New developments in wood and natural fiber composite research

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PELICE, Atlanta
April 7, 2016

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- 67 institutes and research units
- More than 24,000 staff members
- €2 billion annual budget. More than 1.7 billion Euros generated through contract research
  - Roughly two thirds of this sum is generated through contract research (industrial and public sectors)
  - Roughly one third from the the German federal government in the form of base funding

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Joseph von Fraunhofer

The Fraunhofer-Gesellschaft

Joseph von Fraunhofer		The Fraunhofer-Gesellschaft
Discovery of the "Fraunhofer lines" in the solar spectrum	**Researcher**	Research and development on behalf of industry and state
New methods for processing lenses	**Inventor**	mp3 music format, white LED, high-resolution thermal camera
Director and partner in a glassworks	**Entrepreneur**	Research volume: approx. €2 billion annually

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- http://www.wki.fraunhofer.de/en.html

150 staff

6 departments

15 Mio € annual budget

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Innovation in wood and natural fiber-based materials

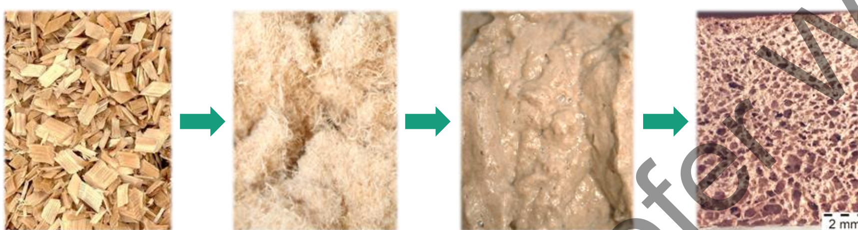
- General observations

- Contrary to common belief, the wood industry is highly innovative and has relatively short cycle between R&D and implementation
- Examples include: LVL, Parallam, MDF, CLT……
- Number of innovations came directly from the industry
- In resent years, non-wood fibers gained interest
- Other bio-based products find their way either in wood composite industry or in other industrial applications (coatings, adhesives, hybrid textiles, matrix-dominated composites…)

Foamed material of lignocellulose „Wood Foam“

Production of wood foam

- From tree to foam in 4 steps:
  1. Production of wood chips
  2. Production of wood fibers in a refiner (TMP)
  3. Intensive refining by high water content
  4. Foaming and final drying



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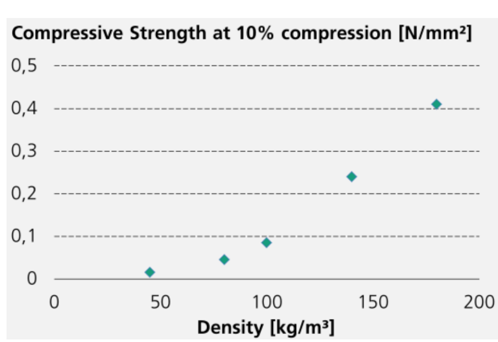
Properties of wood foam

45 kg/m³ 0,015 N/mm² | 80 kg/m³ 0,045 N/mm² | 100 kg/m³ 0,085 N/mm² | 140 kg/m³ 0,240 N/mm² | 180 kg/m³ 0,410 N/mm²

- Compressive strength increases with increasing density
- Reference values:
  - *Styrofoam*: 15 – 30 kg/m³ 0,10 N/mm²
  - *Balsa wood*: 100 – 150 kg/m³ 5 – 15 N/mm²



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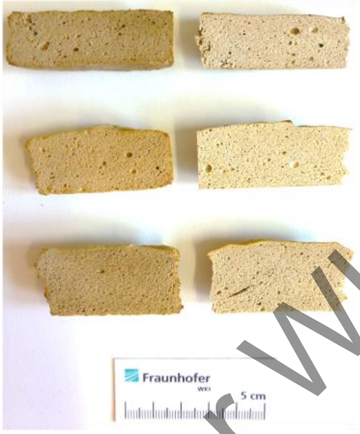
Properties of wood foam

- **Hygroscopic properties** after 24 h water storage:
  - Porous structure retains
  - Thickness swelling < 1%
  - Water consumption increase with decreasing density (300…900 %)
- **Heat conductivity**:
  - Between polystyrene and wood-fiber insulation boards
- **Fire resistance properties**:
  - Similar to natural fiber insulation materials
  - Burn and smolder, flame often self-extinguishes



left: after 24 h water stoarge
right: without water storage

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ScrimberWood

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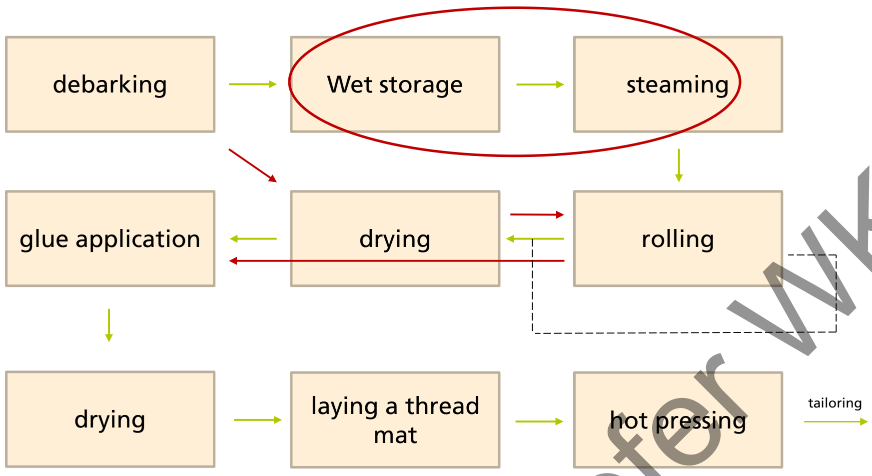
ScrimberWood - flow chart



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ScrimberWood: First results

Ashwood scrimber

Adhesive: Phenolformaldehyde
Density: 900 kg/m³ to 1000 kg/m³
Bending strength: 70 N/mm² to 130 N/mm²
Flexural modulus of elasticity: 11 kN/mm² to 15 kN/mm²
Tensile strength: 0,8 N/mm² to 1,8 N/mm²

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1. Projectsection (WKI-project) : Raw material - preparation

Preparation of raw material „ScrimberWood“:

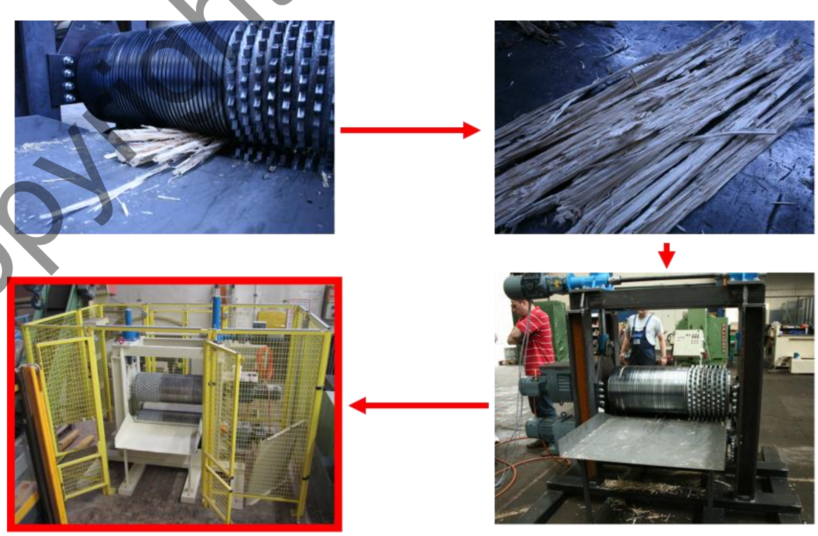
➔ Debarking and „crushing“ («scrimber»)

➔ Appropriation of a rough fibermat (85 % raw material efficiency)

➔ Determination of an optimal pretreatment of raw material and further operating parameters of roller system to treat and fabricate ash wood assortments




2. Projectsection (WKI-project): Scrimber roller



3. Projectsection (WKI-project): Material development

Development of „scrimber materials“:

- ➔ Production of **boards** and **scrimberbeams**
- ➔ Optimizing the mechanical-technological product properties and the inclination of emissions
- Variation of process parameters (press diagram, behavior of agglomeration and steam extraction, presstime, etc.)
- **Determination of optimal glue amount and development of adequate glue application systems**
- ➔ Application of the results to other wood species

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Natural fiber reinforced press moulded parts for automotive, construction and furniture industry

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Production of press moulded parts

-Extrusion (WPC)

-Injection moulding

-Compression moulding

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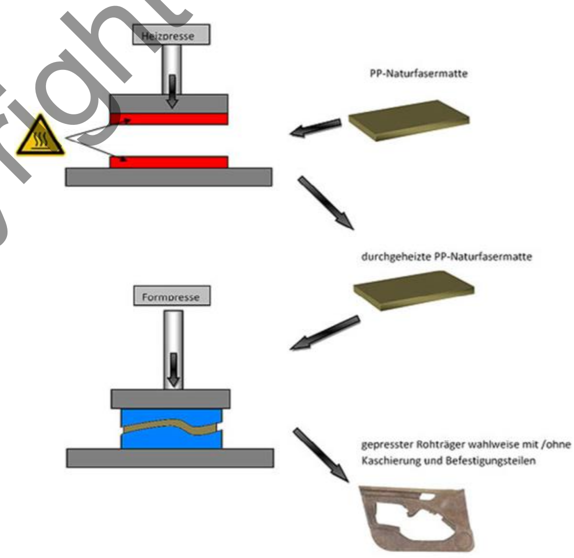
Compression moulding process (Thermoplastic)



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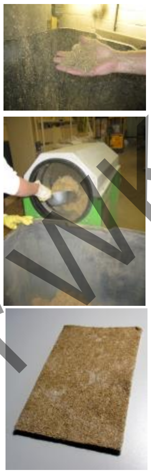
Natural fiber reinforced press moulded parts - Main focus of research of the WKI

- Optimization of fiber production during the defibration process by using different materials and lignocellulosic by-products
- Optimization of fiber digestion and improving of the process parameters
  - Maximising of fiber yield
- Optimization of press moulded part production by
  - Application of adehsive systems with low emissions
  - Application and suitability test of additives
  - Process adjustment on raw material and additives
  - Optimization of product properties by aimed process modification
    - good mechanical properties (“crash behavior”)
    - low VOC emissions
    - neutral odor
    - significant increase of natural fiber share strength in molding part
      - thermoplastic bonding: > 55 %
      - thermoset bonding: > 70 %



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Challenges (I)

- **Raw materials:**
  - **Sustainable, regional availability (logistics)**
  - **Anatomy (short-fiber vs. long-fiber plants)**
  - **Maximum application quantity in the moulded part**

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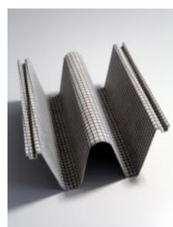
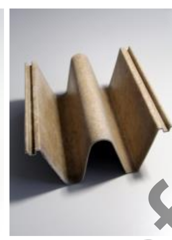
Challenges (II)

- **Feeding of the pressing tools**
  - Cooling/ time slot to the transfer of thermoplastic bound „pre-compaction" into the forming die
  - Even density distribution over the total extension of the press moulded part, respectivly, deliberated distribution (spreading, mat manipulation)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Using bioresources for coatings and adhesives

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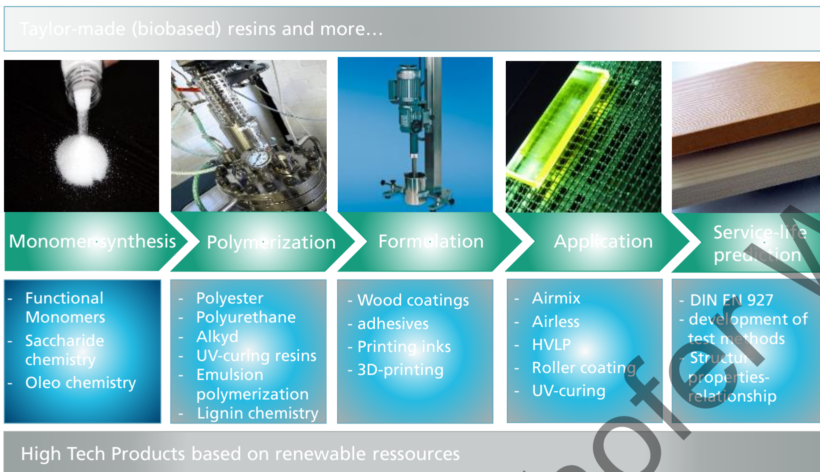
R&D along the entire value chain of coatings, printing inks and adhesives



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Project: NEXT1KOAT
Coatings from seaweeds

- Development of water-based, one component coatings using sugar isolates and derivates from brown algae

Funding: **7.Frameworkprogramme EU**
Funding Agent: **REA**
Duration: **2013-2015**

HELIOS · Indema s.a · Tecnologías Avanzadas Inspiralia S.L. · ISOLACK, S.A · CETEM · BPF · Fraunhofer WKI · BÖÖGARE · Lesarski grozd Wood Industry Cluster · Malta Furniture Manufacturers Organisation

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Project:
UV-curing Coatings Based on Itaconic acid

- Development of coating resin(dispersions) using biotechnologically produced itaconic acid for radiation curable coatings
- Resins are free of acrylates !
- High natural content
- Extreme durable exterior coatings
- Suitable for furniture coatings

Funding:	**BMEL**
Projekt Executive Body:	**FNR**
Duration:	**2011-2013**

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Project:
UV-Curing Printing Inks Based on Itaconic Acid

- Project aim: Binder 100% derived from renewable resources without (meth)acrylates
- Itaconic acid as UV-curing
- Low allergenic potential

FNR · Gefördert durch: Bundesministerium für Ernährung und Landwirtschaft aufgrund eines Beschlusses des Deutschen Bundestages

WORLÉE seit 1851 · Jänecke+Schneemann Druckfarben ...natürlich umweltgerecht

FKZ: 22015614: UV-curing inks derived from renewable resources, 2015-2017

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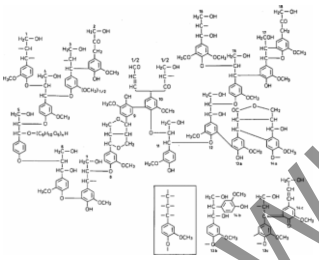
Project: LignoGlue
Lignin Sourced Adhesives

- Synthesis of lignin sourced binders for:
  - reactive hotmelts
  - prepolymers
  - PU-dispersions
  - protective colloids



Funding: **BMEL**
Projekt Executive Body: **FNR**
Duration: **2015-2018**

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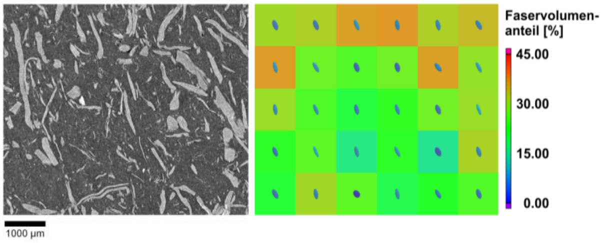
Hybrid materials for transportation industry



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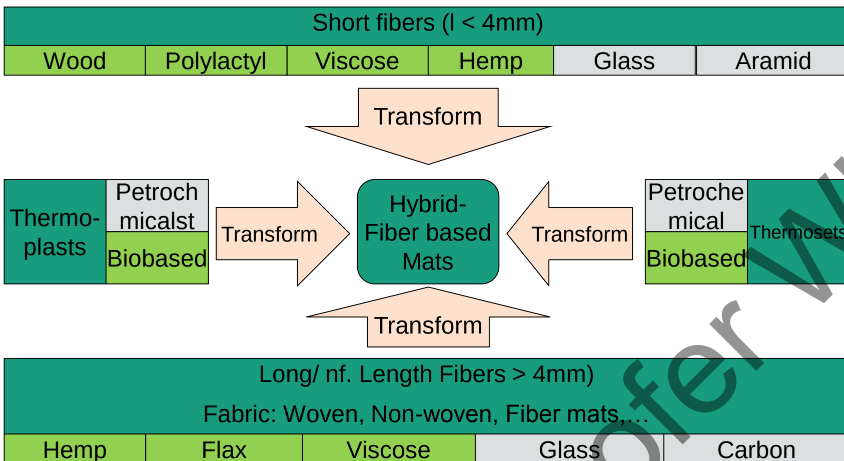
DEVELOPMENT OF SUSTAINABLE HYBRID MATERIALS



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COMPARISON OF FIBERS

	Glass fiber	Flax	Carbon fiber
Tensile strength [MPa]	2400 →	400 - 1500 ↓	3500 ↑
E [GPa]	80 →	10 - 80 ↓	300 ↑
Density [gcm^{-3}]	2,6 ↓	1,4 ↑	1,8 →
Costs [€kg^{-1}]	2 →	0,5 – 3,5 ↑	18 - 500 ↓
Carbon-Footprint	→	↑	↓

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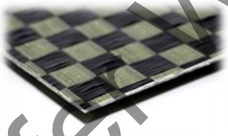
Research using natural fibers

- Natural fibers
  - Surface modification
  - Fiber analysis
- Technical (hybrid) textiles
- Bio-hybrid composites
- Short fiber-reinforced composites
- Organic sheets
- Recycling


Jute fabric
©Fraunhofer WKI/HOFZET


Moulded components
©Lingnau Fraunhofer WKI


Various laminates
©Lingnau Fraunhofer WKI


Aramid/carbon fiber reinforced epoxide
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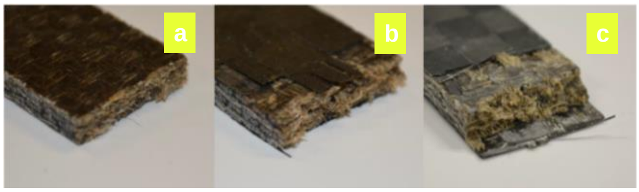
Bio-hybrid laminates

- Lamination of natural and high-performance fiber fabrics with thermoplastic or thermoset matrices
- Application-oriented development of new bio-hybrid composites
  - Application-specific material combination
  - Improvement of crash behavior



Fracture behavior of CF/NF bio-hybrid laminate with increasing number of CF plies

Photos: ©Fraunhofer WKI/HOFZET

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Bio-hybrid textiles

- Manufacture of integral application-specific semi-finished textile products using multi-materials
- Multi-material systems combining natural, high-performance and matrix fibers
- Extended multilayer design using modern weaving technique
- Near-net-shape manufacture of semi-finished 2D&3D products
- Development of novel technologies for the manufacture of load-oriented semi-finished textile products
- Integration of additional functions (e.g. sensor network) in a textile process stage

Double rapier weaving machine
©Lindauer / DORNIER GmbH

Ondulation free multilayer hybrid textile
©TU Dresden/Sraubli

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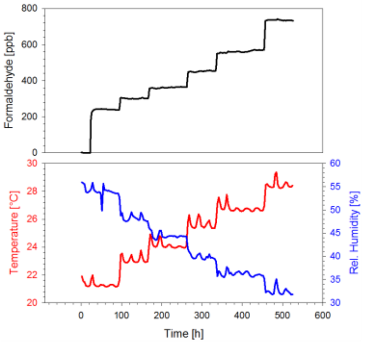
Formaldehyde reference source for validation of emission test chamber measurements



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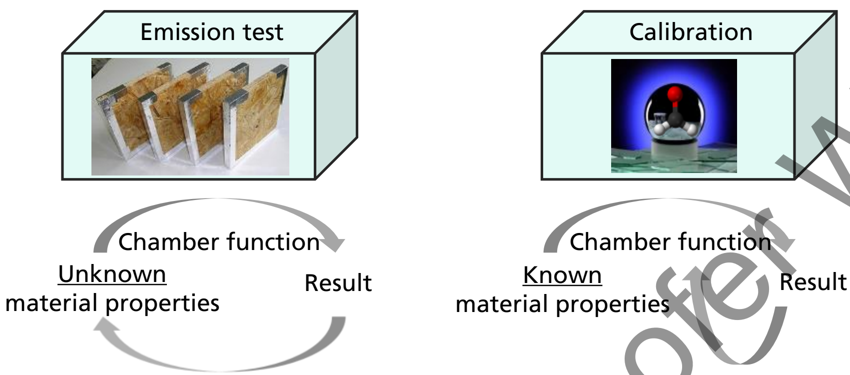
FORMALDEHYDE REFERENCE SOURCE FOR VALIDATION OF EMISSION TEST CHAMBER MEASUREMENTS: WHY?

- Goal: Validation of emission test chamber performance (chamber & analytics)
- Mimicking „real“ emission profiles (e.g. from particle boards)



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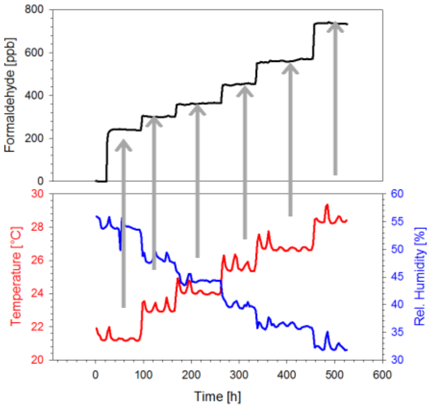
FORMALDEHYDE REFERENCE SOURCE FOR VALIDATION OF EMISSION TEST CHAMBER MEASUREMENTS: HOW?

Known material properties
Similar characteristics as a regular test object

Sensitive adverse to Emission test chamber parameters

Verification of compliance with regulations

Climate → Formaldehyde concentration



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WKI REFERENCE SOURCE

- Characteristics
  - Formaldehyde release depends on temperature and humidity
  - Constant emission profile > 28 d
  - Reproducible emission profile
  - Easy-to-use; easy setup

- Approach
  - Basis: Paraformaldehyde
  - Physical hindrance / diffusion-controlled emission
  - Air-tight screw box (no leakage)

see: Giesen, R., Schripp, T., Salthammer, T., 2016. Characterizing a formaldehyde reference source for validation of emission test chambers. Indoor Air 2016, Gent, Belgium, ID 552.

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Development of flame-retarded Wood-Plastic Composites (WPC)

Dr. Arne Schirp, Andreas Hellmann, Fraunhofer WKI. Dr. Aitor Barrio, Jokin Hidalgo , Tecnalia, Azpeitia, Spain

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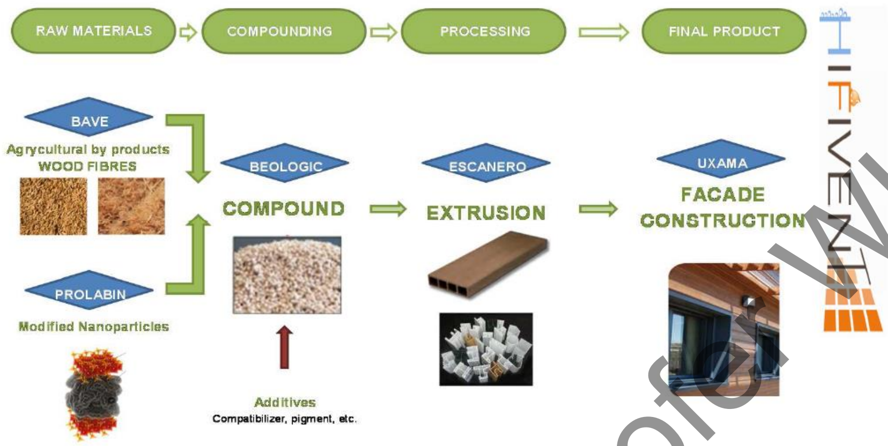
Project HIFIVENT - Overview



Two approaches in HIFIVENT project

- Use **thermomechanical pulp (TMP)** because fire retardants can be applied continously to the fibres using the refiner blow-line

→ pre-treated fibres can be pelletized and mixed with polymer plus further additives

- Use **rice husks** because they contain a high amount of inorganic, non-flammable material (silica)

→ additional fire-retardants may be added during compounding

→ commercially available fire-retardants and nano-FR

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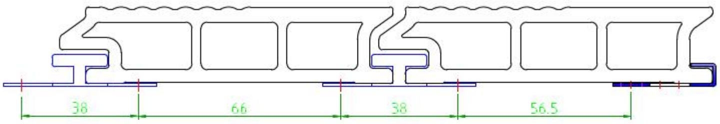
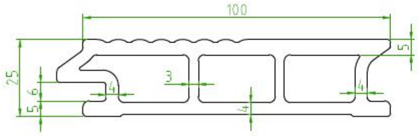
Siding profile extrusion





Option for co-extrusion

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Siding profile extrusion at WKI

Processing parameters :

Temperature settings:
Zone 4 (closest to tool): 180°C
Zone 3: 185°C
Zone 2: 165°C
Zone 1 (closest to feeder): 190°C
Melt temperature: 169°C
Melt pressure: 125 bar
Throughput: 30 kg/h
Vacuum degassing: 300 mbar

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Fire shaft test: Results for commercial WPC-profiles (without fire-retardants)

PVC-based: passed (B1)

PP-based: failed (B2)

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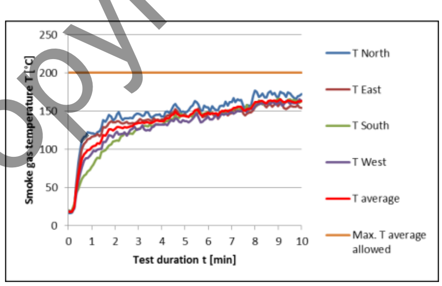
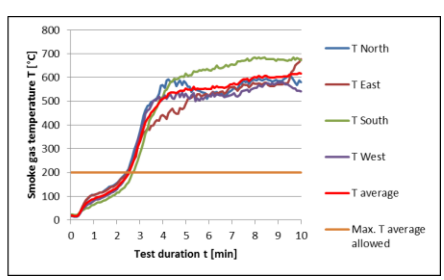
Smoke gas temperature results for commercial WPC without FR

PVC-based WPC (B1 passed)



PP-based WPC (B1 failed)



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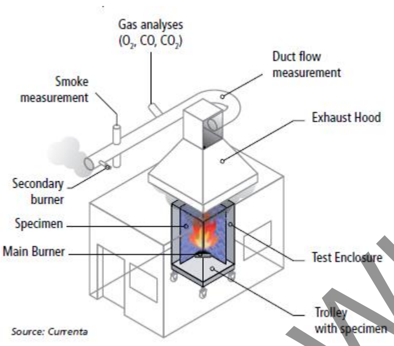
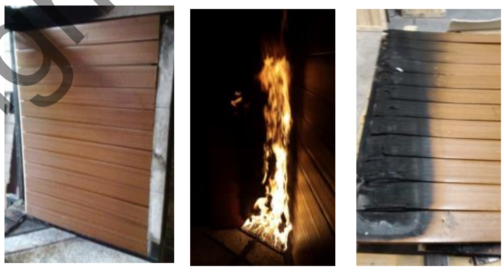
Single burning item – Test setup (EN 13823)

- Simulates a single burning item burning in a corner of a room
- The total exposed specimen surface area is 1.5 m x 1.5 m
- Specimen consists of two parts which form a right-angled corner
- A propane gas burner (30 kW) acts as heat and ignition source representing a burning waste paper basket
- Burner is placed at basis of specimen corner
- Duration: 20 min.



Source: PINFA (http://pinfa.org/)

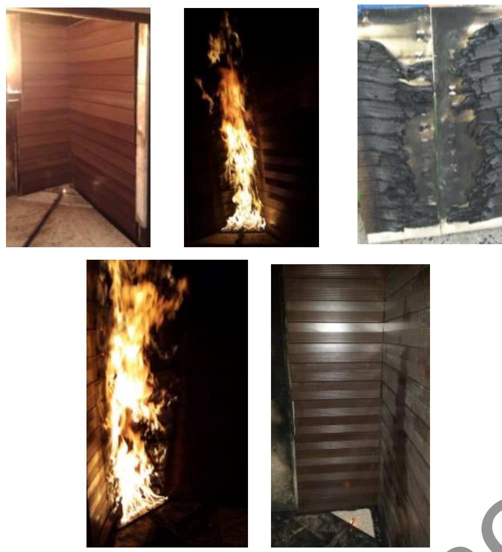
Single burning item tests – results for prototypes I and IV



Prototype I: B-s2, d0

Prototype IV: C-s3, d0

Single burning item test – results for prototypes II and III



Prototype II:
D-s3, d0

Prototype III:
D-s3, d0

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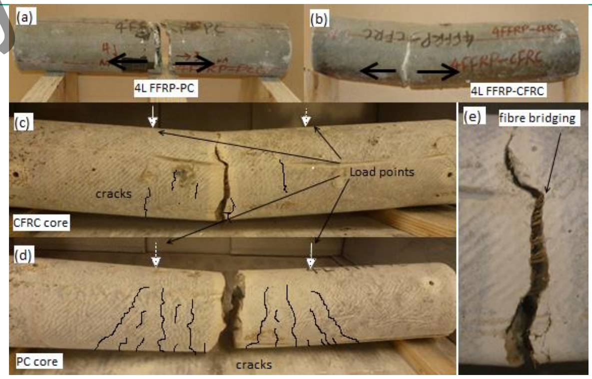
Natural fibers and anorganic matrix



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NATURAL FIBERS AND ANORGANIC BINDERS (CONCRETE) – LIBO YAN

- Steel corrosion is a main reason for infrastructure deterioration
- Steel is still expensive and comes from non-renewable resources with high energy consumption
- Natural fibres: light and inexpensive, low toxicity, environmentally-friendly, high degradable and readily available
- Natural fibres: less resource-intensive production (water, energy, waste), reduce greenhouse gas emission, support to rural development, increased industrial competitiveness through eco-efficient bio-based products
- Natural fibres: good specific mechancial properties (stiffness and strength) comparable to glass fibres or other synthetic fibres
- Natural fibres: good thermal insulating and acoustic properties due to their hollow tubular structures

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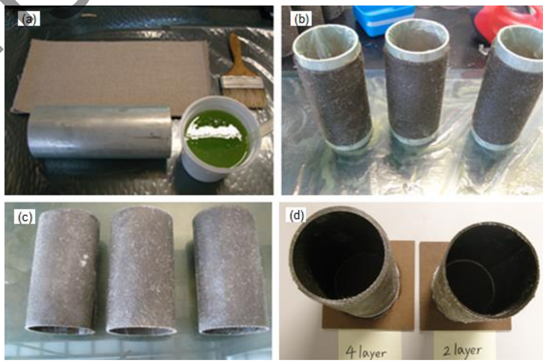
FLAX FIBERS FOR COLUMN REINFORCEMENT



Fabrication of Flax FRP tubes: (a) flax fabrics, (b) FFRP tubes with mould, (c) demould and (d) FFRP tubes

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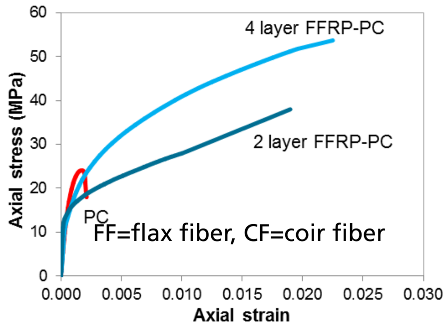
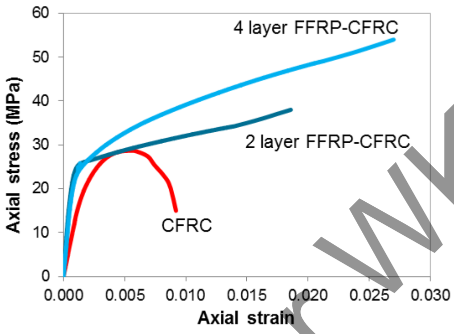
COMPRESSIVE BEHAVIOR OF THE FFRP-CFRC



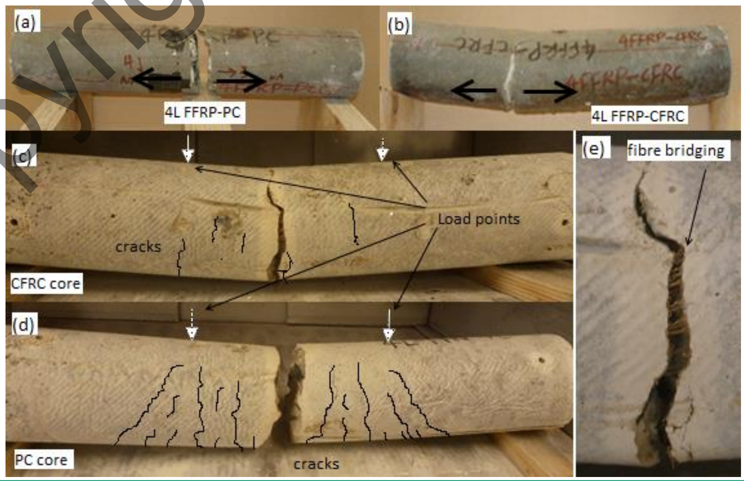
FFRP-PC



FFRP-CFRC

"PC" for plain concrete without coir fibre, "2 layer" and "4 layer" for FFRP tube thickness of 2 plies and 4 plies flax fabrics

BENDING



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