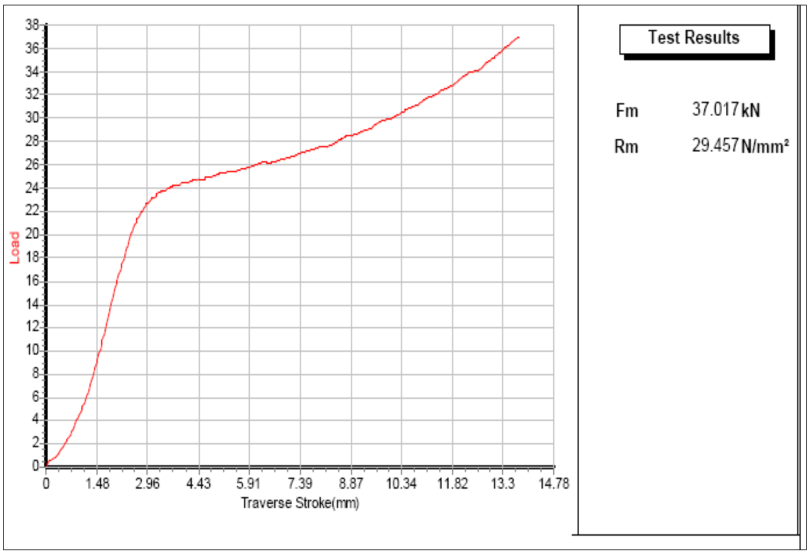

Figure 4. The load-traverse stroke curve for a representative DA50 sample

From the Table 1 values it can be concluded that the compression strength decreases with the dammar resin increase. This can be explained by the fact that de dammar resin has lower compression characteristics compared to the acrylic one.

3.2. Scanning electron microscopy (SEM) and element identification for the hybrid resin samples, graphics and values

For two DA50 and DA60 representative samples, the SEM images are presented in Figure 5 and Figure 6. From the two figures no bubbles can be observed which means that the chemical reaction between the acrylic resin and the dammar one was done completely, with the release of all air bubbles through the samples upper surface. Also very small pores can be observed, which means that for the resin we obtained an almost unitary structure. By EDS analysis, the peaks of chemical elements presented in the Tables 2 and 3 were obtained, for one sample from each DA50 and DA60 cathegory.

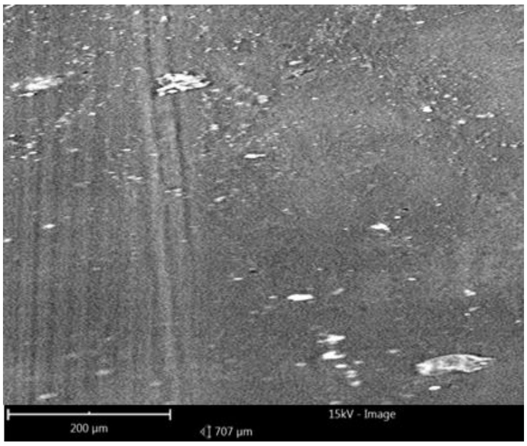

Figure 5. The SEM image for a DA50 sample

From the Tables 2 and 3 we can see a decrease in carbon and an increase in oxygen if the dammar quantity increases from 50% to 60%.

Figure 6. The SEM image for a DA60 sample

Table 2. The peaks of chemical elements obtained for DA50 sample

Element number	Element symbol	Element name	Atomic conc.	Weight conc.
6	C	Carbon	89.34	86.08
8	O	Oxygen	10.41	13.37
14	Si	Silicon	0.25	0.56

Table 3. The peaks of chemical elements obtained for DA60 sample

Element number	Element symbol	Element name	Atomic conc.	Weight conc.
6	C	Carbon	85.65	81.76
8	O	Oxygen	14.35	18.24

3.3. Shore hardness values of the hybrid resin samples

There were obtained the values and graphic from Figure 7. From the Figure 7 it can be seen a decrease of shore D hardness with the increase of dammar percentage. This result can be explained by the fact that the dammar resin is more elastic and softer than the acrylic resin.

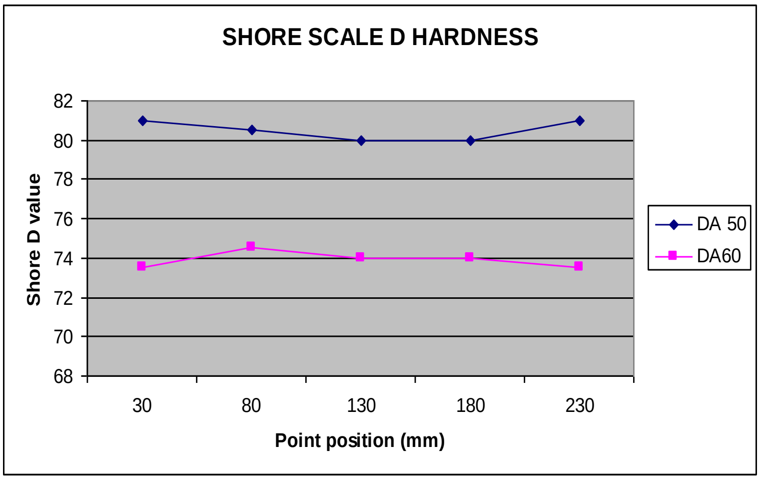

Figure 7. The Shore D values for the hybrid resin samples

3.4. Compression test values for composite samples reinforced with corn cob powder

The force-traverse stroke, for a representative sample of CDA50, is presented in Figure 8. All the compression results are written in Table 4.

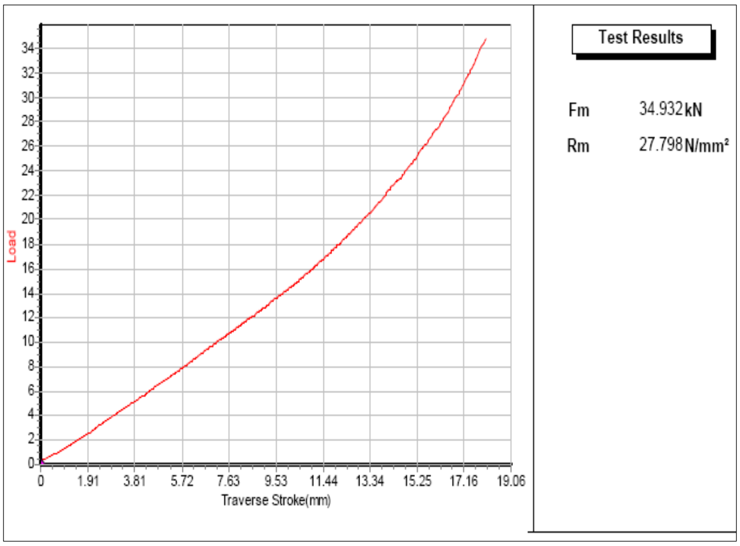

Figure 8. The load-traverse stroke curve for a representative DA50 sample

Table 4. Compression test values for composite samples

Sample type	Maximum force at breack (kN)	Breaking strength (Mpa)
CDA 50	34±1.8	27±2
CDA 55	30±1.3	24±1.8

If a comparison is made with the results from Table 1, it can be seen that the insertion of corn cob powder in the matrix structure produced a slighty decrease of the compression mechanical characteristics (a decrease of 9.25%).

3.5. Shore D hardness values for composites reinforced with corn cob powder

The results obtained for the samples CDA50 and CDA 55 are presented in Figure 9. If the values from Figure 6 and Figure 9 are compared, it can be seen a slightly decrease in Shore D hardness if the corn cob powder reinforcement is inserted into the hybrid bio-resin. This can be explained by the fact that the corn cob has a lower hardness compared to the hybrid bio-resin (made from dammar and acrylic combination).

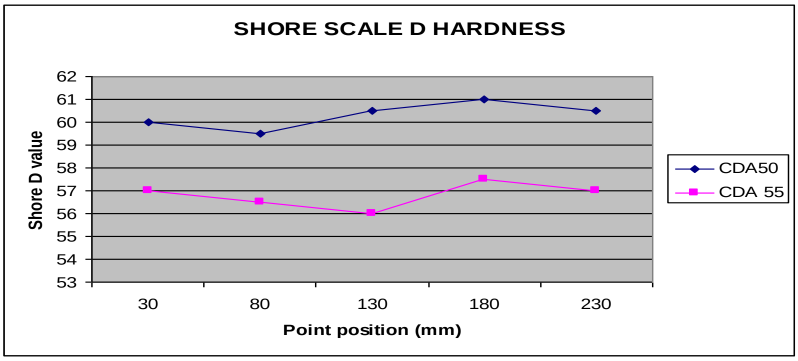

Figure 9. The Shore D hardness values for CDA samples

The poposed bio-composite from this research has acceptable properties compared to the other similar materials. For example, some researches regarding bio-composites reinforced with corn cob powder were made in [18]. There were used particles sizes between 0.090..1.8 mm and reinforcement proportion between 10..35%. There were obtained maximum values for the compression breaking strength of 20 MPa and 320 MPa for the Young modulus. The CDA50 has an increased breaking strength with about 35% compared to the samples studied in [18] and the CDA55 has an increased breaking strength with about 20% compared to the samples studied in [18].

4. Conclusions

The added value of this study is manufacturing a hybrid with a combination between dammar and a small percentage of acrylic resin and determining its mechanical characteristics like: compression strength, maximum force at compression breaking, identification of chemical elements through EDS analysis, shore D hardness.

With this hybrid resin there were created samples for compression test. From the Figure 4 it can be seen two different domains: a first elastic domain where the Hook law is checked and it appeared because of the dammar natural resin elastic properties; a second non-linear domain where is also produced the samples breaking, which corresponds to the plastic behaviour of acrylic resin. Similar conclusions can also be extracted from Figure 8, where CDA 50 sample was tested.

There was also investigated the DA50 and DA60 microstructure by SEM analysis. From Figure 3 and 4 no bubbles can be observed which means that the chemical reaction between the acrylic resin and the dammar one was done completely, with the release of all air bubbles through the samples upper surface. Also very small pores can be observed, which means that for the resin we obtained an almost unitary structure. By EDS analysis, the peaks of chemical elements presented in the Tables 2 and 3 were obtained. It can be observed that with the increase of dammar percentage (from 50 to 60%) there was obtained an increase in oxygen and a decrease in carbon atomic and weight ceoncentrations.

There was also investigated the samples hardness in Shore D scale values. From Figure 6, samples DA50 and DA60, it can be observed that the hardness decreases with the dammar percentage increase. This can be explained by the factor that the dammar resin in softer than the acrylic one and with its percentage increase the hardness decreases. From the Figure 9, it can be observed a decrease in Shore D hardness values with the percentage increase of corn cob powder. This can be explained by the fact that the corn cob material is softer compared to the acrylic and dammar resins. The corn cob presence in the samples as reinforcement produces also a decrease in the compression mechanical properties if the Tables 4 and 1 are compared.

The studied composite material has quite low mechanical properties, so it can be used as a core in making sandwich pannels. For example, it can be used as a core to manufacture sandwich furniture parts like doors or shelves.

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