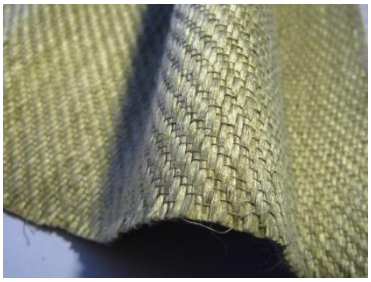
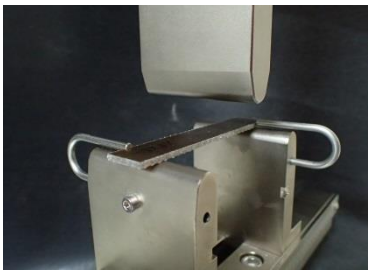
Natural fibres and reinforcements

Material solutions





Fibres Recherche Développement®

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1 Introduction

1.1 Fibres Recherche Développement®

Fibres Recherche Développement (FRD) is a private **innovation company** and engineering platform for industrial projects FRD promotes the emergence and development of innovative applications for agricultural fibres. It was established in 2008 by 11 shareholders, either producers of natural fibres (flax, hemp, miscanthus, linseed flax, and wood) or actively working to promote bioresources (ARD, Sofiprotéol). FRD now brings the majority of French natural-fibre producers and processors together.

Working within the "Industries et Agro-Ressources" (Industries and Bioresources) competitiveness cluster, FRD is one of the biosourced materials sector's main representatives.

FRD develops green, ready-to-use material solutions.

Thanks to **FRD-Lab**, the first French technological platform dedicated to the extraction and characterization of natural-based pellets and fibres for material end-uses, FRD is able to:

- supply manufacturers with materials, pellets and fibre samples with application-specific characteristics so they can perform preliminary formulation and design tests for innovative products;
- offer technical support to fibre processors by helping them to adapt their extraction processes over the mid or long term, optimize their quality approach and prepare technical data sheets for their products;
- help partners develop R&D programs.

FRD also offers a complete range of biosourced reinforcement materials (pellets, powders, short and long fibres, woven and nonwoven fabrics, unidirectionals, multiaxials, etc.) that can be tailored to the target product specifications.

FRD is an engineering platform for projects. FRD benefits from a range of skills that are applicable to the design and development of innovative materials:

- Data base of market, products, specifications, process, resource
- Enhancing the performance of bio-based materials by transformation and functionalization
- Formulating materials that incorporate natural fibers
- Analyzes and quality management
- Support to R&D projects development

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FRD applies its expertise to implementing innovation & research projects on the design or improvement of biosourced materials:

In the thermoset composite field, FRD coordinated the national FINATHER project to develop thermoset composites with low ecological impact for automotive and railway applications. FRD is also member of the BIONICOMP project which aims to improve composite materials performances by ionization.

In the thermoplastic composite field, FRD is involved in several projects of whom MATAGRAF which aims to develop a biodegradable innovating material dedicated to wine industry. FRD is also a partner in the Defibrex project to develop a predictive model for defibration under mechanical stress.

In the building & construction field, FRD has managed a project to develop and industrialize thermal insulating wools and participated in a project to develop natural-based concretes that incorporate pellets for acoustic insulation.

In the textile field, FRD is involved in the development of an eco-friendly hemp based yarn for knitting with the project CHAMAILLE.

In the fibres and reinforcement field, FRD coordinates the Sinfoni project, supported by the French government via the "Future Investments" program. The goal of this 5-year project is to structure the natural-fibre supply chain. It should guarantee availability, price, quality and product performance all along the production line. The main purpose of the regional Maprofi project, which finished in 2014, is to understand the growing factors that influence flax-fibre physical and chemical properties. This research aimed to enhance the characteristics of raw materials, with direct positive repercussions on the final products

Upstream, On the subject of natural-fibre reserves in France, FRD co-published with the environment and energy control agency ADEME the first study about the availability and accessibility of natural fibres for material uses.

To support its customers and partners, FRD offers its services in several main fields:

- **Highlighting the potential of natural-based materials:** training on natural fibres, their performance and potential uses, and the processing methods used.
- **Innovate and design bio-based composite materials:** support on developing innovative materials based on natural fibres, assistance on using natural fibres to replace mineral or synthetic fibres.
- **Guaranteeing the supply of natural fibres and reinforcements:** supply-chain strategy definition, disposal of materials in compliance with industrial specifications, control and approval of incoming batches.
- **Mastering performances during industrial process :** support to the implementation of a quality management system of bio-based products at input of process
- **Analyzes :** Characterization on materials, fibers, powders, reinforcements, composites, concrete and insulation wool.

1.2 Catalogue aims

This FRD catalogue presents its services offering, from designing support of innovating materials to quality management system. A complete range of biosourced fibers, powders and reinforcements for materials applications are presented in this catalogue. These products are available at pilot scale as part of design and development of new products and materials. Their productions are also available at **industrial scale**.

The data presented further on will give the reader an overview of the potential of natural materials for industrial applications. The catalogue lists the main material properties that can be expanded as a function of the customer's development needs.

In sum, this catalogue showcases the natural materials dedicated to technical applications.

Interactions between producers, transformers and users will help us develop the product offering into more targeted and commercially available technical solutions. Our role at FRD is to act as a network promoter and industrial solutions integrator.

2 First processing: natural fibres

2.1 Definition

Apart from wood, for which the fibre is a co-product from its processing industry, the natural fibres produced worldwide come from four main parts of the plant (cf. Figure 1):

- stems
- leaves
- seeds
- fruit

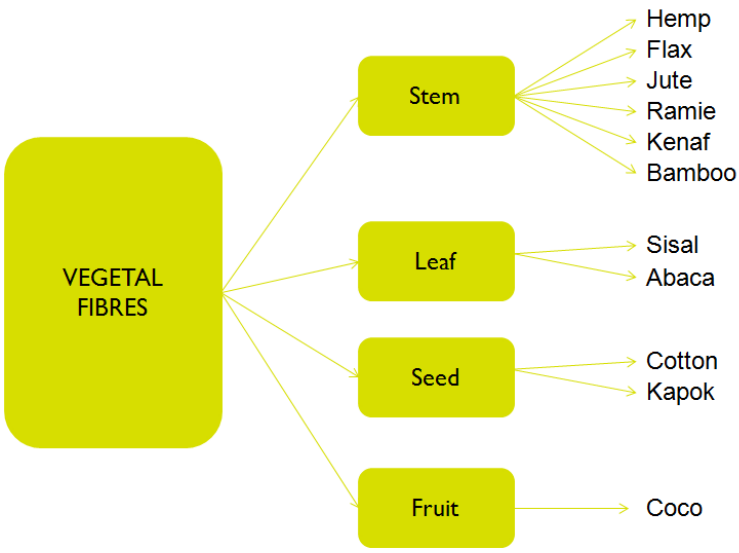

Figure 1. Origins of the major natural fibres produced worldwide

In Europe, the natural fibres produced industrially are flax and hemp; both of these come from the stems. Another fraction, the lignified core tissues (or shives) extracted from the central part of stems, is obtained when flax and hemp are processed. This shive fraction represents more than the half of all the vegetal fractions produced from flax and hemp stems.

2.2 Related vocabulary

As for any material, there is a specific technical vocabulary attached to the different activities and application sectors for natural fibres. For all vegetal materials handled by FRD (textile flax and linseed flax, hemp, miscanthus and wood) we will consider two types of products:

- fibres (with lengths in the millimetre–decimetre range)
- powder, meal and pellets, representing particle sizes ranging from hundreds of micrometres to several millimetres

This gives four qualifiers for the fibres and natural fractions used in material applications (cf. Figure 2):

- **fibres [mm]**, measuring in millimetres,
- **fibres [cm]**, measuring in centimetres,
- **fibres [dm]**, measuring in decimetres,
- **powders and meals [µm]**, which are particles and fibrous objects measuring in microns or millimetres.

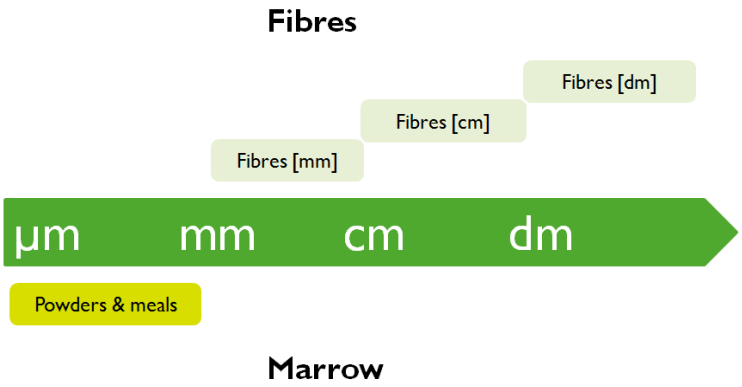

Figure 2. Vocabulary used for plant fractions according to type and size

2.3 Production/consumption

In December 2016, FRD as part of the project SINFONI published a study on market dedicated to the technical plant-based fibres for material use. **French production** of **natural fibres** (wood excluded) is close to **200 000 tons per year** on average, and **375 000 tons for powders and aggregates**. Europe as a whole produces 210 000 tons of natural fibres (wood excluded) per year on average, so France is Europe's leading natural fibre producer, accounting most of European production.

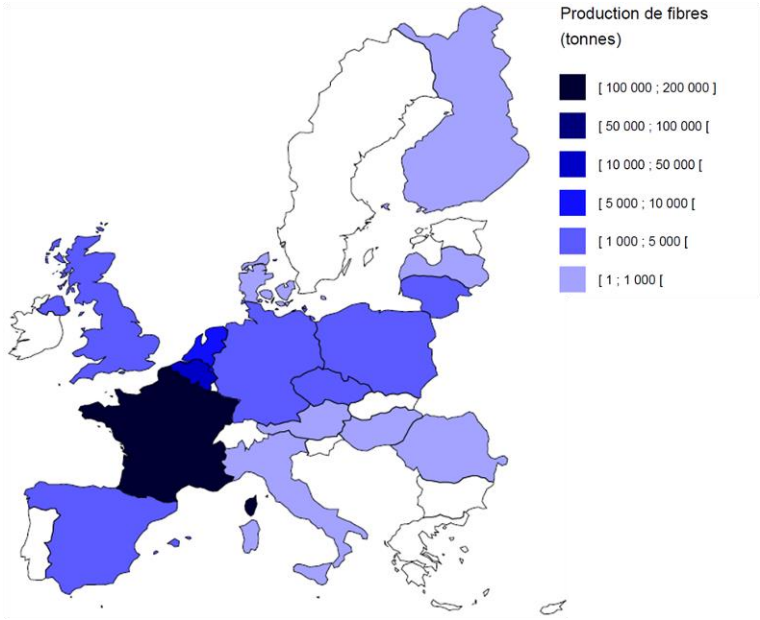

Figure 3. European natural-fibre resources. Average data 2001-2008. Source: FRD.

It is interesting to compare the production capacity for natural fibres to the consumption of glass fibre for composite materials. According to AVK's study on the European market for glass-fibre reinforced composites (glass fibre accounts for 90% of fibrous reinforcement for composites), consumption of glass fibre was an estimated 1 049 000 tons in 2011 (back up to the 2008 level). In France, glass fibres production was about 240 000 tons comparing to 200 000 tons of potential natural fibres for material applications. Only 2-2.5% of composite applications worldwide incorporate natural fibres, an indication of the tremendous potential of these materials.

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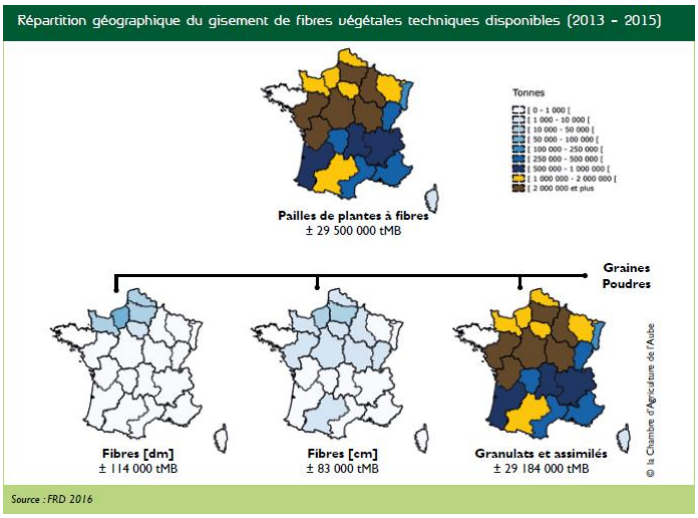
For more detailed information about natural fibres market:

Panorama of markets
"Technical plant fibres for materials (excluding wood)"

1. Presentation of Memento
2. Technical plant fibre resources
3. Economics of the french plant fiber sector
4. Main markets and evolution perspectives: insulation, panels, concretes, plastics, composites
5. Conversion coefficients
6. Technical glossary, acronyms and abbreviations
7. References



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2.4 Sustainable development

In Europe, industrial flax and hemp production consumes less energy and releases fewer greenhouse gases compared to synthetic fibre production.

Plant growth is directly related to the supply of light, heat, water and mineral salts. Because the synthesis of their carbonaceous skeletons involves the capture of atmospheric CO_2 (producing glucose via photosynthesis), flax and hemp act as **carbon sinks**. Planted in the spring, they require very little soil preparation and no irrigation at all for their growth; they need much less nitrogen fertilization than do grains, lowering the risk of nitrates leaching into the soil. They are also relatively easy to harvest.

Finally, flax and hemp are part of a multi-year crop rotation cycle. They are planted as spring break crops, so they favour crop pest/disease management by arresting their development. Hemp is also a good cover crop, helping to naturally suppress the growth of weeds and to reduce the seed population in the soil. Its combination taproot/fibrous-root system leaves good soil structure for the following crops.

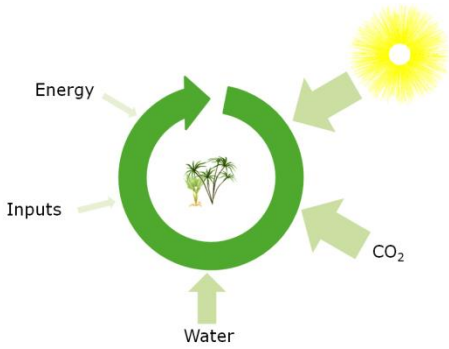


Figure 4. Simplified cycle of flax and hemp production

So the eco-balance for European flax and hemp cultivation is very positive:

- Production requires little fossil fuel
- The plants act as carbon sinks
- Irrigation is not necessary
- Few inputs are required
- Crops can be integrated into a classic farming rotation system, with benefits for the following crops

2.5 Advantages, drawbacks

Six main distinguishing performances of natural fibres and other biobased materials make them attractive for the railway and building sectors:

- their **lightness**
- their good **specific mechanical properties** (in relation to density)
- their good **insulation properties and thermal inertia**
- their **vibration dumping** behaviour
- their hydrophilic behaviour which enable sorption and **water uptake and desorption**
- their low **carbon footprint**

Natural fibres not only are renewable resources by their very nature, but they have a density of only 1.4-1.5 g/cm^3 — hardly more than half that of glass fibre, yet with similar mechanical properties (cf. Table 1). Thanks to their fineness (from 20 to 200 µm) and physical structure, they also have good thermal-insulation and acoustic properties.

Mechanical properties	Values	Specific values
Elasticity modulus	30-60 GPa	20-40 GPa/ρ
Tensile strength	500-1300 MPa	300-900 MPa/ρ
Deformation	3-4%	2-3%/ρ

Table 1. Mechanical properties of hemp and flax fibres.

Natural fibres and fractions also have other advantages, like:

- biodegradability
- low density
- non-abrasiveness

Despite these advantages, however, natural fibres do have some drawbacks when used in materials:

- they deteriorate at temperatures above 200-230°C,
- their hydrophilic behaviour and biodegradability can restrict their use in some applications, even if specific finishes do exist.

3 Second processing: reinforcements

3.1 Value chain of natural fibres products

The term "plant fibres" is generic and can mean a wide range of different products. For dedicated crop plants such as flax and hemp, the fractions obtained from the first transformation of the stems or straws are short/long fibers and aggregates. The succession of subsequent transformations makes it possible to produce increasingly complex materials ranging from raw fibers to final applications such as composites.

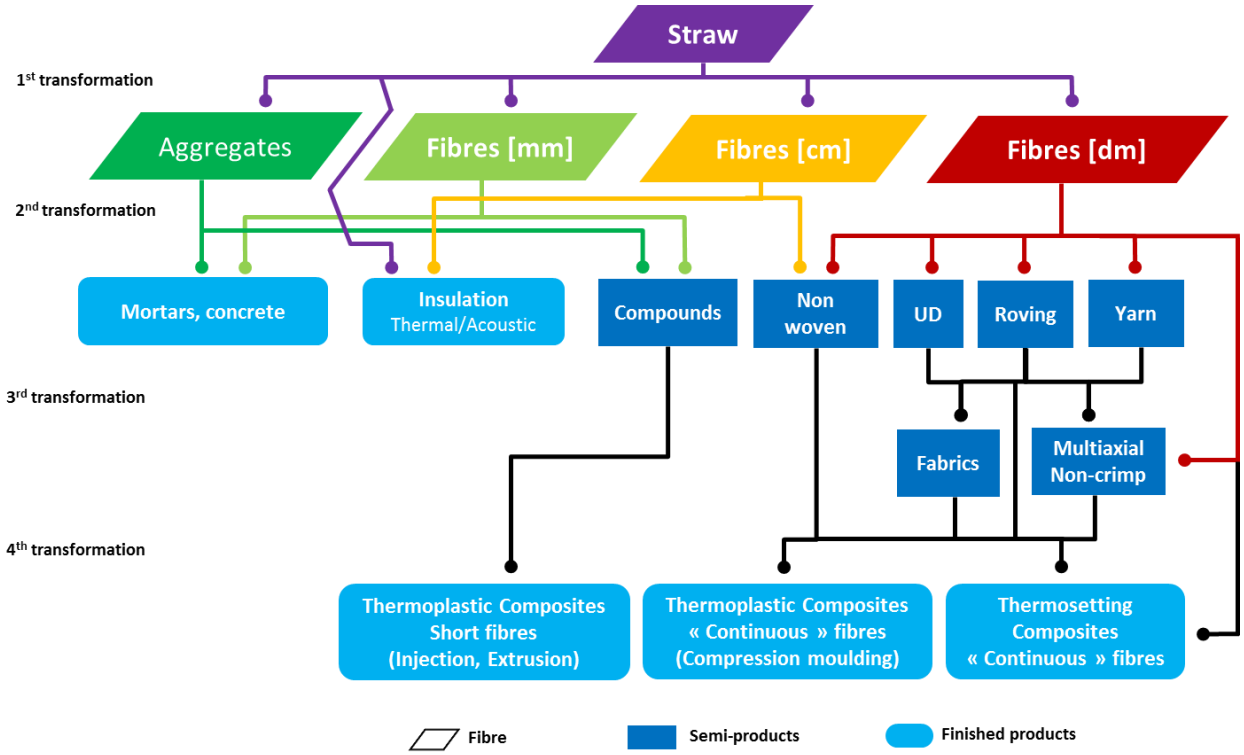
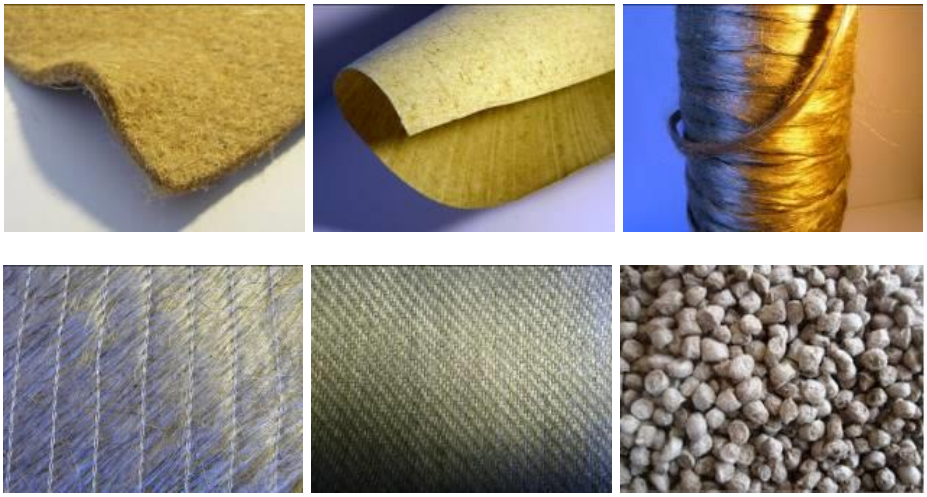


Figure 5: Plant-based fibres and semi-products value chain (Projet investissement d'avenir SINFONI)

3.2 Semi products dedicated for composite applications

There are different types of composite reinforcements, whether used with thermoplastic or thermoset resins. The types of available natural-fibre products are similar to those made from synthetic fibres. However, the discontinuous nature of natural fibres requires adapting the processes. The major products available industrially are as follows:

- **compounds**: polymer pellets reinforced with fibres [mm],
- **rovings/yarns**: continuous assembly of unidirectional fibres [dm] bound together with a low twist for overall cohesion, yarns are more twisted than rovings,
- **unidirectionals**: fibres [dm] or rovings laid preferentially in a single direction and stitched together with perpendicular yarns,
- **multiaxials**: unidirectional fibre fabrics stacked in two or more directions (e.g. 0°,90°) and stitch-bonded together,
- **fabrics**: uniform woven assembly of perpendicular yarns,
- **nonwovens**: web or mat of fibres [cm] arranged randomly and bonded by mechanical or chemical action.



4 Decision-support tables

Several different decision-support tables are presented below for help in selecting the most adapted product for a specific process and application.

Most current processes are adapted or adaptable for natural fibres and textiles. The temperature ranges should not exceed 180-200°C and the residual humidity of the material should always be taken into consideration before processing at temperatures over 100°C.

Photo credits: SNCF, PSA

4.1 From application to product

Application areas	Thermoplastic process	Thermoset process	Products
Automotive	Injection moulding, stamping, thermo-compression	SMC, BMC, RIM	Fibres [mm], fibres [cm], compounds, nonwovens, rovings/yarns
Building	Extrusion, lamination	Pultrusion, winding	Fibres [mm], fibres [cm], compounds, rovings/yarns
Electronics	Injection moulding, extrusion, lamination	SMC, BMC, RIM	Powder and meals, fibres [mm], fibres [cm], compounds, nonwovens, rovings/yarns
Aerospace	Injection moulding, extrusion	RTM, infusion	Nonwovens, woven fabrics, UD, multiaxials, rovings
Railway		Hand lay-up, RTM, spray-up	Needle-punched nonwovens, hydroentangled nonwovens, woven fabrics, UD, multiaxials, rovings, fibres [mm] or [cm]
Sports and leisure	Injection moulding, extrusion, stamping	Hand lay-up, RTM, infusion, pultrusion, spray-up	Fibres [mm], fibres [cm], compounds, nonwovens, woven fabrics, UD, multiaxials, rovings/yarns
Medical	Injection moulding, extrusion		Powder and meals, fibres [mm], fibres [cm], compounds
Naval		Hand lay-up, RTM, infusion, spray-up	Needle-punched nonwovens, hydroentangled nonwovens, woven fabrics, UD, multiaxials, rovings, fibres [mm] or [cm]
Consumer goods	Injection moulding, extrusion, stamping	Pultrusion, winding, SMC, BMC	Powder and meals, fibres [mm], fibres [cm], compounds, nonwovens, woven fabrics, UD, multiaxials, rovings
Wind energy		Hand lay-up, RTM, infusion	Nonwovens, woven fabrics, UD, multiaxials, rovings, fibres [mm] or [cm]

4.2 Products by transformation process

Process		Products	Application areas
Manual	Hand lay up	Nonwovens, fabrics, UD, multiaxials	Railway, sports and leisure, naval, wind energy
	Spray-up	Fibres [mm], fibres [cm], rovings	Railway, sports and leisure, naval, wind energy
	SMC	Fibres [mm], fibres [cm], rovings, nonwovens	Automotive, electronics, consumer goods
Compression	Thermo-compression TP	Nonwovens, fibres [cm], rovings	Automotive
	Stamping	Powder and meals, fibres [mm]	Sports and leisure, automotive, consumer goods
	BMC	Fibres [mm], Fibres [cm], rovings,	Automotive, electronics, consumer goods
Injection	RTM	Nonwovens, fabrics; UD, multiaxials	Aerospace, wind energy, railway, sports and leisure, naval
	RIM	Nonwovens, fabrics, UD, rovings, fibres [cm], fibres [mm]	Automotive, electronics
	Injection moulding TP	Powder and meals, fibres [mm], compounds	Automotive, electronics, aerospace, sports and leisure, consumer item, medical
Infusion	Vacuum infusion	Nonwovens, woven fabrics, UD, multiaxials, rovings	Wind energy, naval, sports and leisure, aerospace
	Lamination	Powder and meals, fibres [mm]	Building, electronics
Continuous	Pultrusion	Rovings	Building, consumer goods, sports and leisure
	Extrusion	Powder and meals, fibres [mm], fibres [cm], compounds	Building, electronics, aerospace, sports and leisure, medical, consumer goods
	Winding	Rovings	Building

4.3 Product range and textile preforms

Products	Thermoplastic process	Thermoset process	Application areas
Fibres [mm]	Injection moulding, stamping, extrusion, lamination	SMC, BMC, spray up	Automotive, electronics, aerospace, sports and leisure, consumer goods, medical, building, medical, railway, wind energy
Fibres [cm]	Injection moulding, stamping, extrusion, lamination, thermo-compression	SMC, BMC	Automotive, electronics, aerospace, sports and leisure, consumer goods, medical, building
Fibres [dm]	Textile preforms	Textile preforms	Textile preforms
Powders and meals [µm]	Injection moulding, stamping, extrusion, lamination		Automotive, electronics, sports and leisure, consumer goods, building, medical
Yarns, rovings	- After cutting : Fibres [mm] or [cm] - Textile preforms	Pultrusion, filament winding	Building, consumer goods, sports and leisure
Nonwovens	Thermo-compression	SMC, RIM, contact moulding, infusion, RTM	Automotive, electronics, aerospace, sports and leisure, consumer goods, building, railway, naval, wind energy
Fabrics	Thermo-compression	RTM, infusion, contact moulding, spray up, pultrusion	Aerospace, railway, naval, sports and leisure, wind energy
UD	Thermo-compression	RTM, infusion, contact moulding, spray up	Aerospace, railway, naval, sports and leisure, wind energy
Multiaxials	Thermo-compression	RTM, infusion, contact moulding, spray up	Aerospace, railway, naval, sports and leisure, wind energy
Compounds	Injection, extrusion	BMC	Automotive, electronics, sports and leisure, consumer goods, building, medical

5 Our services

5.1 Expand its product range and incorporate plant-based fiber materials

You wish to:

- **Develop materials incorporating natural products**
- **Identify natural materials available at an industrial scale adapted to your requirements**
- **Undertake technology transfer with technical assistance and support to the implementation**

Our support:

- **Substitution audit**
  - Supporting conception and integration of natural fibers based materials in accordance with specifications
  - Supporting the selection of fibers, reinforcements, polymer and resins adapted to your process
  - Supplying qualified samples and supporting to manufacturing
  - Conclusion on the feasibility of the operation. Operational recommendations
- **Services**
  - Supplying a complete range of natural fibers, shieves, yarns, rovings, weaves, non wovens, multiaxials, unidirectionnal based of flax, hemp and other plants
  - Development of treated fibers and reinforcement (fireproof, waterproof…)
  - Support for the use and the processability of these materials
  - Production and characterization of materials for insulation, board panels, concrete, plastics and composite applications
  - Realization of technological feasibility studies
  - Realization of market studies on targeted sectors
  - Supplying environmental data for LCA (Life Cycle Analyze)



5.2 Innovate and design bio-based materials

You wish to:

- **Be supported in the design of innovative composite materials**
- **Identify natural fibers and reinforcements in accordance with composite production process**
- **Start a technology transfer with a technical assistance to production**

Our support:

- Design of innovative materials and products: bio-based material, process, reinforcement, resin…
- Support for the production of prototypes : manufacturing, material innovation, partner identification,
- Functionalization and optimization of materials in order to meet the specifications
- Material characterization (thermoplastic and thermoset comoposites…)
- Realization of market studies and laboratory tests
- Realization of technological feasibility studies

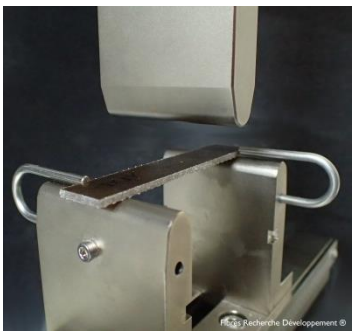
Materials analysis:

Reinforcements:

- Areal weight / thickness
- Tensile properties
- Water repellant / Spraytest
- Moisture content

Composites:

- Tensile properties
- Flexural properties (3 points)
- Impregnated Fibre Bundle Test (IFBT)

5.3 Develop and provide a thermoplastic/plant fiber compound specific to your products applications

You wish to:

- **Use a thermoplastic/plant fiber based compound specially suitable for your products applications and specifications.**
- **Identify and choose suitable materials for defined and precise specifications**
- **Identify and choose materials suitable for your processing technologies**
- **Get technical assistance as well as support for processing and industrialization for your production system.**

And you are ready and available to implement this change in your company?

Our support :

- **We offer you, through our partnership with the company APM, a "concept approach" aiming to use the material in a complete system rather than just as substitution material.**

- **Need definition**
  - Identification of your need(s) and assistance to the specifications definition
  - Validation of the concept feasibility

- **Formulation and compounding**
  - Joint development of a final product through the formulation and the processing of thermoplastic/plant-based fibers compounds.
  - Support to the identification and the selection of the compounds components suitable for your products specifications and your processes.
  - Support to the compound formulation adapted to your products specification.
  - Supply of compound for trials and characterizations
  - Characterization of these materials

- **Technical assistance and processing support**
  - Support to use and process compounds
  - Support to the implementation of materials sourcing
  - Support to technological transfer and industrialization

5.4 Establishing a supply chain

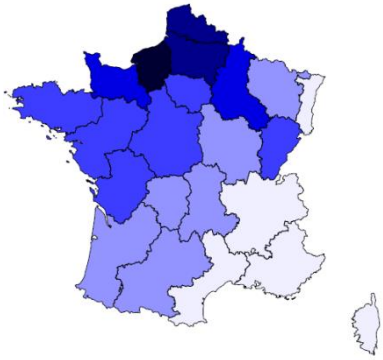
You wish to:

- **Define the sourcing strategy of an industrial site**
- **Choose the fibers/reinforcements and best suppliers**
- **Establish the operational supply chain**

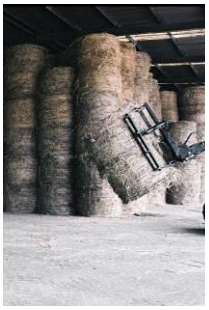
Our support:

- **Supplying studies**

  - Know the current deposit of a plant raw material (straw, fibers, preforms, …)
  - Understand the potential sourcing of a plant raw material
  - Know the conditions of access to these resources (availability, price, quality, …)
  - Define an operational qualified suppling area and their actors and stakeholders





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5.5 Mastering performances during industrial process

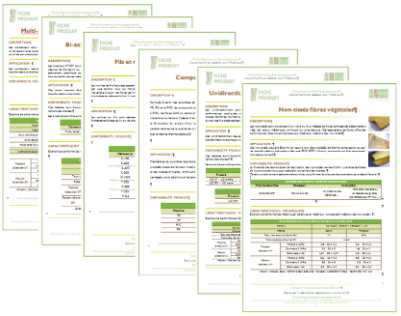
You wish to :

- **Control performance consistency of bio-based products at input of your process**
- **Guarantee processing of natural fibers and other bio-based products**
- **Create or upgrade a quality management system**

Our support:

- **Bio-based material analyzes**
  - Characterization of natural fibers and reinforcement
  - Technical data sheet adapted to bio-based material
  - Quality check during process

- **Technical data sheets for specific markets**
  - Evaluating major properties of natural fibers and reinforcements required for their qualification in specific market
  - Support to process upgrading in order to enhance consistency of the products



- **Quality management**
  - « Quality control » audit : check your quality management system to improve its performances:
    - If you need to be in accordance with new specifications
    - If you have to enhance consistency of your products performances
  - Support to quality management system implementation dedicated to a new market : process, tool, training and team coaching…

5.6 Analysis and quality check

Straw analysis

- Efficiency fibers / sheaves
- Moisture content and absorption capability (static and dynamic)
- Chemical composition
- pH
- Microscopy analyze
- Morphology
- Color

Fiber analysis

- Tensile properties
  - Elementary fibers
  - Fiber bundles
- Morphology
- Length
- Fineness :
  - Linear density
  - Average diameter
- Tentering potential
- Cleanliness :
  - Dust content
  - Shieves content
- Moisture content
- Chemical composition
- Color

Insulation wool and concrete analysis

- Thermal conductivity

Aggregate analysis

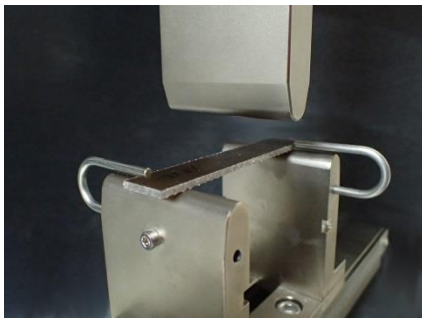
- Granulometry and morphology
- Density (apparent and tapped)
- Cleanliness :
  - Dust content
  - Fiber content
- Moisture content
- Moisture content and absorption capability (static and dynamic)
- Chemical composition
- Thermal conductivity
- pH
- Color

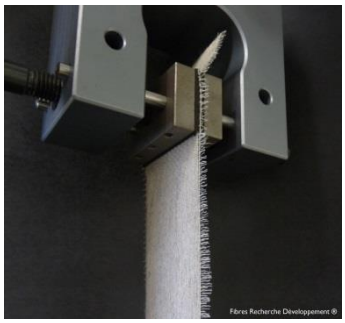
Reinforcement analysis

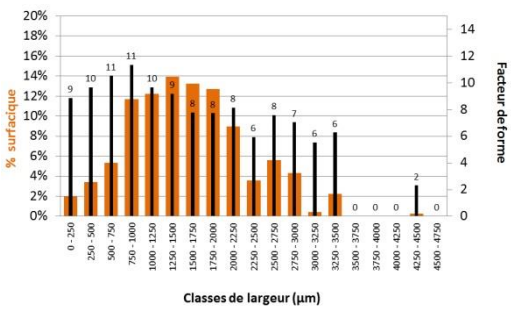
- Areal weight
- Tensile properties
- Water repellant / Spraytest
- Moisture content

Composite analysis

- Tensile properties
- Flexural properties (3 points)
- Impregnated Fibre Bundle Test (IFBT)







6 Natural products range

6.1 Fiber Box: short fiber range for materials

You wish to:

- **Develop materials integrating natural fibers**
- **Identify natural fibers available industrially on the market and in accordance with specifications**
- **Have samples of fibers [mm] and powders in order to carry out our development tests**

Our support:

- **Provide support in the selection of adapted natural fibers**
- **Supply a full range of short natural fibers, European and exotic.**

European Fiber Box

Species	Powders < 1 mm	Fibres available with 6 sizes (2 mm, 3 mm, 5 mm 6 mm, 10 mm, 15 mm)	Pellets
FLAX	x	X	x
HEMP	x	x	x
MISCANTHUS	x		

Exotic Fiber Box

Species	Fibres 2 mm
JUTE	x
SISAL	x

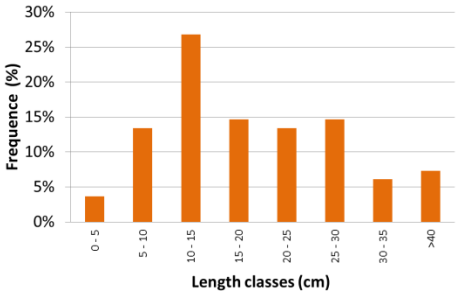
Species	Fibres 2 mm
COIR	x
KENAF	x

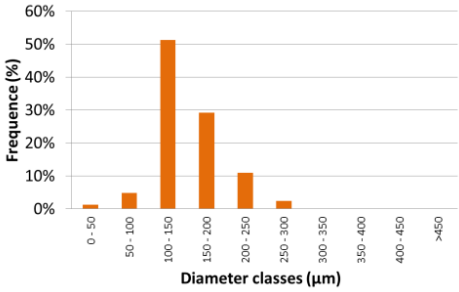
6.2 Fibre-based products

6.2.1 Fibres [cm] for non-woven (composites and insulation): FTECH

FTECH is a range of hemp or flax fibres available with length between 20 and 150 mm, and available with different fineness. Other species are available upon request (sisal, jute…).

These fibres are for example dedicated to non-wovens forming for acoustic and thermal isolation materials. These fibres can be mixed with other types of fibres (whether natural or synthetic) to combine their advantages.





Example of technical data sheet : Fibres for compounds and concretes FTech A19		
Technical data		
	Values	**Units**
Relative humidity [1]	9 - 11	%
Morphology		
Length	190,0	mm
Diameter	150,0	µm
Length and shape distribution	cf. curve	
Diameter and shape factor distribution	cf. curve	
Chemical composition [2]		
Cellulose	77,1 ± 0,1	%
Hemicelluloses	6,7 ± 0,2	%
Lignin	2,6 ± 0,2	%
Solubles	13,1 ± 0,3	%
Mineral matter	0,5 ± 0,0	%
Cleanliness		
Dust (< 150µm)	-	%
Residual shive	-	%
Color (L*a*b*)	54,25*2,51*9,79	

Using recommendations (non-wowens)	
Store away from humidity	
Process	Crosslapping - Needle punching

[1] Conditioning 48h to 20°C, 65 % of humidity

[2] According to norms NF EN V18-122 and NF EN ISO 13906

6.2.2 Fibres [mm] for reinforced thermoplastics and concretes: FIBRA

FIBRA is a range of european fibres (flax, hemp) and exotic fibres (sisal, coco, kenaf...) with a mean length between 1 and 20 mm.

These fibres are targeted for the reinforcement of thermoplastic, thermoset materials and concretes.

FIBRA range exists as well in the version FIBRA+ with precise length, available with lengths between 3 and 20 mm.

Example of technical data sheet : Fibres for compounds and concretes Fibra B2		
Technical data		
	Values	**Units**
Relative humidity [1]	9 - 10	%
Morphology		
Length	< 2	mm
Diameter	110,0	µm
Length and shape factor distribution	cf. curve	
Diameter and shape factor distribution	cf. curve	
Chemical composition [2]		
Cellulose	82,4 ± 0,1	%
Hemicelluloses	6,3 ± 0,1	%
Lignin	2,3 ± 0,3	%
Solubles	8,6 ± 0,4	%
Mineral matter	0,5 ± 0,1	%
Cleanliness		
Dust (< 150µm)	5,3	%
Residual shive	1,0	%
Apparent Density [3]	1,4-1,5	g/cm^3
Color (L*a*b*)	56,18*1,83*8,32	

Using recommendations (compounds)	
Store away from humidity - Drying	
Process	Extrusion, other processes

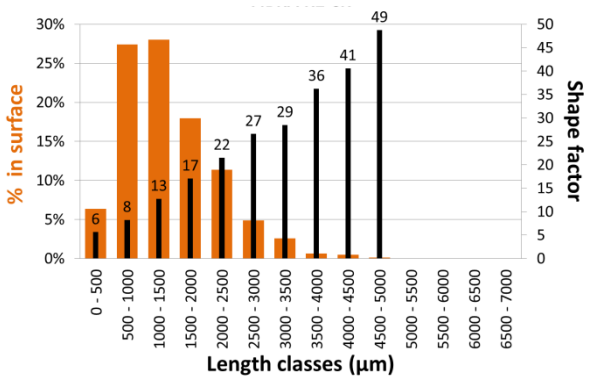
Using recommendations (concretes)	
Store away from humidity	
Process	Incorporation during the mixing

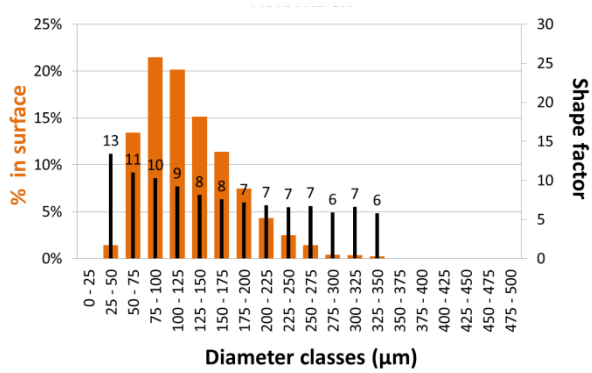
[1] Conditioning 48h to 20°C, 65 % of humidity

[2] According to norms NF EN V18-122 and NF EN ISO 13906

[3] Bibliography Data

To illustrate, the curves of length, diameter and shape factor distributions of FIBRA B2 are given below. Orange histograms show the length and diameter distributions of fibres in surface. Black histograms show the mean shape factor L/D for each class of length and diameter. Then, it appears that 50 % of the surface is occupied by fibres with a length between 500 and 1500 µm, for a mean shape factor of 8-13.





For illustrative purpose, the mechanical properties of polypropylene extruded and injected with FIBRA B2 are given in the table below.

Polypropylene composites (PP) (PP-30%m fibres - coupling agent)			
	PP	FIBRA-B2	Standards
Tensile mechanical properties			ISO 527-1 et 2, ISO 1873-2
Elasticity modulus (Gpa)	1,6 ± 0,1	4,0 ± 0,1	
Maximal strength (MPa)	42,0 ± 0,6	46,3 ± 1,6	
Elongation at break (%)	-	3,4 ± 0,3	
Flexural mechanical properties			ISO 178 : 2010
Elasticity modulus (Gpa)	1,5 ± 0,1	3,4 ± 0,1	
Maximal strength (MPa)	48,5 ± 2,8	76,7 ± 0,7	
Impact properties (unnotched)			ISO 179-2 : 2010
Charpy impact strength (kJ.m-²)	114,1 ± 10,2	18,0 ± 1,2	

6.2.3 Micronized powders: µFIBRA

µFIBRA is a range of european fibres (flax, hemp) and exotic fibres (sisal, coco, kenaf...) with a mean length under 1 mm.

These fibres are targeted for the reinforcement of thermoplastic, thermoset materials

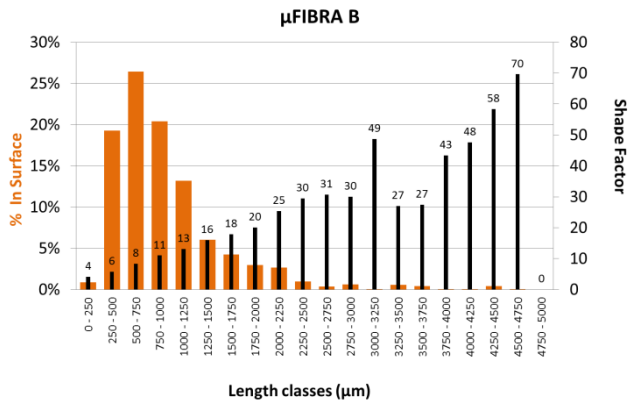
µGREEN range exists as well in the version µGREEN + with natural powder having narrowed granulometry:

Product availability	
Description	**Granulometry**
µFIBRA + 0-250	0-250 µm
µFIBRA + 0-500	0-500 µm
µFIBRA + 0-750	0-750 µm

Example of technical data sheet : Powder for compounds µFIBRA B		
Technical data		
	Values	**Units**
Relative humidity [1]	8 - 9	%
Morphology		
Length	0,6 ± 0,2	mm
Diameter	83 ± 20	µm
Length and shape distribution	cf. curve	
Chemical composition [2]		
Cellulose	82,4 ± 0,1	%
Hemicelluloses	6,3 ± 0,1	%
Lignin	2,3 ± 0,3	%
Solubles	8,6 ± 0,4	%
Mineral matter	0,5 ± 0,1	%
Apparent Density	170 ± 0,2	kg/m^3
Color (L*a*b*)	56,18*1,83*8,32	

[1] Conditioning 48h to 20°C, 65 % of humidity

[2] According to norms NF EN V18-122 and NF EN ISO 13906



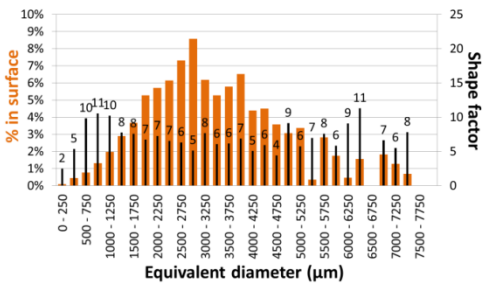
6.3 Aggregate-based products

6.3.1 Aggregates for concretes: NATHERM

NATHERM is a range of natural aggregates for use in concretes and exterior walls for thermal or acoustic insulation. They come in a broad range of size distributions as a function of the target application.

NATHERM range exists as well in the version NATHERM + with particles having narrowed granulometry:

Product availability	
Description	**Granulometry**
NATHERM + 2 - 5	2 - 5 mm
NATHERM + 5 - 10	5 - 10 mm
NATHERM + > 10	> 10 mm



Example of technical data sheet :
Aggregates for Concretes
NATHERM B

Technical data		
	Values	**Units**
Relative humidity [1]	9 - 12	%
Morphology		
Length	< 15	mm
Equivalent diameter and shape distribution	cf. curve	
Real Density	183 ± 21	kg/m^3
Apparent Density	150 ± 2	kg/m^3
Chemical composition [2]		
Cellulose	77,1 ± 0,1	%
Hemicelluloses	6,7 ± 0,2	%
Lignin	2,6 ± 0,2	%
Solubles	13,1 ± 0,3	%
Mineral matter	0,5 ± 0,0	%
Cleanliness		
Dust (< 150µm)	< 2	%
Residual fibers	< 2	%
Color (L*a*b*)	77,09*3,16*17,56	
Water retention capacity [3]	337 ± 11	%

Using recommendations (concretes)	
Store away from humidity	
Process	Incorporation during the mixing

[1] Conditioning 48h to 20°C, 65 % of humidity

[2] According to norms NF EN V18-122 and NF EN ISO 13906

[3] After immersion in water during 1h

6.3.2 Powders as fillers for thermoplastic materials: GREEN

GREEN is a range of fractions for use as reinforcement or filler in thermoplastic materials. These powders with a size inferior to 2 mm, can come from European species (hemp, flax…) but as well from exotic species. Round or needle shaped, these powders are adapted for extrusion processes, and can be used to enhance the mechanical properties of polymer matrices or increase the viscosity of the molten blend.

GREEN range exists as well in the version GREEN + with natural powder having narrowed granulometry:

Product availability	
Description	**Granulometry**
GREEN + 500-750	500-750 µm
GREEN + 750-1000	750-1000 µm
GREEN +1000-2000	1000-2000 µm

Example of technical data sheet : Powder for compounds GREEN B		
Technical data		
	Values	**Units**
Relative humidity [1]	9 - 11	%
Granulometry		
> 2000 µm	0,9	%
between 1000 and 2000 µm	40,9	%
between 500 and 1000 µm	40,7	%
between 250 and 500 µm	15,7	%
< 250 µm	1,8	%
Chemical composition [2]		
Cellulose	58,5 ± 0,6	%
Hemicelluloses	21,8 ± 1,4	%
Lignin	15,0 ± 0,5	%
Solubles	4,3 ± 0,1	%
Mineral matter	0,4 ± 0,2	%
Apparent Density	170 ± 0,2	kg/m^3
Color (L*a*b*)	82,64*1,97*15,19	

[1] Conditioning 48h to 20°C, 65 % of humidity

[2] According to norms NF EN V18-122 and NF EN ISO 13906

6.3.3 Micronized powders: µGREEN

µGREEN is a smaller range of fractions for use as reinforcement or filler in Wood Plastic Composites (WPC) or other applications needing very small particle sizes. These powders with a size inferior to 0,75 mm, come mostly from European species (hemp, flax…) but can as well from exotic species. Round shaped, these powders are adapted for extrusion processes.

µGREEN range exists as well in the version µGREEN + with natural powder having narrowed granulometry :

Product availability	
Description	**Granulometry**
µGREEN + 0-50	0-50µm
µGREEN + 50-100	50-100 µm
µGREEN + 100-250	100-250 µm
µGREEN + 250-500	250-500 µm

Example of technical data sheet :
Powder for compounds
µGREEN B

Technical data		
	Values	**Units**
Relative humidity [1]	6 - 8	%
Granulometry		
> 500 µm	16,7	%
between 250 and 500 µm	37,1	%
between 100 and 250 µm	27,9	%
between 50 and 100 µm	12,0	%
< 50 µm	6,4	%
Chemical composition [2]		
Cellulose	58,5 ± 0,6	%
Hemicelluloses	21,8 ± 1,4	%
Lignin	15,0 ± 0,5	%
Solubles	4,3 ± 0,1	%
Mineral matter	0,4 ± 0,2	%
Apparent Density	170 ± 0,2	kg/m^3
Color (L*a*b*)	82,64*1,97*15,19	

[1] Conditioning 48h to 20°C, 65 % of humidity

[2] According to norms NF EN V18-122 and NF EN ISO 13906

7 Biobased semiproduct range

7.1 Compounds

COMPOUND is a range of semi-finished products tailor-made from thermoplastics and plant-based fibers and/or flours. They can be produced from a wide range of matrices and reinforcements. Additives and/or fillers can be added to optimize the final properties of the materials. Those materials are designed for extrusion, injection molding and thermo-compression plastic processes and for all kind of application fields.

Range available :

Component/parameter	Availability
Matrix	PE, PP, PVC, PS, PLA, ABS, PBS, PBE
Reinforcement	Hemp, flax, miscanthus, sunflower, rapeseed, vinewood, sisal, kenaf, abaca, jute, ramie, agricultural byproducts…
Reinforcement ratio	0-50 % weight
Reinforcement shape	Fibers [0.5-2 mm], Flours [0-2000 µm]

Many size ranges are available on demand.

Other materials can be considered on demand.

7.2 Rovings and yarns

DESCRIPTION

Rovings are continuous assemblies of unidirectional fibres [dm] bound together at low twist for overall cohesion. Yarns are more twisted than rovings. Some references are proposed into blends with PP, PLA, PE or PA

APPLICATIONS

These materials are suitable for the textile production and composite manufacture with pultrusion or winding processes. based on flax or hemp.

AVAILABLE PRODUCTS

Yarn and roving		
Style	**Twist**	**Available fineness**
R-105	Low twist	105 Tex
R-200	Low twist	200 Tex
R-400	Low twist	400 Tex
R-1000	Low twist	1000 Tex
Y-200	High twist	200 Tex
Y-280	High twist	280 Tex
Y-320	High twist	320 Tex
Supply and development of products on specific request		

7.3 Unidirectionals

DESCRIPTION

Unidirectionals are suitable for end-uses where mechanical stresses are applied in one major direction. Fibres, rovings or yarns are lined up and stitch-bonded together or assembled by perpendicularly woven yarns.

APPLICATIONS

These reinforcements can be used for compression moulding, RTM, infusion or contact moulding.

AVAILABLE PRODUCTS

They are available in a wide range of weights and constructions adapted to specifications.

These products can be composed of 100% flax or blended to PP, PE, PA.

UNIDIRECTIONALS			
Bonding	Pattern	Available weights	Warp / weft ratio (%)
Stich bonded		150 g/m²	96/4
UD 0° - warp UD	Twill, Plain, Satin, …	150 to 400 g/m²	95/5 to 70/30
UD 90° - weft UD	Twill, Plain, Satin, …	150 to 450 g/m²	5/95 to 30/70
Supply and development of products on specific request			

MECHANICAL CHARACTERISTICS

Example of mechanical performances obtained with composite material containing natural unidirectionals :

Matrix		Epoxy	
Reinforcement Style		UD07	UD09
Areal weight (g/m²)		300	170
Number of layers		5	10
Fiber content by volum (%)		47	45
Tension (direction 0°)	Modulus E (GPa)	**26,6** *SD = 0,9*	**27,2** *SD = 0,8*
	Strength S (MPa)	**277** *SD = 18*	**279** *SD = 5*
	Elongation (%)	**1,3** *SD = 0,1*	**1,37** *SD = 0,05*
Flexion (direction 0°)	Modulus E (GPa)	**19,9** *SD = 1,8*	**18,9** *SD = 1*
	Strength S (MPa)	**306** *SD = 10*	**296** *SD = 15*
	Elongation (%)	**2,8** *SD = 0,1*	**3,1** *SD = 0,2*

7.4 Technical fabrics (0° / 90°)

DESCRIPTION

Biaxials, or woven fabrics, are assemblies of perpendicular yarns or rovings with specific weave patterns. Their structures determine their mechanical performances in the two directions: 0° and 90°.

APPLICATIONS

These products can be processed via compression moulding, RTM, infusion or contact moulding.

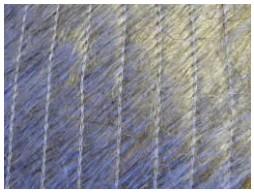
AVAILABLE PRODUCTS

These materials are available in a wide range of weights and weaves adapted to specifications. These products can be composed of flax or hemp which can be blended with thermoplastic fibres like PP, PE and PA.

0°/90° woven fabrics		
Pattern	**Available weights**	**Warp / weft ratio (%)**
Plain, Twill, Satin,…	50 to 600 g/m²	50/50
Supply and development of products on specific request		

7.5 Multiaxials

DESCRIPTION



Multiaxials consist of unidirectional plies stacked in two or more directions (ex: +45°, -45°) and stitch-bonded together.

APPLICATIONS

These materials can be processed via thermo-compression, RTM, infusion or contact moulding.

AVAILABLE PRODUCTS

Stitch binding	
Product	**Available weights**
+45° / -45°	150 to 500 g/m²
0° / 90°	500 g/m²
Supply and development of products on specific request	

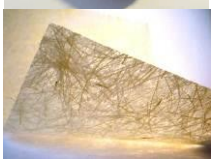
MECHANICAL CHARACTERISTICS

Examples of mechanical performances obtained with composite materials containing natural multi-axials :

Matrix			Epoxy	Polyester
Reinforcement style			M01-E	
Areal weight (g/m²)			820	
Number of layers			2	
Plies direction			0°/90°/90°/0°	
Fiber content by volum (%)			48,6	50,9
Tension	Modulus E (GPa)	0°	**17,6** *SD = 1*	**13,3** *SD = 0,5*
		90°	**14,9** *SD = 1,3*	**12,2** *SD = 1,6*
	Strength S (MPa)	0°	**147** *SD = 14*	**125** *SD = 6*
		90°	**128** *SD = 12*	**125** *SD = 7*
	Elongation (%)	0°	**1,1** *SD = 0,1*	**1,3** *SD = 0,1*
		90°	**1,2** *SD = 0,1*	**1,3** *SD = 0,2*
Flexion	Modulus E (GPa)	0°	**15,3** *SD = 1,6*	**14,7** *SD = 0,9*
		90°	**4** *SD = 0,6*	**4,2** *SD = 0,4*
	Strength S (MPa)	0°	**258** *SD = 33*	**155** *SD = 25*
		90°	**130** *SD = 33*	**168** *SD = 10*
	Elongation (%)	0°	**3,6** *SD = 0,5*	**4,9** *SD = 2,6*
		90°	**4** *SD = 0,6*	**4,6** *SD = 0,4*

7.6 Nonwovens

DESCRIPTION



Nonwovens consist of webs or mats of fibres [cm] arranged randomly and bonded by mechanical or chemical action. The random fibre arrangement gives isotropic mechanical properties to the final material (e.g. composite).

APPLICATIONS

Nonwovens can be used for thermo-compression processing or thermoset converting processes such as SMC, RTM, infusion, pultrusion or hand lay-up. Some products are also available in the ready-to-use form of thermoplastic sheets.

AVAILABLE PRODUCTS

The many different manufacturing technologies for nonwovens allow us to offer a wide range of products.

Available non-wovens			
Available products	Thickness	Composition	
50 to 2 500 g/m²	300 µm to 14 mm	Hemp, Flax, Jute, Kenaf, Sisal, …	100% of natural fibres or blended with thermoplastic fibres (PP, PLA, …)
Supply and development of products on specific request			

MECHANICAL CHARACTERISTICS

Examples of mechanical performances obtained with composite materials containing natural non-wovens :

Matrix		Epoxy	Polyester	
Reinforcement Style		NW15-G	NW06-P	NW15-G
Total reinforcement weight (g/m²)		1500	800	1500
Fiber content by volum (%)		33	24	29
Tension (direction 0°)	Modulus E (GPa)	**5,8** *SD = 0,2*	**6,6** *SD = 0,1*	**7,6** *SD = 0,3*
	Strength S (MPa)	**53** *SD = 3*	**63,9** *SD = 0,5*	**66** *SD = 4*
	Elongation (%)	**1,21** *SD = 0,07*	**1,7** *SD = 0,04*	**1,3** *SD = 0,1*
Flexion (direction 0°)	Modulus E (GPa)	**3,6** *SD = 0,9*	**5** *SD = 0,5*	**4,9** *SD = 0,6*
	Strength S (MPa)	**89** *SD = 8*	**99** *SD = 7*	**110** *SD = 9*
	Elongation (%)	**2,7** *SD = 0,3*	**2,6** *SD = 0,2*	**3,1** *SD = 0,2*

8 Conclusion

Given the increasing determination of industrialized countries to reduce their environmental footprint, bio-sourced materials and specifically natural fibres will garner more and more interest due to their advantages, which combine technical and environmental performance.

Flax and hemp are industrially available natural fibres that are grown in Europe, especially in France. These renewable products offer attractive technical characteristics for the material field, including low density and high mechanical, thermal and acoustic properties.

Demand for natural fibres in technical fields is soaring. This catalogue highlights the strong potential of these vegetal materials and presents their key properties as a function of the targeted application. It also touches on the products that have been developed and could initiates technical discussions between FRD and manufacturers.

FRD works actively to develop and design satisfactory solutions for its customers within the framework of the innovative "natural fibres and materials" sector, converting natural resources into technical solutions adapted to market needs.

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