Composite-dedicated natural fibres in France and Europe

FRD, an R&D competence centre and engineering platform for the "natural fibres for materials" industry, considers a number of plant-based solutions here, covering the range of natural fibres available on the market for composite materials. At the same time, it reviews the French and European markets.

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In the effort to help industrialized countries to reduce their greenhouse gas emissions, biosourced materials –in particular natural fibres – are appealing in that they combine environmental advantages with technical performance. Natural fibres are inherently natural composite materials, as they consist of reinforcing elements, such as cellulose for mechanical strength, and other elements to bind the microfibrils and fibre bundles with the hemicelluloses, lignin and pectins. This complex structure is the reason the fibres are attractive for material applications. What are the specific advantages of these natural fibres? What plant resources are available for these markets? And what kind of properties do the fibres and bio-based industrial materials exhibit?

> *The composite materials on the market that incorporate natural fibres make it possible to reduce weight by 20% on average, compared to a glass solution.*

Natural fibres

With the exception of wood fibre, the natural fibres produced worldwide come from four main plant sources, which are the stalks, leaves, seeds, and seed pods. In Europe, flax and hemp fibres are produced industrially from the plant stalks. Fibre extraction gives rise to what are called "fractions". The lignified, or woody, tissues from the core of the stalk account for more than half of the plant fractions produced from the stalks (or straw) of flax and hemp plants.

The popularity of natural fibres in the transportation and building industries is linked to their main characteristics: they are renewable, and they have a small carbon footprint, a low density (1.4 to 1.5 g/m3), and good mechanical and sound-damping properties. Natural fibres are more easily processed than glass fibres because they are non-abrasive and non-irritating, and thus more easily handled. Their fineness (20 and 200 µm) contributes to recognized heat and sound insulation properties. Their characteristics with respect to polarity, biodegradability or hydrophily (water absorption/desorption properties) can be either an advantage or a constraint for development, as a function of the process and the application involved.

Availability and consumption of plant resources

In March 2011, FRD and French energy conservation agency Ademe put out a study on the supply of fibres and plant fractions in France. French production of natural fibres (excluding wood) is an average 170,000 metric tons (MT) per year, and of powders and aggregates, 390,000 MT/year. For Europe, natural-fibre production (excluding

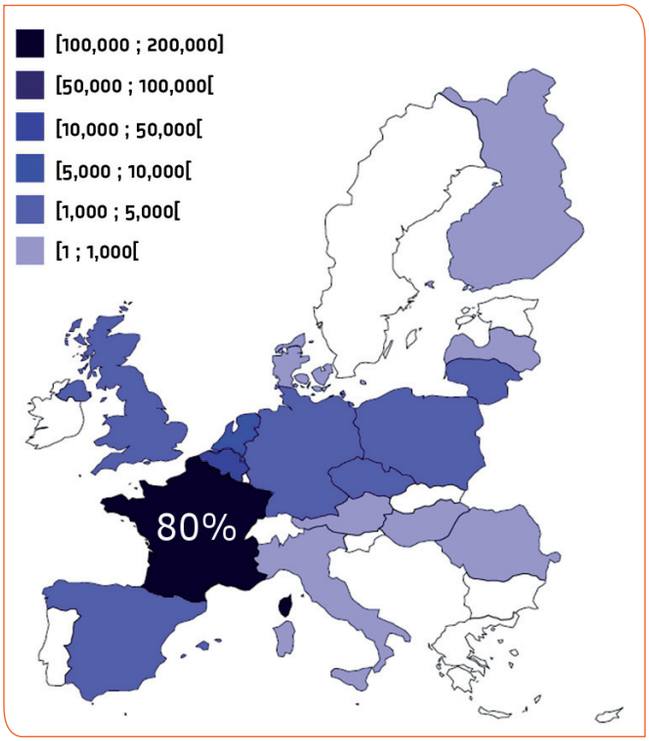

Fig.1: Natural fibre production (metric tons)

wood) is an average 210,000 MT/year. France is therefore Europe's leading natural fibre producer, accounting for 80% of total production (Figure 1).

Natural fibres for composites

Given the growing interest in natural fibres for composite materials, the industrial players involved are faced with a natural fibre value chain that is insufficiently structured for technical markets. FRD acts as a platform for the natural fibre industry and proposes a catalogue of appropriate solutions for the different composite processes, including cut fibres, powders, aggregates, compounds and natural fibre based reinforcements. FRD makes use of its expertise and knowledge of the plants, fibres, and extraction/converting processes used to develop the best plant-based product for material manufacturers' individual specifications.

Mechanical performance

Humans have been cultivating these natural fibres since time immemorial. Flax is the oldest textile in the world, with more than 7,000 years of history behind it. Paradoxically, our level of knowledge of these fibres for technical applications still requires a great deal of research to better understand the parameters that influence the performance of these natural fibres, in order to optimize them.

What we do know about these fibres is that the process used to extract the fibres from the plant has an effect on the mechanical performance of the fibre. FRD studies these impacts, specifically on flax and hemp, in order to identify the process that suits the required properties. Certain extraction processes help significantly to improve the mechanical performance (Table 1).

Tab.1: Average tensile properties for single flax fibres from optimized extraction processes (Source: FRD)

Mechanical property	Average value
Young's modulus	32 GPa
Breaking stress	935 MPa
Elongation at break	3%

Available natural fibre reinforcements

The types of natural fibre textile reinforcements for thermoplastic or thermoset composites are very similar to synthetic-fibre ones (see Figure 2).

There is a very broad range of industrially available reinforcements that covers plant-based products such as:

- **rovings** (low-twist continuous filament) in a wide variety of thicknesses from 100 to 2,000 tex;
- **nonwovens** from different technologies for the manufacture of products with isotropic properties and in a wide variety of thicknesses and densities (50-2,500 g/m²);
- **fabrics** similar to the market's available glass solutions in terms of weight and weave;
- **unidirectional** materials designed for mechanical properties in a single direction;
- **multiaxials** with multiple plies of unidirectional fibres placed in two or more directions and stitched together to ensure good mechanical properties in several different directions;
- **prepreg**, opening the field to

Tab. 2: Performance of natural fibre reinforced composites (Source: FRD)

Matrix		EPIKOTE Epoxy Resin 828 LVEL					
Reinforcement		Multiaxial		UD		Non-woven	
Reinforcement composition		flax 100%		flax 100%		flax 100%	
Density		1640 g/m²		1500 g/m²		1500 g/m²	
Fraction		49%		46%		33%	
Mechanicals characteristics		Values	SD	Values	SD	Values	SD
Traction (direction 0°)	Elastic modulus (GPa)	17.6	1	26.3	0.8	5.8	0.2
	Maximum stress (MPa)	147	14	284.2	12.4	53	3
	Strain (%)	1.1	0.1	1.4	0.1	1.21	0.07
Flexural (direction 0°)	Elastic modulus (GPa)	15.3	1.6	20.1	1.0	3.6	0.9
	Maximum stress (MPa)	258	33	301.2	11.0	89	8
	Strain (%)	3.6	0.5	3.0	0.1	2.7	0.3
Matrix		NORESTER Polyester resin RM822					
Reinforcement		Multiaxial		UD		Non-woven	
Reinforcement composition		flax 100%		flax 100%		flax 100%	
Density		1640 g/m²		1500 g/m²		1500 g/m²	
Fraction		51%		44%		29%	
Mechanicals characteristics		Values	SD	Values	SD	Values	SD
Traction (direction 0°)	Elastic modulus (GPa)	13.3	0.5	25.0	0.3	7.6	0.3
	Maximum stress (MPa)	125	6	290.0	8.5	66	4
	Strain (%)	1.3	0.1	1.5	0.1	1.3	0.1
Flexural (direction 0°)	Elastic modulus (GPa)	14.7	0.9	21.1	0.8	4.9	0.6
	Maximum stress (MPa)	155	25	309.0	7.5	110	9
	Strain (%)	4.9	2.6	3.3	0.1	3.1	0.2

More information

About FRD (Fibres Recherche Développement®) FRD is a research company that is:

- dedicated to developing natural fibres for use in materials (insulation, concretes, composites, etc.),
- created by 11 shareholding producers of fibres (flax, linseed flax, hemp, miscanthus, wood) and key players in bio-resource development (ARD, Sofiprotéol),
- established within the Industries and Bio-Resources competitive cluster in France's Picardy/Champagne-Ardenne region.

FRD is a project engineering platform that uses its expertise to promote the emergence and development of innovative materials. Its expertise includes:

- formulating materials that incorporate natural fibres,
- fractionation and functionalization,
- characterization and managing the quality of the fractions,
- knowledge on resource availability and mobilization.

FRD-Lab is the first French technological platform dedicated to the extraction and characterization of natural fibres and aggregates for use in materials. The platform serves to:

- supply material manufacturers with fibre and aggregate samples that have targeted properties for specific applications, for the purpose of conducting pilot tests for material formulation/design;
- provide technical support to fibre processors so they can adapt their extraction processes over the medium and long term, optimize their quality programmes and establish data sheets for their products;
- sponsor the implementation of formative R&D programmes.

With a nine-member team, FRD bases its work on a nation-wide research network comprising about twenty university laboratories and technical centres.

these processing technologies.

To illustrate the potential of these natural fibre based reinforcements, FRD has made the mechanical performance data from epoxy or polyester resin composite processing available in its "Solutions Végétales pour Matériaux Composites" (plant-based solutions for composite materials) catalogue (may be downloaded for free at www.f-r-d.fr), some of which is shown in Table 2.

Many of the current composite processes either have already been or could be adapted for the use of natural fibres and natural fibre reinforcements. There are a number of precautions to take, however, such as being careful not to expose the natural fibres to processing temperatures above 200-230°C to avoid reducing their performance and that of the composite material.

Conclusion

Flax and hemp fibres are industrially available, renewable products originating from European – and especially, French – agriculture. Their technical properties are attractive for the composite industry in terms of density, mechanical strength and sound/heat insulation. Applications are developing rapidly for products based on these fibres, and this overview gives an idea of their potential and availability.

To help structure the "natural fibres for materials" value chain, FRD has given access to the market's most comprehensive catalogue of fibre-based products for composite applications. The catalogue covers fibres in the form of powder, aggregates, cut fibres, compounds, and reinforcements (fabrics, unidirectional materials, nonwovens) and identifies key fibre properties and the potential for natural fibre reinforced composite materials. ■

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