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Vegetable Fibers for Composite Materials In Constructive Sector

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Vegetable Fibers for Composite Materials In Constructive Sector

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Abstract: The aim of the research is to study and to test bio-mixture for laminas to use in construction field components. Composite materials are becoming more common in different sectors, but their embodied energy is an environmental problem. For this, in recent years, the researchers investigate new mixtures for composites, in particular with vegetable fibers and bio-based epoxy resin.

The research carried out different laboratory tests for material and mechanical characterization, starting from the analysis of vegetable fibers, and arriving to test different kind of laminas with sundry fabrics and bio-based epoxy resin.

In the most general organization of the theme, the research has the overall objective to contribute to reduce composites environmental impacts, with the promotion of local production chains about innovative materials from renewable and sustainable sources.

Keywords: Bio-composites, N.F.R.P., vegetable fibers, green materials.

1. INTRODUCTION

Composite materials had a recent diffusion in different kind of industry fields [1]. Civil engineering is one of the last sector where composite materials are used, thanks to a process of transferring technologies from other fields, like automotive and aerospace industry.

There are different kind of applications of composites in construction sector, between the most common ones there are the use of carbon fibers in reinforcement tapes and of the glass fibers in pedestrian bridge and in the general little ones. Actual testing would lead to an increase of the applications, in renovations and in 100% composite structures too.

The significant effects on the environment of the composite materials, have long been an area of particular interest for the researchers, given the high level of CO₂ products in manufacturing process, and both to obtain the raw materials, fibers and matrices. The most used fibers currently are the carbon, glass and aramid ones, all of which considered synthetic materials [2] where the embodied energy is a high percentage of the total energy balance. In addition, large part of the matrices actually used are derived oil products, so they have a significant environmental impact, but also they create a problem for the products' end of life management. The ongoing research which aims to reduce the composite materials environmental impact, they focus on different methodologies to obtain this result: to reduce carbon emissions in the fibers



production, using bio-based ones, to use matrices which are not derived from oil, to produce with more ecological and safe manufacturing systems, to improve methodologies to recycle the materials and to reuse the components. Our research aims to produce laminas with a percentage of no carbon based raw materials as high as possible. Bio-based thermosetting and thermoplastic resins are actually commercially available, including epoxy resin with interesting mechanical characteristics for civil engineering. So the major investigation is focused on possible bio-based fibers, in our case, on vegetable fibers, and to select the best ones, with good mechanical properties, and which are more sustainable than the synthetic ones.

So the general objective of this research is structured on three different levels:

- Product innovation, to propose new green composite materials, with bio-based epoxy resin, derived from vegetable oils, reinforced with plant fibers' fabrics. At the same time, this product will have a better recyclability level. In fact, although the recycling technology for a traditional thermosetting resin is the same that the technology for a bio-based one, the percentage of biodegradable parts of final product will increased [3];
- Process innovation, the environmental gain of this kind of bio-composites is not only limited to their better end-of-life management. In fact, less energy is required for their production, as compared with inorganic ones [4];
- System innovation, to increase local production chain on vegetable fibers that are historically cultivated in the territory or that could be cultivated in Mediterranean environment. In this case, there will be a high impact on local economy and on territory development.

2. VEGETABLE FIBERS

Vegetable fibers, the plant derived ones, they are in use in different kind of fields for years. Between the first research in this thematic, one of the most important is the Henry Ford's Hemp Body Car, a vehicle with a frame in a composite material obtained with hemp fibers and a soy based matrix.

Our research aims to select the better fibers which are derived from a plant could be cultivated in the reference territory, in this case the Calabria region, and so to obtain the final product with an environmental level as low as possible. That's because the most general goal, is to participate in a social and economic recovery of the reference territory, aiming to a development typology which is sustainable in all its aspects, environmental, social and economic ones. Some typologies of fibers have been selected from a literature study, and they are selected for their mechanical characteristics and because they are cultivable in Mediterranean environment. Vegetable fibers' mechanical properties are directly proportional to the percentage of cellulose in their chemical structure. Three kind of plants have been selected: hemp, flax and the broom one.

The hemp (*cannabis sativa*) is one of the most studied in the sector literature, thanks to the fibers' mechanical characteristics, derived from the high level of cellulose of plant's chemical structure (tab. 1), and because the plant is resistant. In fact, the hemp, is an easy to grow plant, it doesn't need any type of fungicide and it could be cultivated in different latitudes. Moreover, the hemp was widely cultivated in Italy, which was considered the main producer in Europe, until the prohibition period and the arrive of the cheapest synthetic fibers from Asian countries.

The flax (*linum usitatissimum*), has been an area of particular interest for the research. It's a plant with a high level of cellulose too, so it's good subsequent mechanical properties. Furthermore, it's a plant which is historically cultivated in Mediterranean areas, to extract its fibers, most used in textile industry, and for ornamental use too.

Both of fibers, hemp and flax ones, are bast fibers, so they are extraxilares.

Finally, another fiber was selected, the broom (*spartium junceum*). It's a plant very little known and poorly investigated, but it's very diffuse throughout the Calabrian territory. This plant was object of some previous research, because it's a plant diffused, infesting end with a high level of cellulose in its fibers. In Table 1, the different percentage of main components in fibers that are considered [5] [6].

Table 1. Main components of vegetable fibers

<i>Fiber\Component</i>	<i>Cellulose (%)</i>	<i>Emicellulose (%)</i>	<i>Lignin (%)</i>
Hemp	70,2 – 74,4	17,9 – 22,4	3,7 – 5,7
Flax	71 – 78	18,5 – 20,6	2,2
Broom	80,72	9,45	6,56

3. TESTING

Three types of fabric have been compared, a hemp, a flax and a broom one.

The analyses performed create the data which characterize the matter and its mechanical properties.

Four different kind of fabric have been subjected to the scanning electron microscope: two hemp ones, a handicraft derived and an industrial origin one (Fidia 454 g\mq), a flax industrial one (Biotex 400 g\mq), and a broom fabric, handicraft derived.

Data about mechanical characterization on handicraft fabrics are extrapolated from a previous research carried out in Ditec of Calabria's University, supervised by Prof. G. Chidichimo. They concern hemp, flax and broom fabrics.

These data were compared with industrial origin's fabrics, the hemp fabric's properties come from literature [7], the flax ones are from original data. There are not information about the existence of a broom industrial fabric.

3.1 SEM analysis

There are two kind of hemp fabric analyzed, the first one is a handicraft fabric, produced in Calabria (Fig. 1). These fibers appear dirty, with a non-uniform section and with different frayed parts. Similar considerations apply to the broom fibers (Fig. 4).

The hemp industrial fabric is in Fig. 2. Fibers are more clean and their section is regular. Also, they appear more braided. These comments are hereby confirmed by Fig. 3, about industrial flax fabric.

3.2 Mechanical characterization

Vegetable fibers' mechanical properties are directly proportional to their cellulose content. But also their production's origin has an important part in mechanical resistance.

In Table 2, there is a comparison of the most important mechanical properties of the five kind of fabrics. Between the handicrafts ones, the hemp fabric has better characteristics, featuring a

Young's Modulus of 383,00 MPa and a tensile strength of 29,00 MPa. Broom fabric, with a Young's Modulus

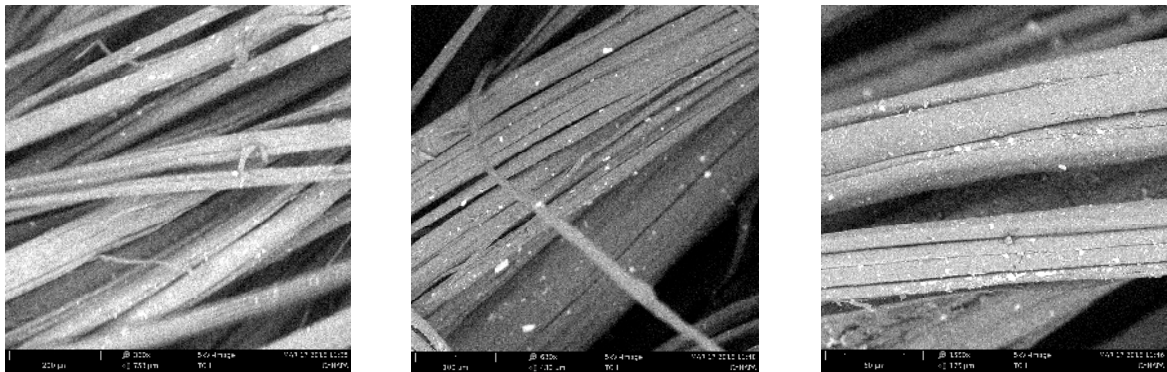


Fig. 1. Handcraft hemp fabric's SEM analysis

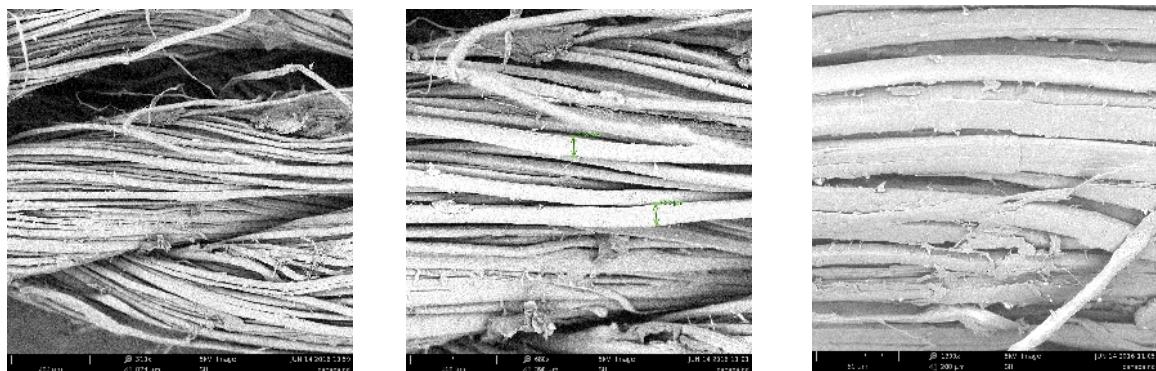


Fig. 2. Industrial hemp fabric's SEM analysis

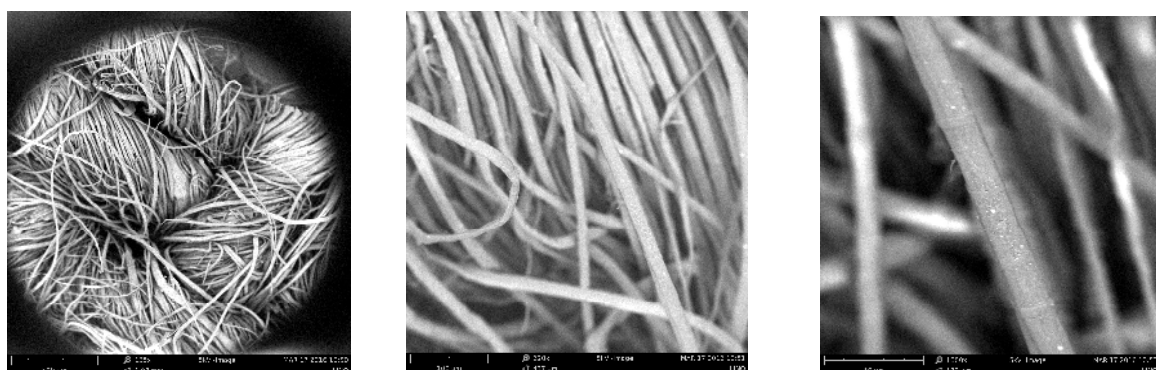


Fig. 3. Industrial flax fabric's SEM analysis

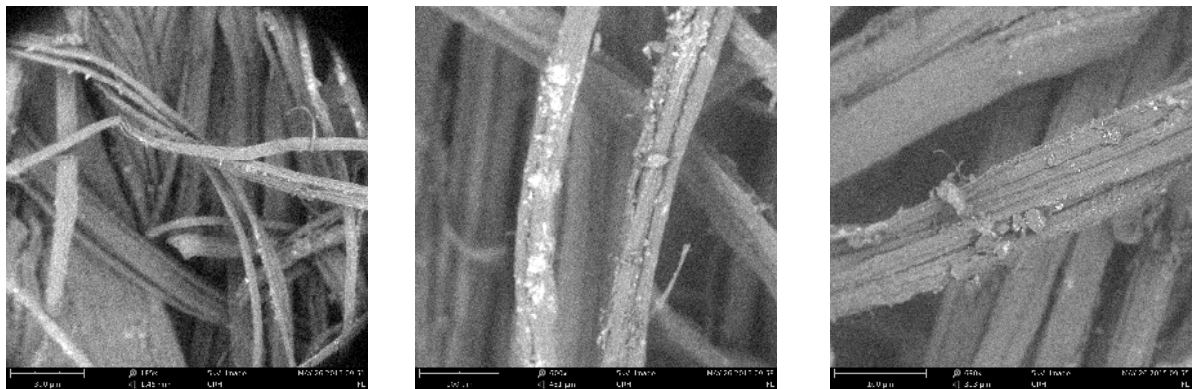


Fig. 4. Handicraft broom fabric's SEM analysis

of 201,00 MPa and a tensile strength of 23,00 MPa, corresponding to a level half-way between hemp and flax, that is characterized by the worst performances, with a Young's Modulus of 108 MPa and a tensile strength of 18,00 MPa.

Industrial fabric's data are very different. There is a substantial increase in mechanical properties, hemp fabric is characterized by a Young's Modulus of 618,65 MPa and a tensile strength of 46,68 MPa. But it's the industrial flax fabric that achieve the best outcomes, with a Young's Modulus of 832,00 MPa and a tensile strength of 73,64 MPa.

So there is an increase, in hemp of a 219, 37% for Young's Modulus and 186,72% for tensile strength

The particularly high increase recorded in industrial fabric is ascribable to the improved process control, and proves that this kind of fabric is the best one to realize lamina for composite materials.

4. CONCLUSION

The realization of lamina in composite materials reinforced with vegetable fibers, which have good and controlled mechanical properties, could be a possible solution to environmental problems that limited the spread of FRP in construction sector. In particular, the use of industrial fabrics seems desirable.

The diffusion of these plants could be positive to create an induced business in extraction and processing, to follow the fiber from plant to fabric.

Table 2. Main mechanical properties of fabrics

<i>Fabric\Characteristic</i>	<i>E - Young's Modulus (MPa)</i>	<i>f_t - Tensile strength (MPa)</i>
Handicraft Hemp	383,00	29,00
Handicraft Flax	108,00	18,00
Handicraft Broom	201,00	23,00
Industrial Hemp	618,65	46,68
Industrial Flax	832,00	73,64

Moreover, networking data of cellulose percentage in fibers and data of mechanical properties increased moving from a handicraft fabric to an industrial one, we obtain a good future prospect about the use of broom fibers. In fact, if the trend is wholly or partially confirmed, an industrial broom fabric could have further improvement in mechanical properties and maybe better than hemp or flax ones.

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