Tensile Testing of a Biocomposite Material – "Liquid Wood"

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Abstract. Modern society has faced significant economic development in the previous decades. In this, the construction industry played (and continues to play) a central role, contributing an important amount to the GDP of both developed and developing countries. However, development comes with negative consequences as well – pollution, waste and excessive CO_2 emissions often being mentioned. For the construction industry, this means that new solutions should be found that can minimize, as much as possible, the impact upon the environment. One such solution may reside in the development and employment of biocomposites. In short, biocomposites are nothing else than "classic" composite materials when it comes to their structure (fibers held together by a matrix), but the fibers are naturally – sourced and so are the matrix resins. In theory, they are up to 100% biodegradable and completely eco – friendly. "Liquid wood" is a relatively new biocomposite, which is compliant with the above – mentioned principles, but it is thermo – injectable (just like plastics). This has the potential to open up some interesting ways of employing it. The following article is organized as follow: in the introduction, "liquid wood" is presented in more detail. After that, some wood – specific degradations that can be solved by using "liquid wood" are discussed. Then, the "liquid wood" samples are presented. Following this, tensile testing in laboratory is explained. Finally, some conclusions may be drawn related to the obtained results, as well as following up with more research.

Keywords: Biocomposite · Liquid wood · Testing

1 Introduction

The necessity of finding new, sustainable materials, with their use ranging from everyday items to construction materials and other advanced applications (ex.: automotive and aero industries), represents a significant direction of research for modern societies. The massive pollution and subsequent damage to the environment caused by the production of "classic" building materials, along with the ubiquitous use of plastics, are driving factors for the discovery of new materials.

In the construction industry, the first "modern" material was considered to be what actually turned out to be a new class of materials – composite materials. A composite material is made of matrix and reinforcement. The matrix is usually a type of resin (epoxy,

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vinyl ester etc.), which binds together a type of fiber (Kevlar, aramid etc.). Composites were adopted in the construction industry at a later time, as the aero industry was the premier user of such materials, followed by the automotive industry.

In time, composites have proven to be suitable in rehabilitation work, being quite easy to apply and proving resilient to some forms of degradations. Nevertheless, composite materials share a common problem with "classic" building materials: sustainability. Usually, they require significant amounts of energy to be produced and some of their base "ingredients" may include petroleum – derived products.

Logically, the answer to the aforementioned problem is the development of biocomposites. Biocomposites is a term describing biodegradable composite materials. The term implies that the matrix is biodegradable and the reinforcement is made of natural fibers (Pilla 2011). Furthermore, the matrix can be made from polymers sourced from recyclable, renewable resources. This is important in protecting the fibers from degradation, as well as in binding them together, the end result being an increase in mechanical and structural properties (Nägele et al. 2013). The fibers have biological origins and can be made out of various plant species (hemp, cotton, flax), recycled wood or regenerated cellulose.

2 A Short Description of "Liquid Wood"

"Liquid wood" is a relatively new polymeric biocomposite material, initially developed by a German company, Tecnaro GmbH. The "composite" aspect means that it has a matrix which holds together the reinforcement. In the case of "liquid wood", the matrix is made of lignin (a naturally – occurring substance that lends strength to plants) and the reinforcement is made of various natural fibers (hemp, flax, straw – depending on the recipe). The "polymeric" aspect of this product is not a reference to plastics, but rather to the material's behavior, which is akin to thermoplastics – it is possible to inject it and mold it into various objects. Finally, the "bio" aspect of the product is a result of the constituent materials present in "liquid wood". Depending on the presentation form (or recipe), it can be up to 100% biodegradable. Sustainability is ensured thanks to the fact that its constituents are naturally – sourced and can be obtained from renewable resources and the manufacturing procedure has a low environment impact (according to the manufacturer).

As such, "liquid wood" appears to be a good candidate for a modern, sustainable material with a good range of applications.

3 "Liquid Wood" Injection – Material and Technology

Everything written in the previous chapter holds true on a still mostly theoretical level. To make sure that "liquid wood" is a valid material for the construction industry, there is only one way to do that – laboratory testing. Because "liquid wood" has, as stated by the producer, the same processing characteristics as thermoplastics (Tecnaro GmbH 2019), Arbofill and Arboblend material was injected into dumbbell shapes (according with technological sheets provided by the manufacturer) and then it was tested to tension.

Characteristics of dumbbell shapes: L = 150 mm; T = 4 mm; W = 8 mm; M = 8–10 g.

Following the installation of tensiometric marks (red color in Fig. 1), the samples were installed and tested up to failure, one by one, in the tension press (Figs. 2 and 3).

Fig. 1. Arbofill and Arboblend dumbbell samples

Fig. 2. Dumbbell sample fixed in the press

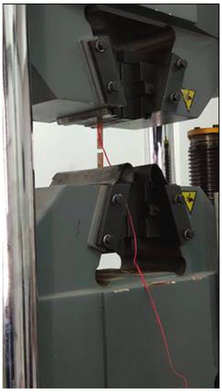

Fig. 3. Dumbbell sample after failure

4 Experimental Results

It has been observed that the samples failed in a rather brittle way, although they did suffer a slight elongation. This would be in accordance with the manufacturer's stated 3% elongation ratio. The results shown in Fig. 4 have been obtained on Arbofill (brown) and Arboblend (white) samples.

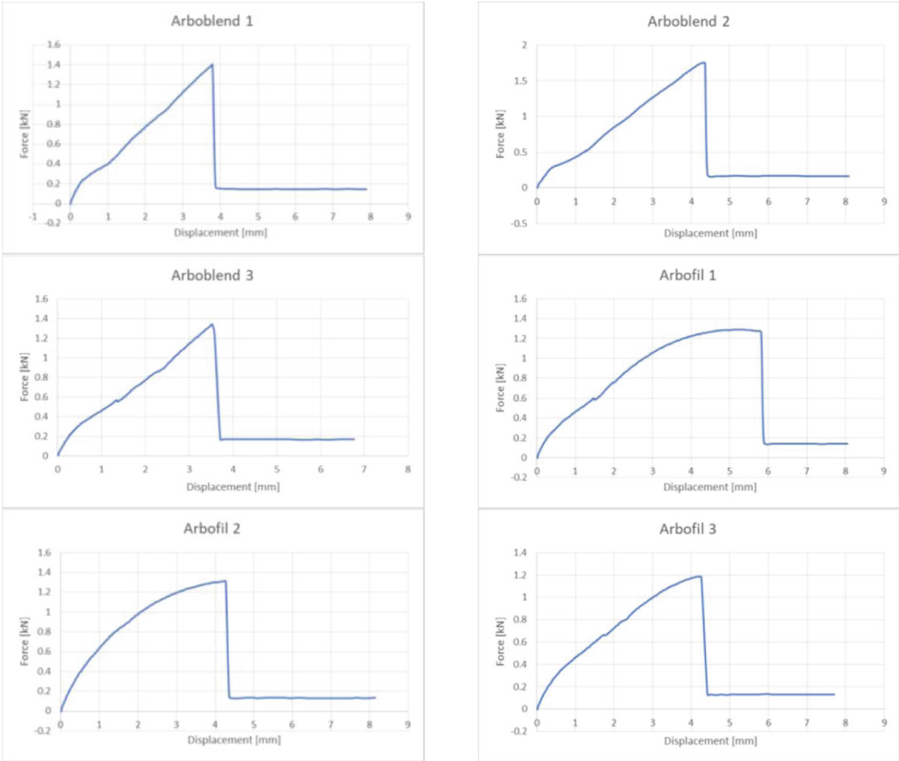

Fig. 4. Charts describing Arbofill and Arboblend tensile performance

5 Conclusions

From the obtained diagrams, it can be observed that both Arbofill and Arboblend present a good behavior in tension (40.6 MPa), in comparison with traditional wood (average value under 30 MPa). The results indicate that "liquid wood", from a structural point of view, could be used to rehabilitate existing degraded wooden structures.

As an average of values, breakage occurred at a force of approximately 1.3 kN (40.6 MPa), at a maximum displacement of approx. 4–4.5 mm. Correlated with the fact that the mid – cross section has a dimension of 8 mm $\times$ 4 mm, it is suggested that the material has enough strength to be used in conjunction with existing wooden structures.

Finally, the brittle fracturing of the material depends a lot on the intended use of "liquid wood", so it can be viewed either as an advantage or a disadvantage, depending on its purpose. This effect might also matter less, as it is more likely that the wooden element will be the first to fail. In studying the two recipes, Arbofill has been observed to present a bit more elasticity than Arboblend, but Arboblend has a slightly lower melting point. Overall, both materials are fairly balanced in terms of performance.

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