Potential of Bicomposites for Economic Development in Southern Africa

4^{th} Biennial Conference

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What is Composite Material?

- **A material consisting two or more very different <u>constituents (phases)</u> in reasonable proportions (say > 5%)**
- **Material is fabricated <u>by mixing</u> (not by phase separation) in order to compensate for the deficiency of the un-reinforced material**

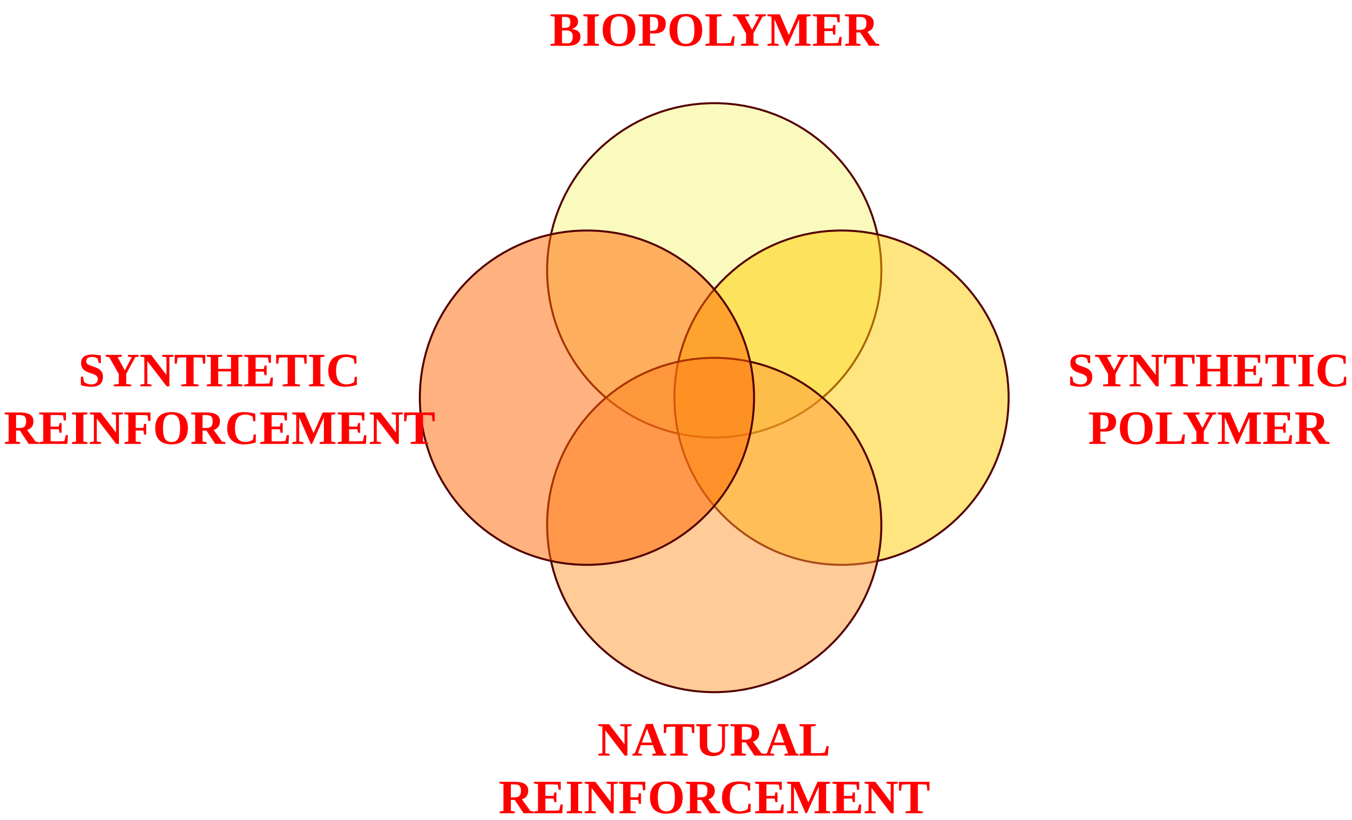
Composite Material

- **It consists of mainly following constituents:**
  - **Matrix**, it can be polymeric, ceramic or metallic
  - **Reinfrocement**, it can be fibres, platelets, spheres, fillers, particles, pieces, etc.

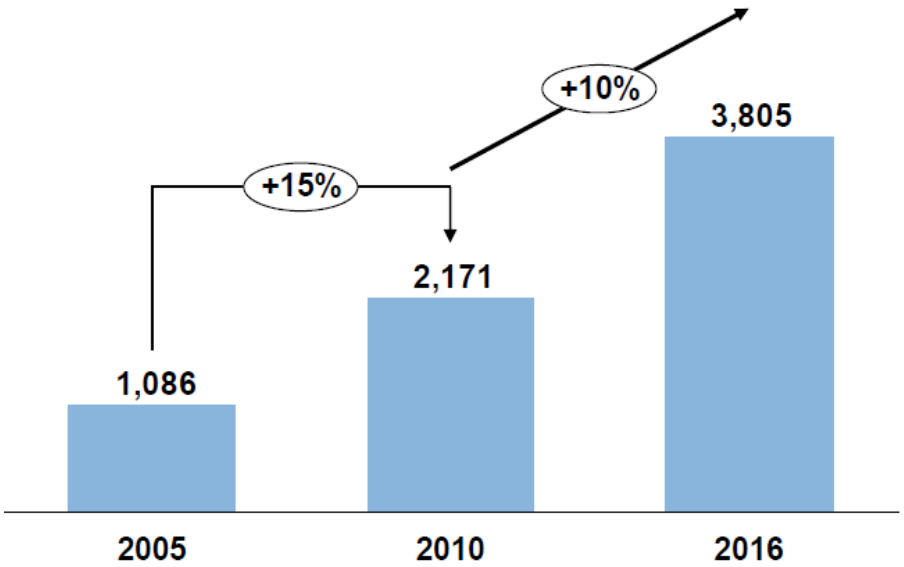
Not necessarily, composite materials are only binary, they can be ternary as well.

For example, filler can be added to a fibre reinforced composite to make it fire retardant or flame proof!!

Composite and Biocomposite Materials



Natural Fibre Composites Market Trends (US $million)



Source: Licintel

Includes both wood and non-wood fibres

Salient Highlights

- **Increasing potential and market share.**
- Actual growth, according to natural fiber suppliers, has been at **10 to 15 % per year**

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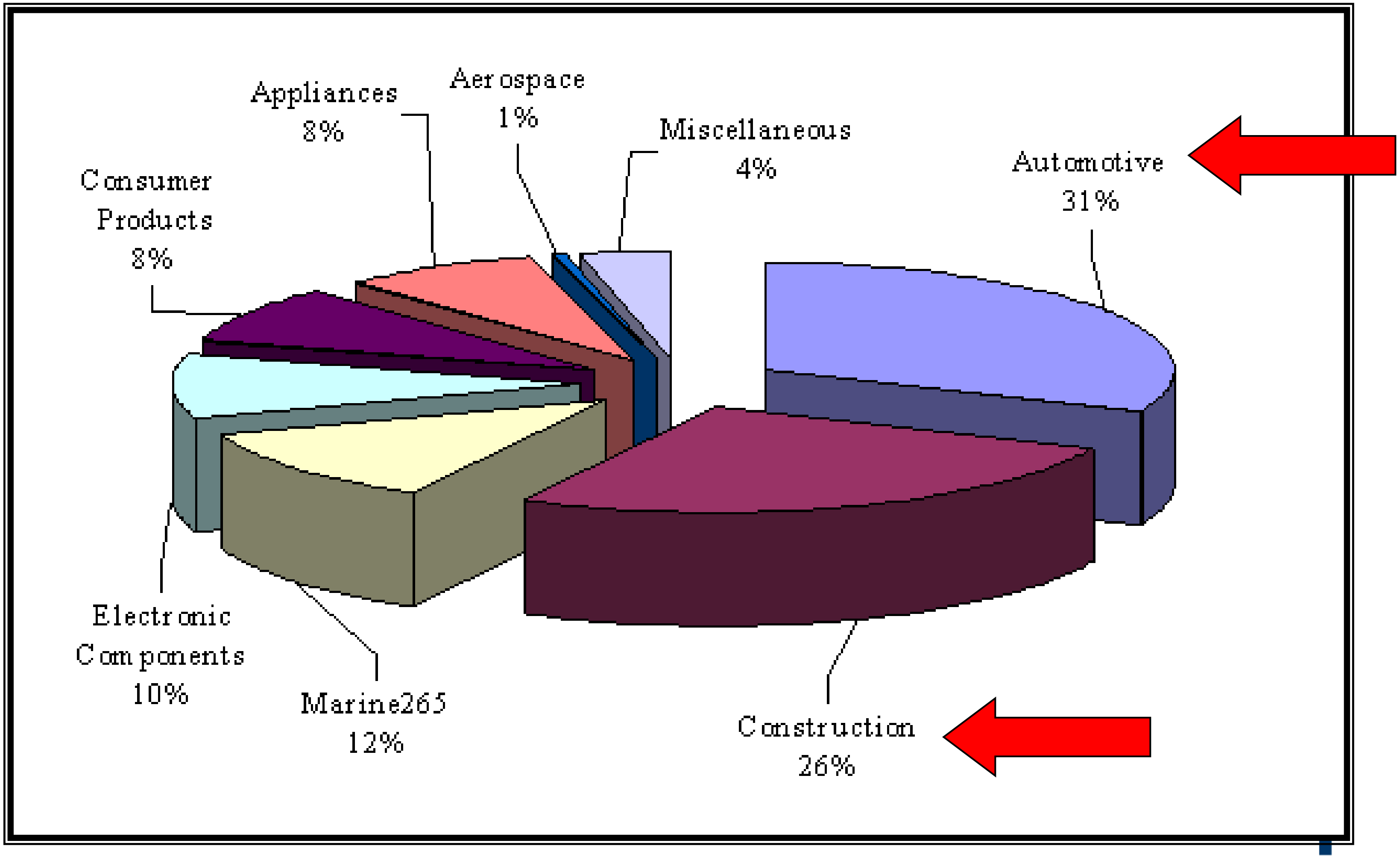
Market and Applications



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Major Market Drivers

- **Environmental**
  - **Energy savings**
  - **CO_2 Sequestration**
  - **Renewability – Sustainability**
- **Regulatory pressure**
  - **End-of-life of vehicle (ELV) laws by EU require the automotive manufacturers to ensure that all new vehicles are 95% recyclable by 2015**
  - **CO_2 Trading**
- **Need for lighter and fuel efficient transport vehicles**
- **Going “green” is imperative! Not a choice!**

Advantages of Fibre Reinforced Composites (1 of 2)

- Low density of products.
- Acceptable specific strength and high toughness.
- Ease of shaping into complex shapes in a single manufacturing step.
- Reduced tool wear.
- Most thermoplastic composites are recyclable.
- Safe manufacturing processes, no airborne glass particles, relief from occupational hazards.
- Lower price of polymer composites reinforced with natural fibres than those reinforced with glass fibre.

Advantages of Fibre Reinforced Composites (2 of 2)

- **Reduced dermal and respiratory irritation**
- **Possibility of recycling the cuttings and manufacturing wastages.**
- **No emission of toxic fumes when subjected to heat and incineration.**
- **High flex modulus - up to 5X base resin**
- **High tensile modulus - up to 5X base resin**
- **High notched impact - up to 2X base resin**
- **Lower processing energy requirements.**

Disadvantages of Fibre Reinforced Composites (1 of 2)

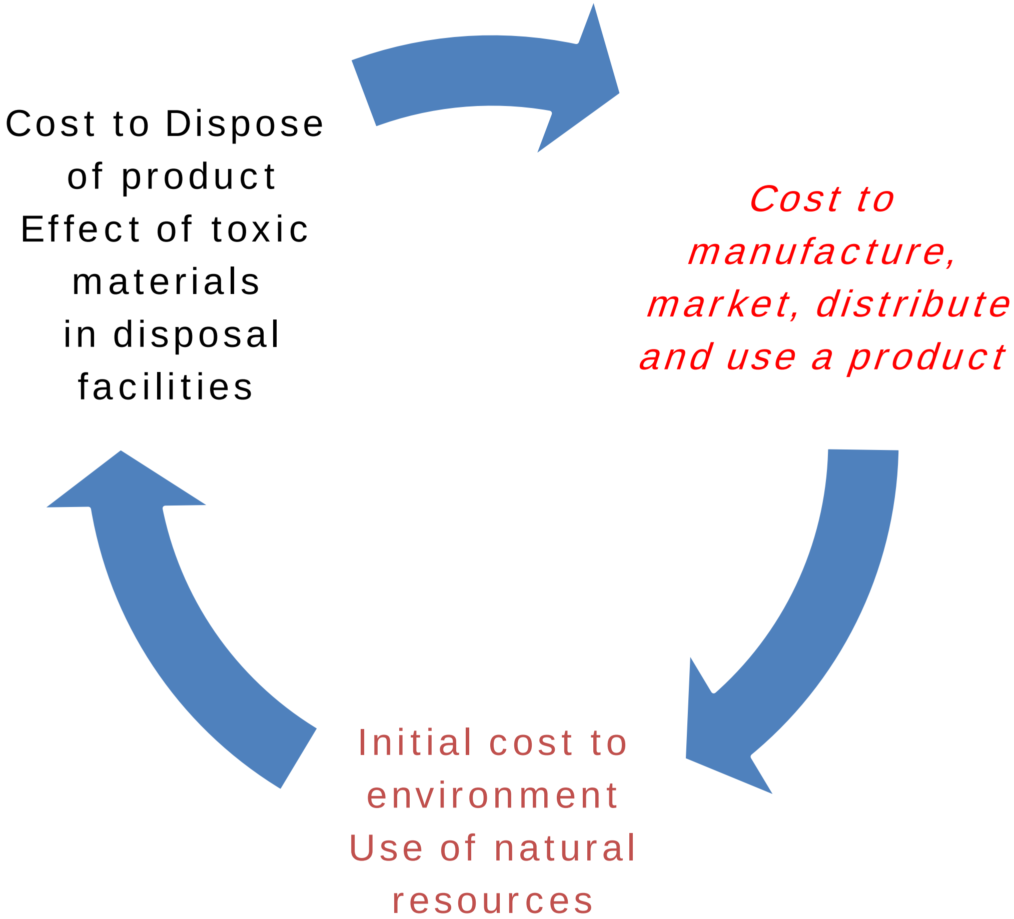
- Lack of consistency in fibre quality, high level of variability in fibre properties depending upon source and cultivars
- Preparation of fibre is time- and labor-consuming
- Poor compatibility between fibres and matrix
  - Poor interfacial adhesion
  - Requires surface treatment
- High moisture sorption which brings about dimensional changes leading to micro-cracks development and deformed shapes.
  - Also, must dry before compounding with the matrix.
  - Interferes with fibre/matrix adhesion!!

Disadvantages of Fibre Reinforced Composites (2 of 2)

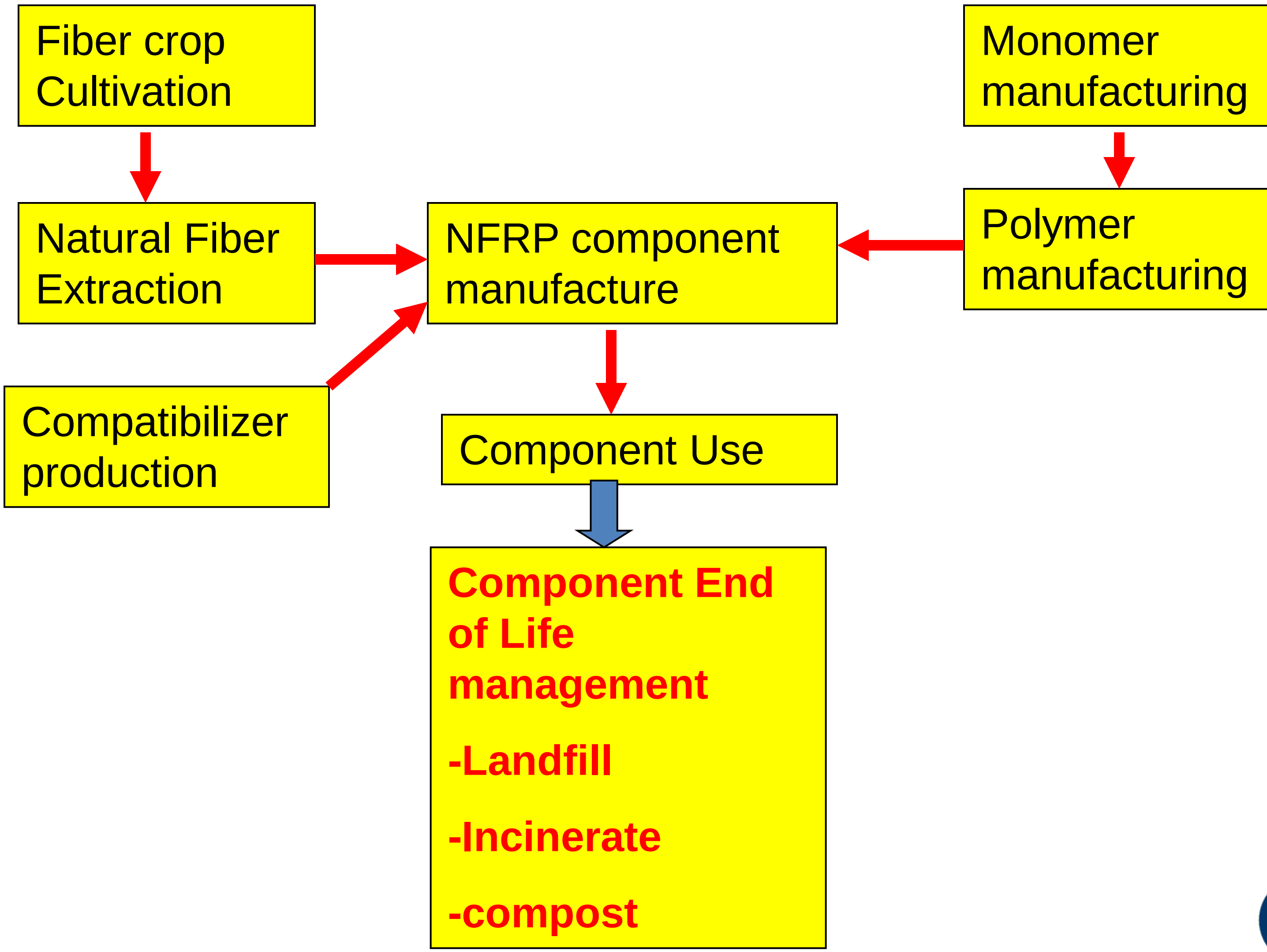
- Problem of storing raw material for extended time
  - Possibility of degradation
  - Biological attack of fungi and mildew
  - Loss in colour
  - Foul odour development
- Uncertainty and irregularity of supply. Adversely influenced by national agricultural policy and politics!!!
- Low density of natural fibres causes processing difficulty, fibres tend to float and emerge out on the surface
- Requires large area for cultivation
- Thermal degradation, lignin starts degrading above 70 ^{o}C, then hemocellulose, cellulose is quite stable. This prevents employing very high temperature (< 200 ^{o}C)

Life Cycle Analysis

Impact of environmental and social costs often neglected!!



Life Cycle Analysis of Natural Fibre Composites



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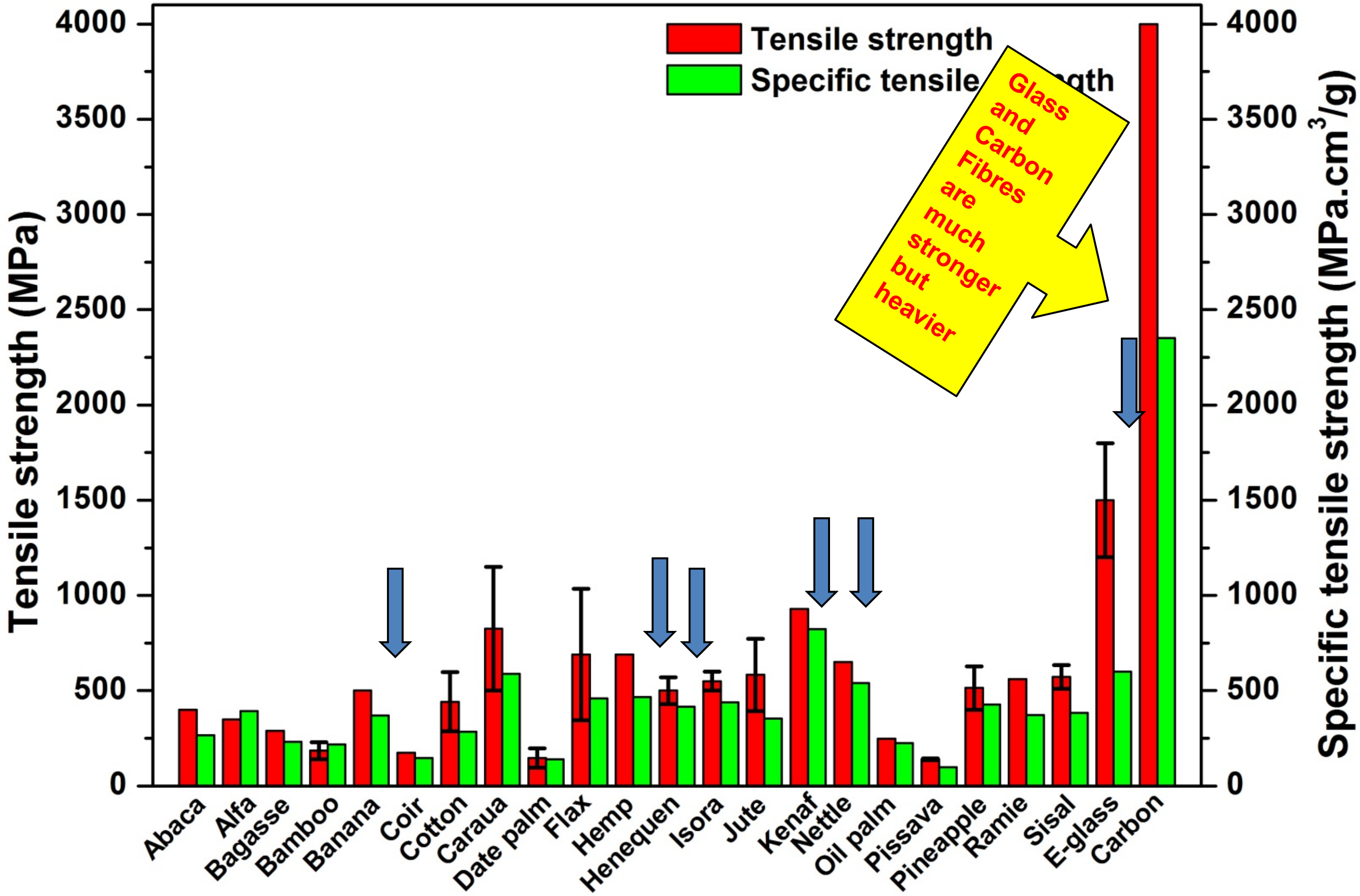
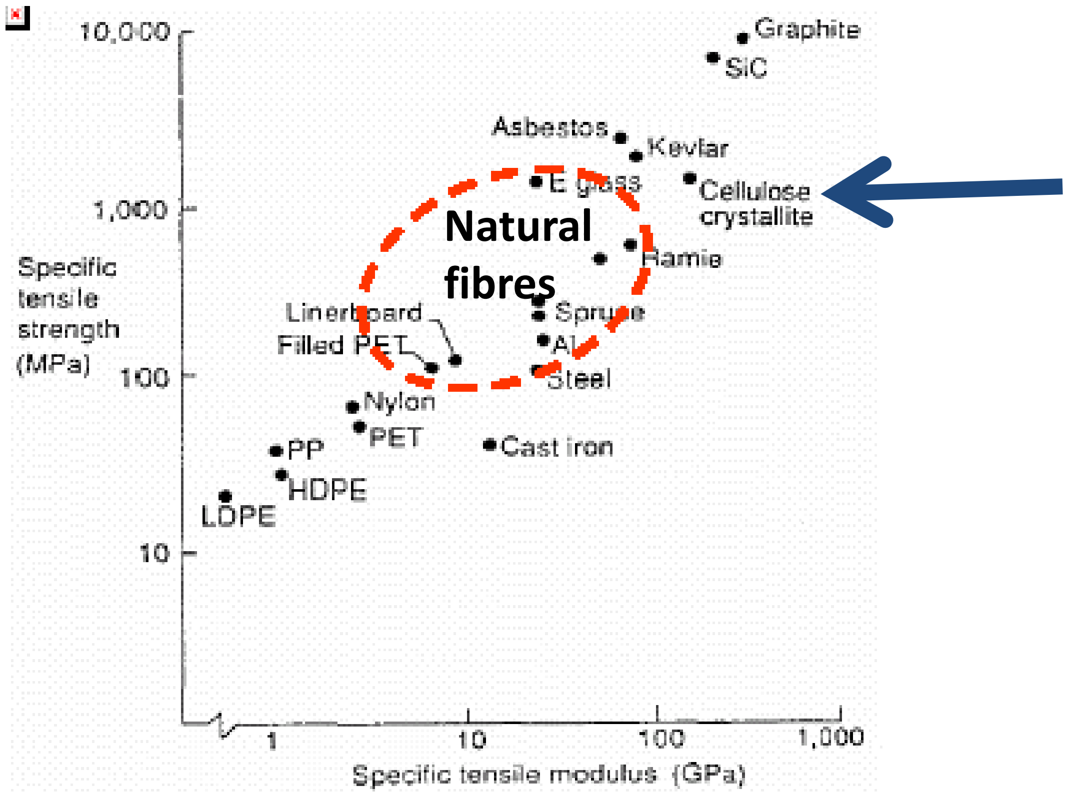
Specific Tensile Strength

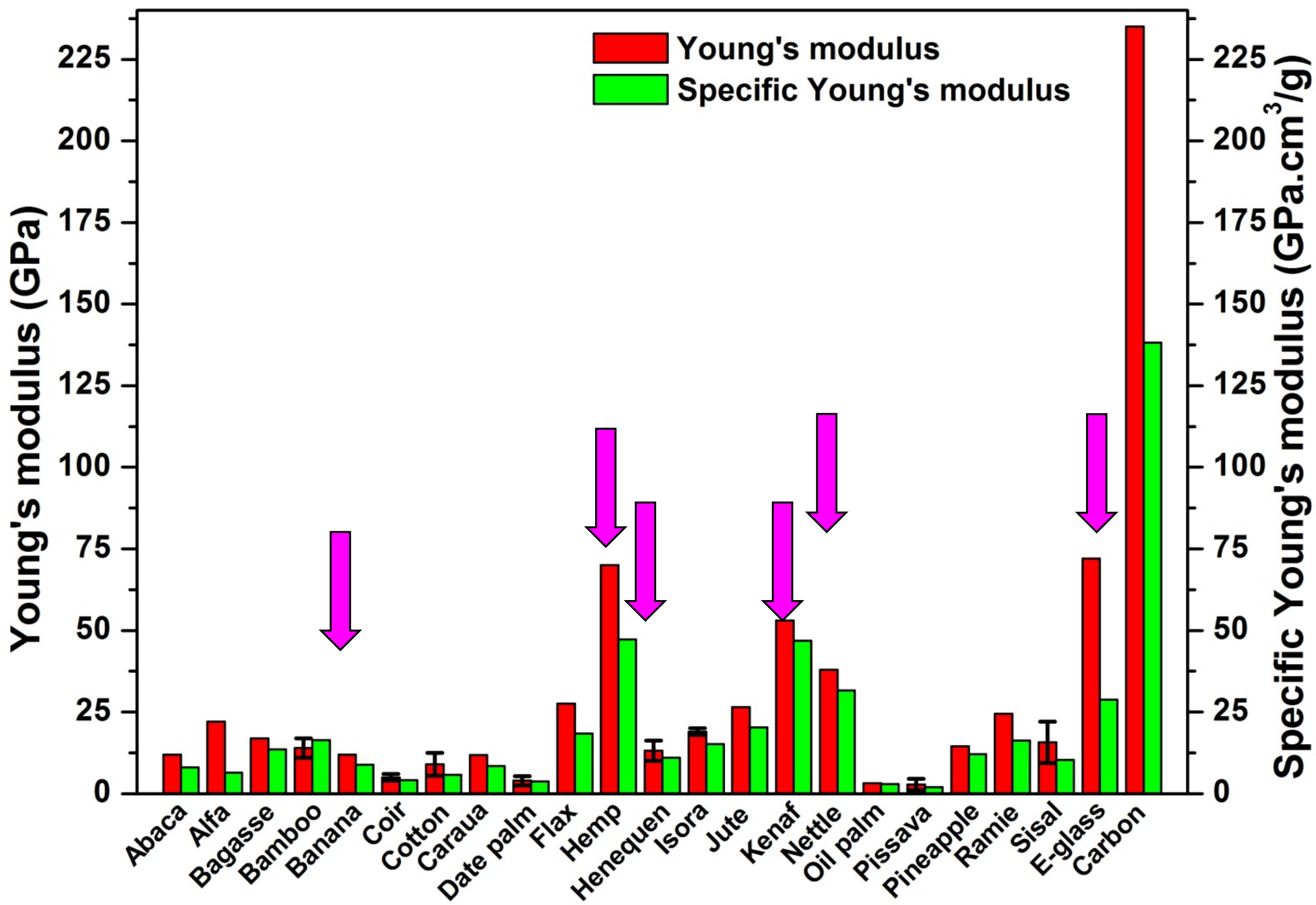


Specific Tensile Strength – Comparison with other material



Source: M.T. Ton-That & J. Denault, National Research Council Canada

Specific Young's Modulus



What Are We doing?
Automotive Sector

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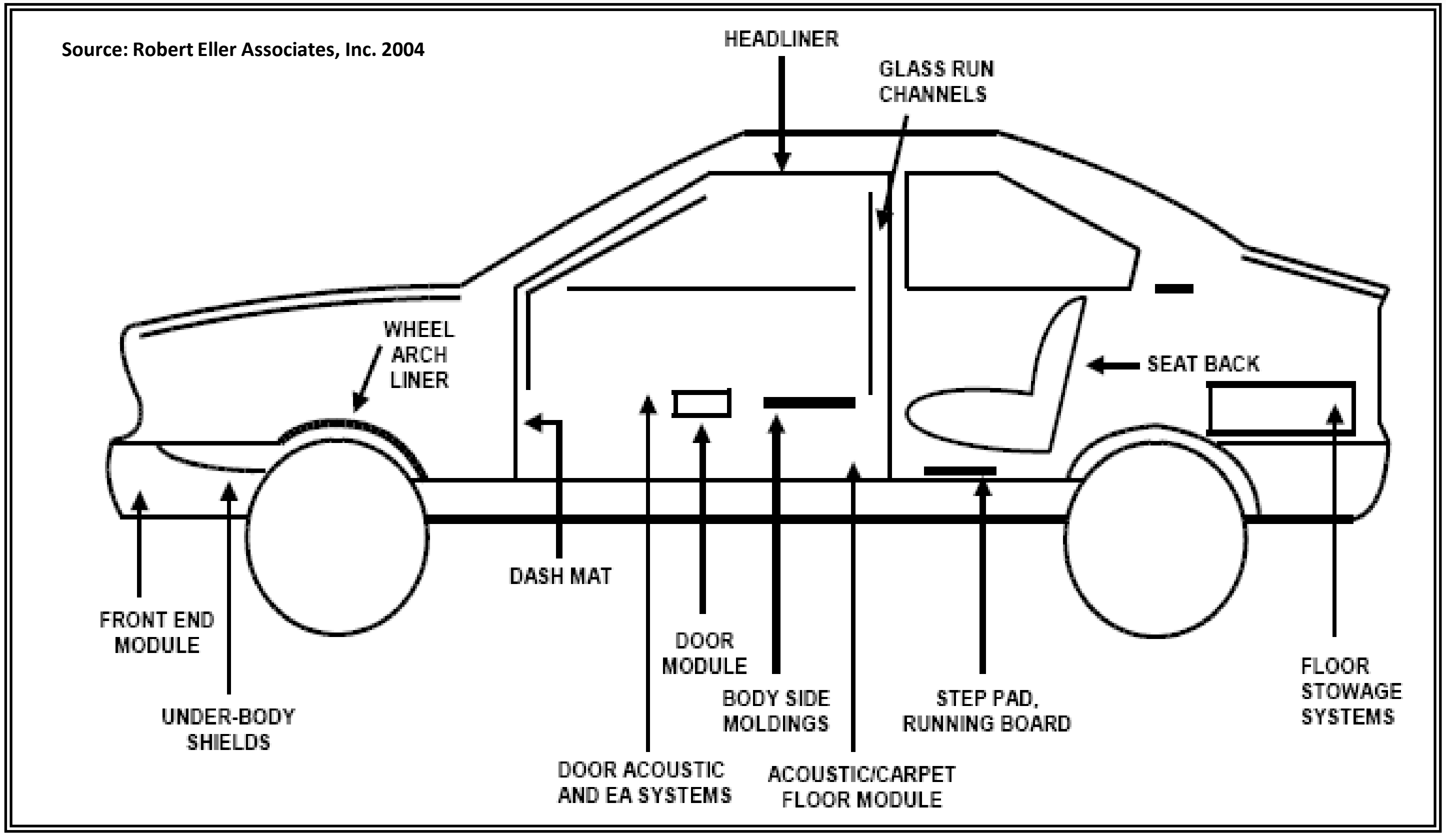
Automotive Applications



Most widely exploited application of natural fibre based composites

From Material to Component

Nonwoven Mat

Thermoplastic or Thermoset Resin

Polypropylene

Polyamide

Polyolefin

Polyurethane, etc..

Finished

Semi-Finished

Advantages of Using Nonwoven in Automotive Component

- **Nonwoven technology is very cost-effective, a mat for reinfrocement can be produced at a very low price.**
  - **Needle-punching, air-laying and hydroentangling techniques**
- **Nonwoven as reinforcing medium improves flexural strength of the panel by 120% (11 MPa to 25 MPa) and stiffness by 23%**
- **Improvement in impact strength of phenolic resin due to addition of bast fibre nonwoven reinforcement**
  - **Transfer of impact from the matrix to fibres**
  - **Reduction in voids due to curing**

Advantages of Using Nonwoven in Automotive Component

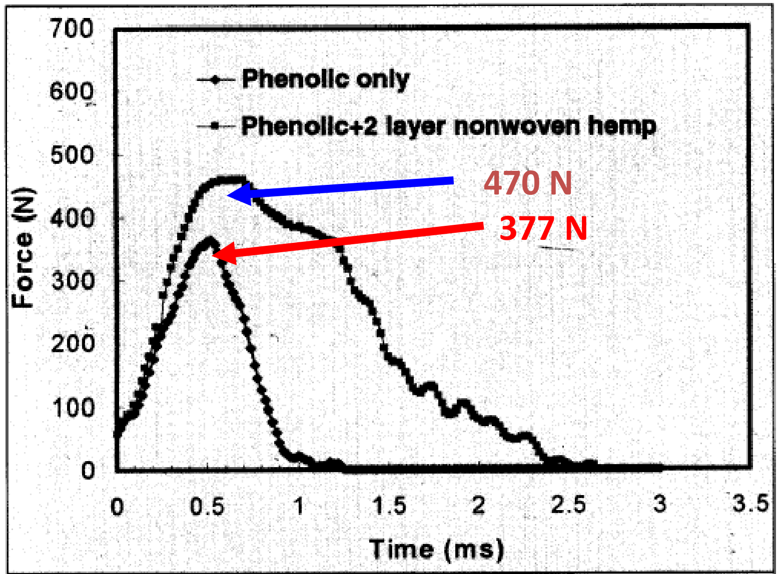


Figure 3. Force/time traces of impact events.

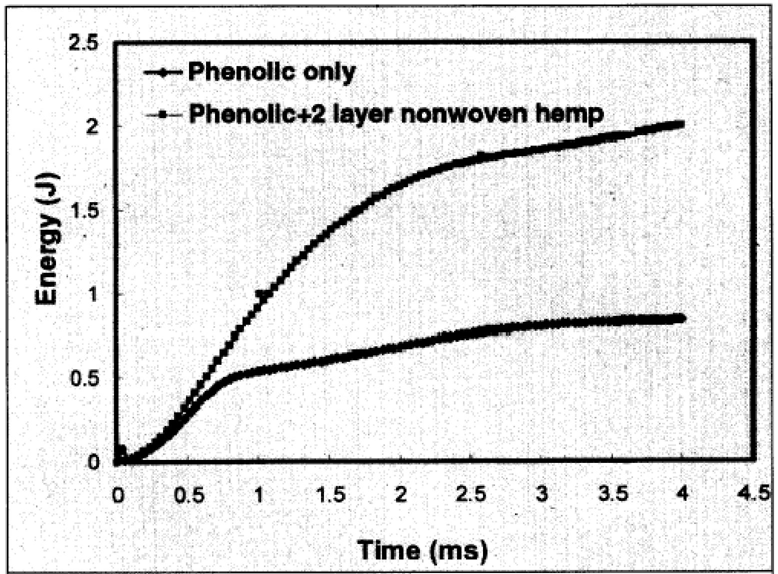


Figure 4. Incremental variations of impact energy.

Increase in peak impact force for panel with nonwoven hemp reinforcement

Large amount of energy absorption and dissipation for the panel with hemp nonwoven

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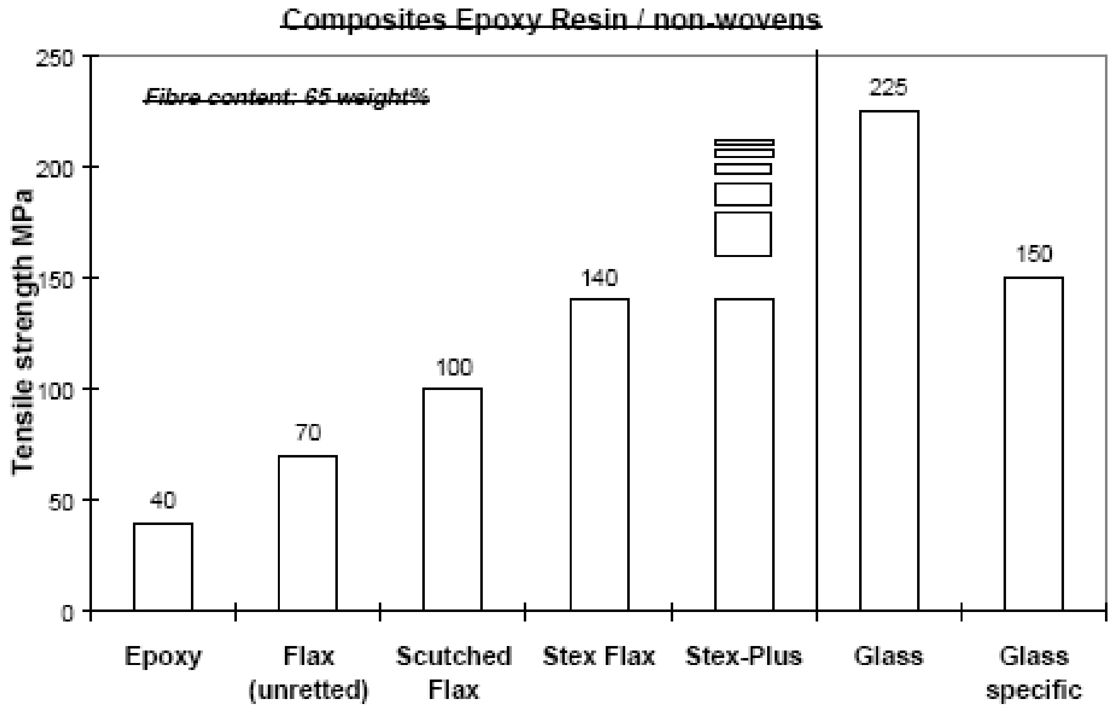
Can we Bridge the Performance Gap?



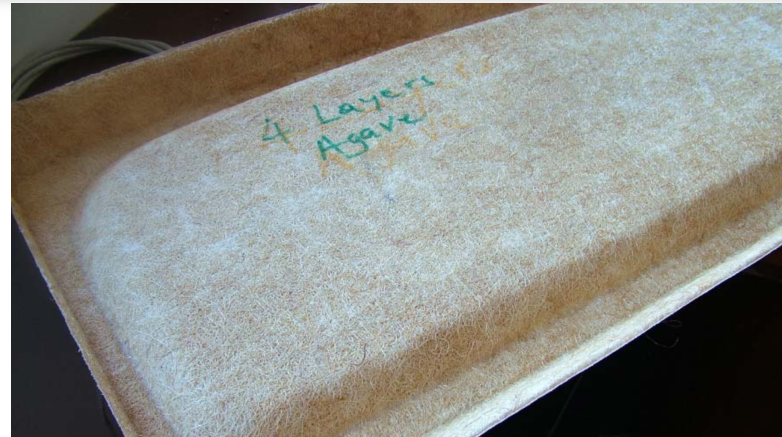
R.W. Kessler, R. Kohler und M. Tubach

Fine fibres show a much higher performance than coarser fibres

Development of agave fibre (South African) reinforced thermoplastic composites for industrial applications

- Use of agave nonwoven blends (pineapple leaf fibre, wool waste and PP) in polypropylene composites
- Characterization of mechanical and thermal properties

- Manufacture of parcel tray from agave – polypropylene composites
- Future studies will focus on functional tests for comparing properties with currently used glass fibre reinforced parcel trays



Parcel trays from agave - PP composites

Life is dull if there are no problems!

Failure under 3 kg load at various temperature and humidity conditions for 80 hrs

Impression mark visible after load testing

Delamaination

We are working to resolve these problems

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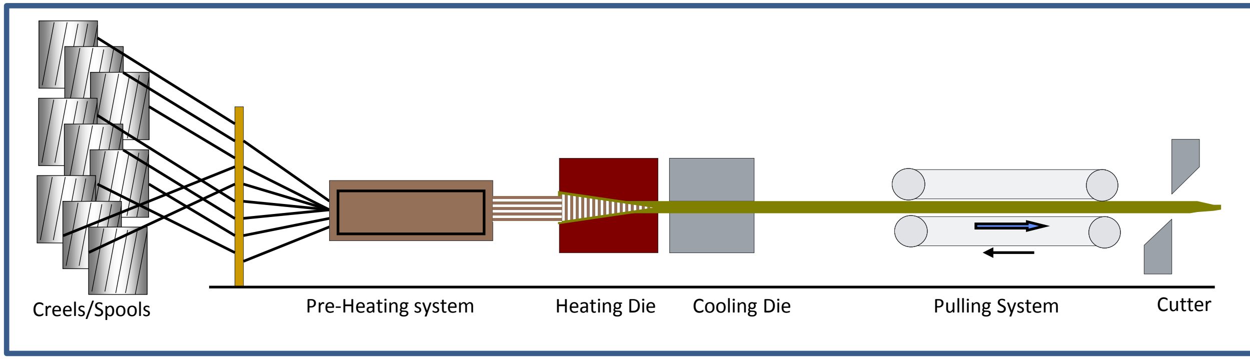
Pultrusion of Flax-PLA Profiles (SA – Germany Project)

Creels/ Spools with guiding

Pre-Heating System

Preheated fiber Die entrance



Fiber getting impregnated & cooled

Pulling System

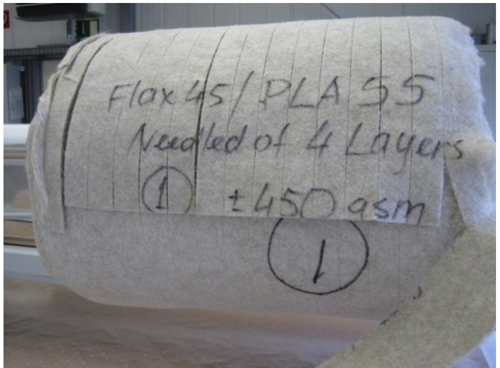
Pictures: Courtesy, Fraunhofer ICT, Pfintzal

Pultrusion of Flax-PLA Profiles (SA – Germany Project)

Pultrusion of flax/poly (lactic acid) commingled Yarns and non-woven material.

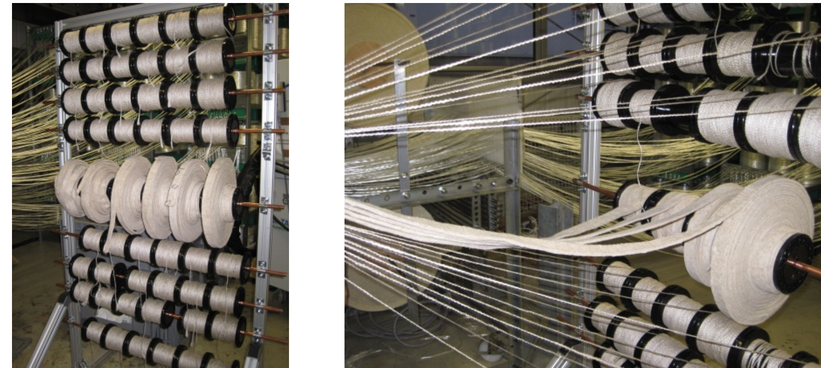
Rectangular cross-sectional profiles of 30 mm x 3 mm (90 mm) from co-mingled yarns and flax-PLA nonwoven fabrics were successfully produced

Production of Pultruded Profiles (trial May 2012)



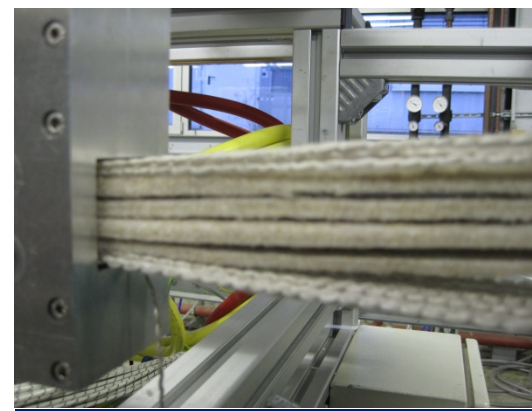
Flax/PLA Nonwoven

Slitting of Nonwoven



Co-Mingled Flax Yarn + Nonwoven

Pultruded Profiles



Pulling Through Die

Pictures: Courtesy, Fraunhofer ICT, Pfintzal

Opportunities: Can we produce all these in South Africa?

AUTOMOTIVE MANUFACTURER	MODEL APPLICATION
AUDI	A2, A3,A4,A6,A8 Seat backs, side and back door panels, boot lining, hat rack, spare tyre lining
BMW	3,5,7 series Door panels, headliner panel, boot lining, seat backs, noise insulation panels, moulded foot well linings
MERCEDES BENZ	A, C, E and S-class models Door panels, windshield, dashboard, business table, pillar cover panel
FORD	Mondeo CD 162, Focus Door panels, B-pillar, boot liner
VOLVO	Seat padding, natural foams, cargo floor tray
TOYOTA	Door panels, seat backs, Spare tyre cover
VOLKSWAGEN	Golf, Passat, Bora Door panel, seat back, boot lid finish panel, boot liner

What Are We doing?
Built Environment Sector

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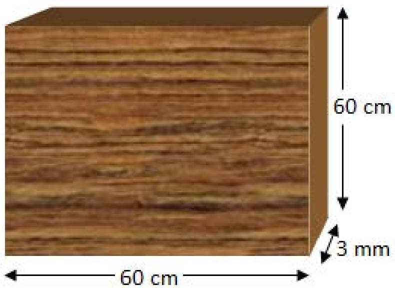
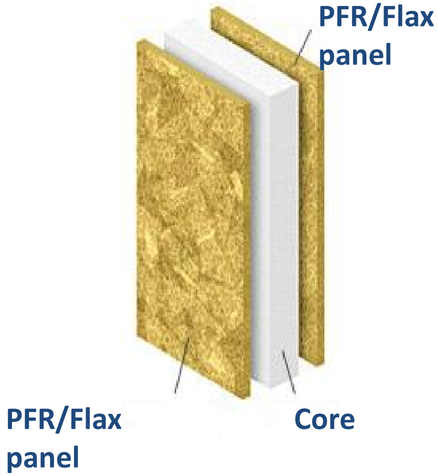
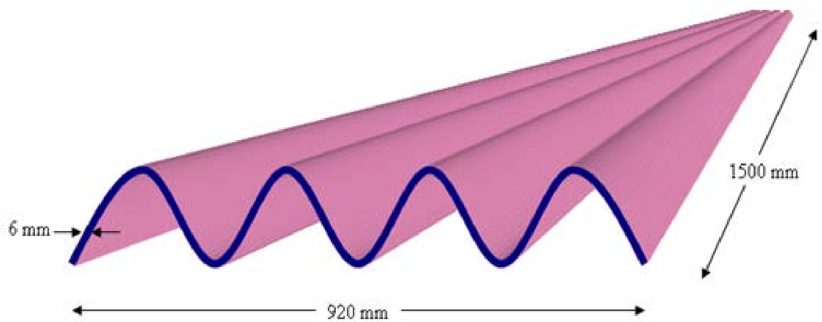
Composites for Built Environment Applications

- **Development of flax (nonwovens) reinforced phenol formaldehyde composites for construction applications**
  - Structural Insulated Panels
  - Foam core: Expanded polystyrene (EPS) / Extruded polystyrene (XPS) / polyurethane (PU)
  - Bio-core



Ceiling panel





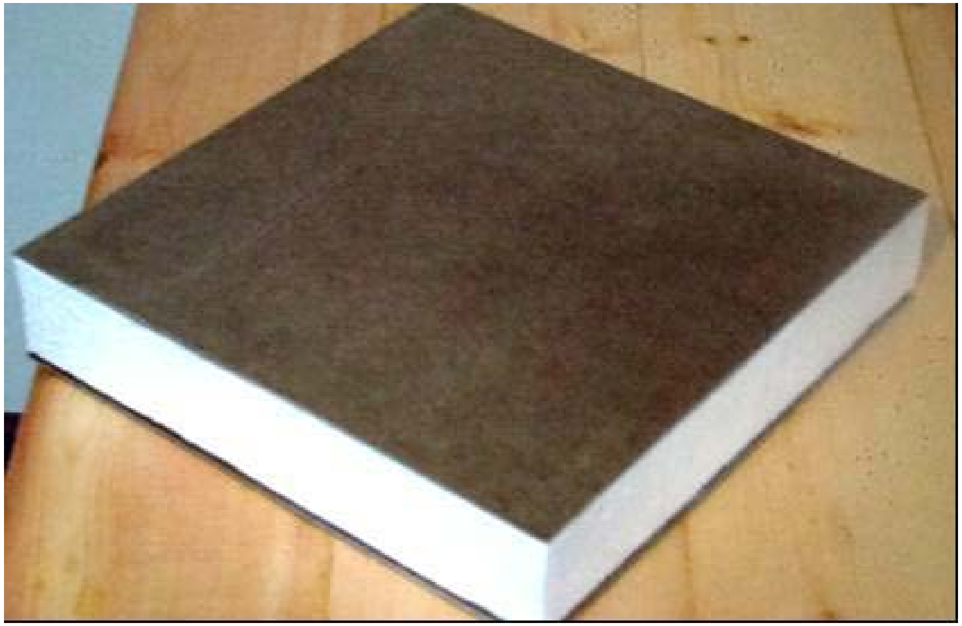
Corrugated roof panel

- **Natural fibre reinforced cement in collaboration with Built Environment**

Prototype Ceiling Panel (Soybean Resin / Flax Nonwoven)

Length	=	60 cm
Width	=	60 cm
Thickness	=	3 mm

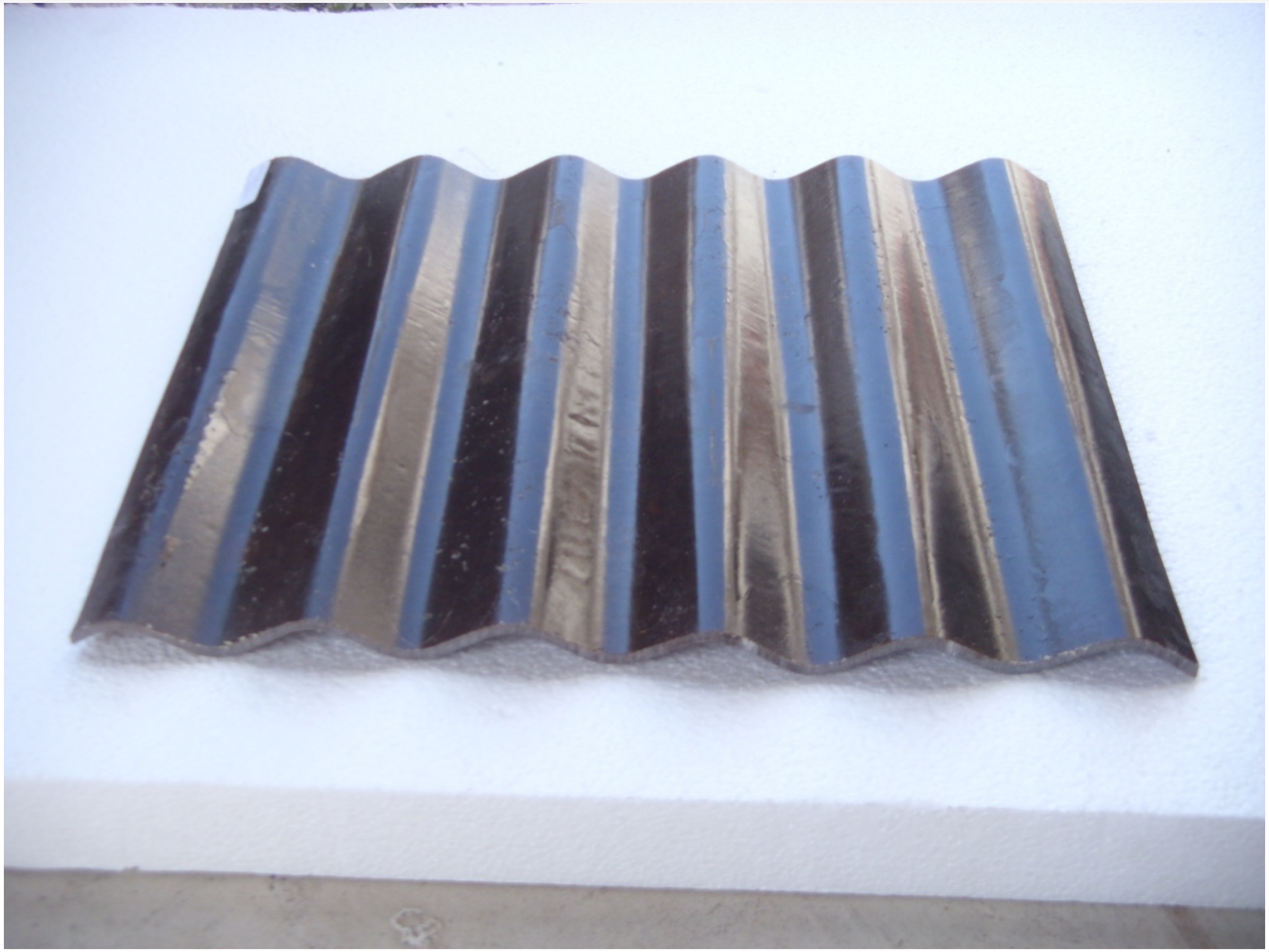
Prototype Ceiling Panel (insulated)



Natural Fibre Reinforced phenolic resin skin and polystyrene core

Length	= 30 cm
Width	= 30 cm
T-Thickness = 56 mm	

Prototype Corrugated Panel (soybean Resin/Nonwoven Flax)



Length	=	50 cm
Width	=	50 cm
Thickness	=	6 mm

Prototype Insulated Corrugated Panels

Expanded Polystyrene Insulation

(a)

(b)

(a) non-insulated roof panel and (b) insulated roof panel

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Prototype – Bricks and Insulation Media

(a)

Hemp/lime brick

(b)

Sandwich nonwovens for Insulation

What Are We doing?
Aerospace Sector

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NATFIBIO Project – Partnership with Airbus

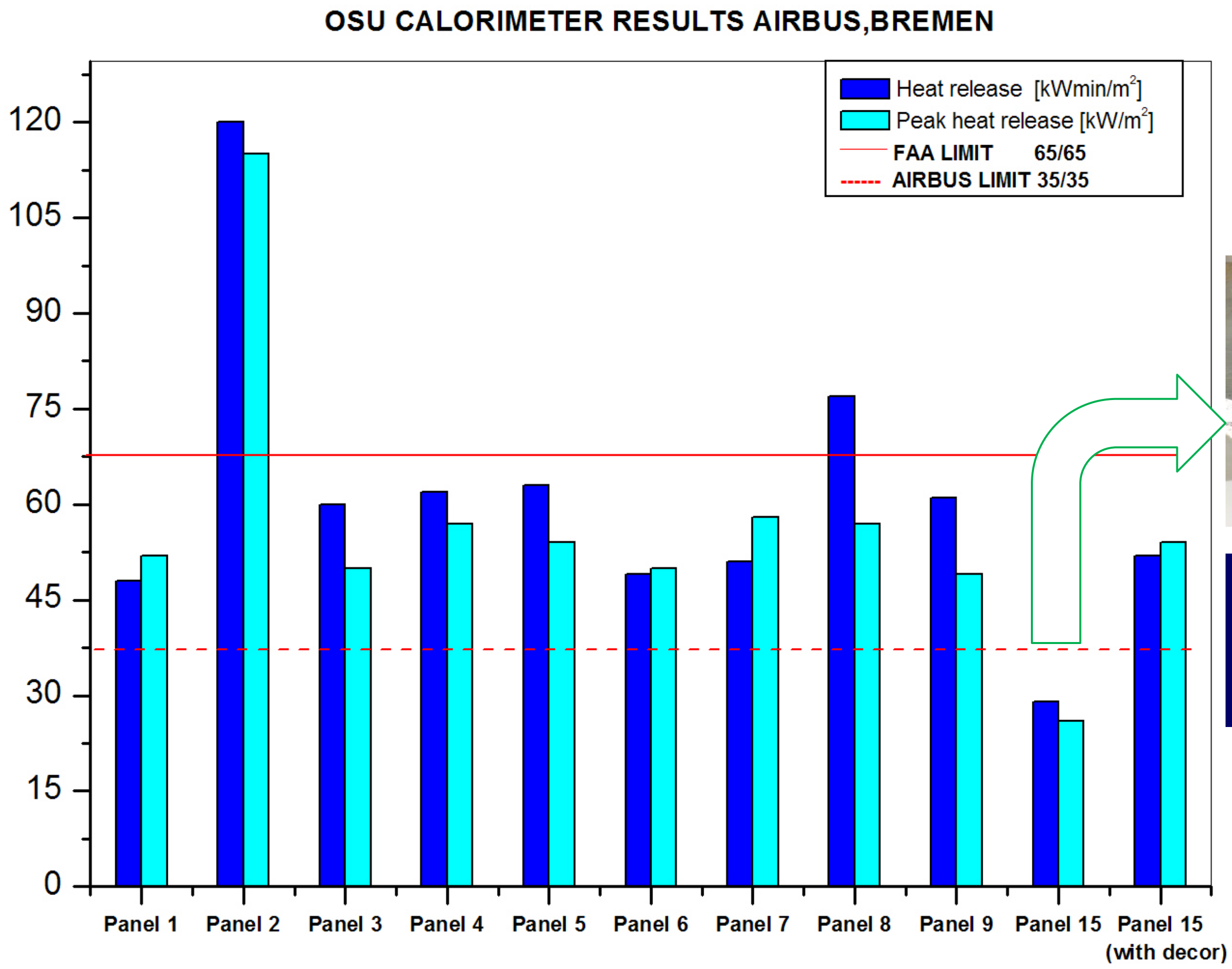
- To develop a **new generation of bio-composites** based on natural fibres reinforcement for **replacing** currently used **secondary** (non load bearing) **structures** in cabin and cargo areas.
- The project will focus on the delivery of a **sample composite panel** to Airbus specification.

All synthetic panel

Challenges:

- Maintain balance between strength and flame, smoke and toxicity standards as required by **AIRBUS**
- Maintain weight as required by AIRBUS

Optimization of Fire Properties



Surface of panel showing exfoliated vermiculite and protective char layer

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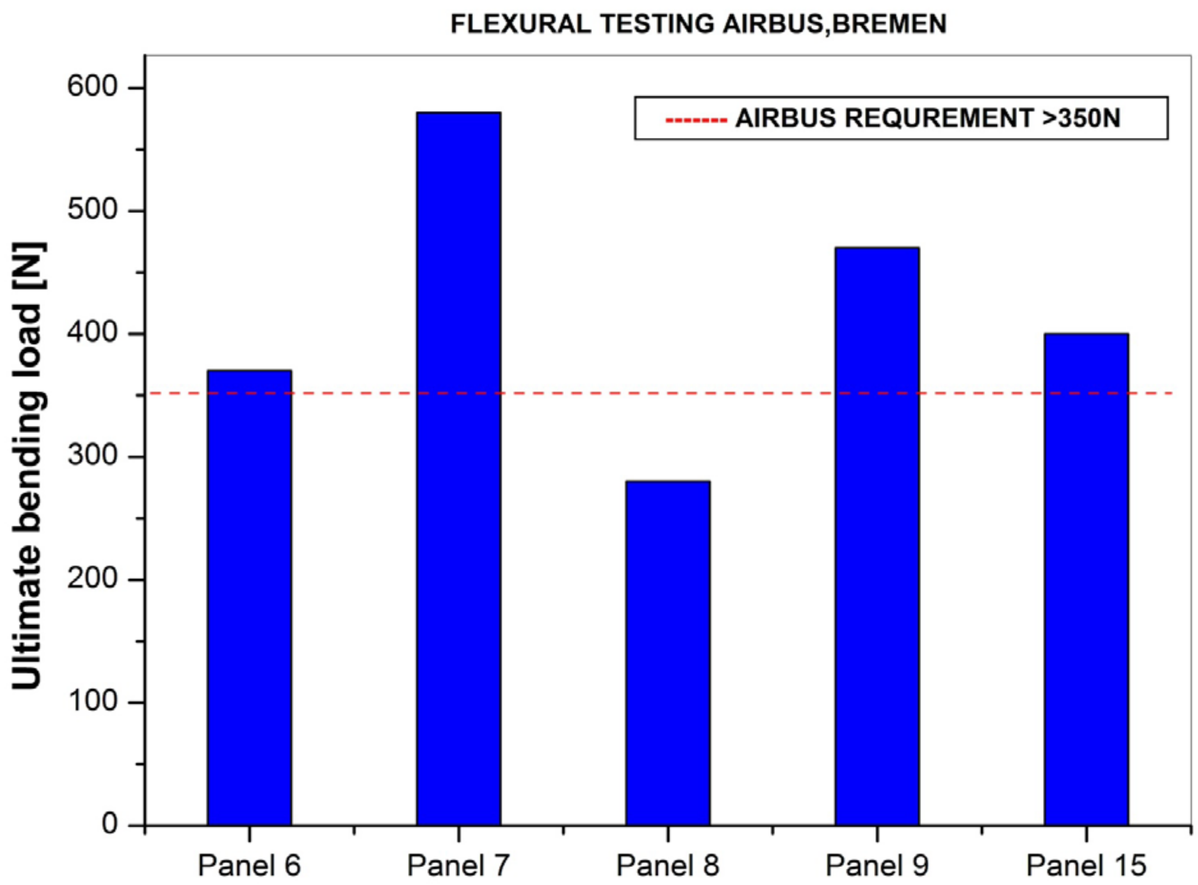
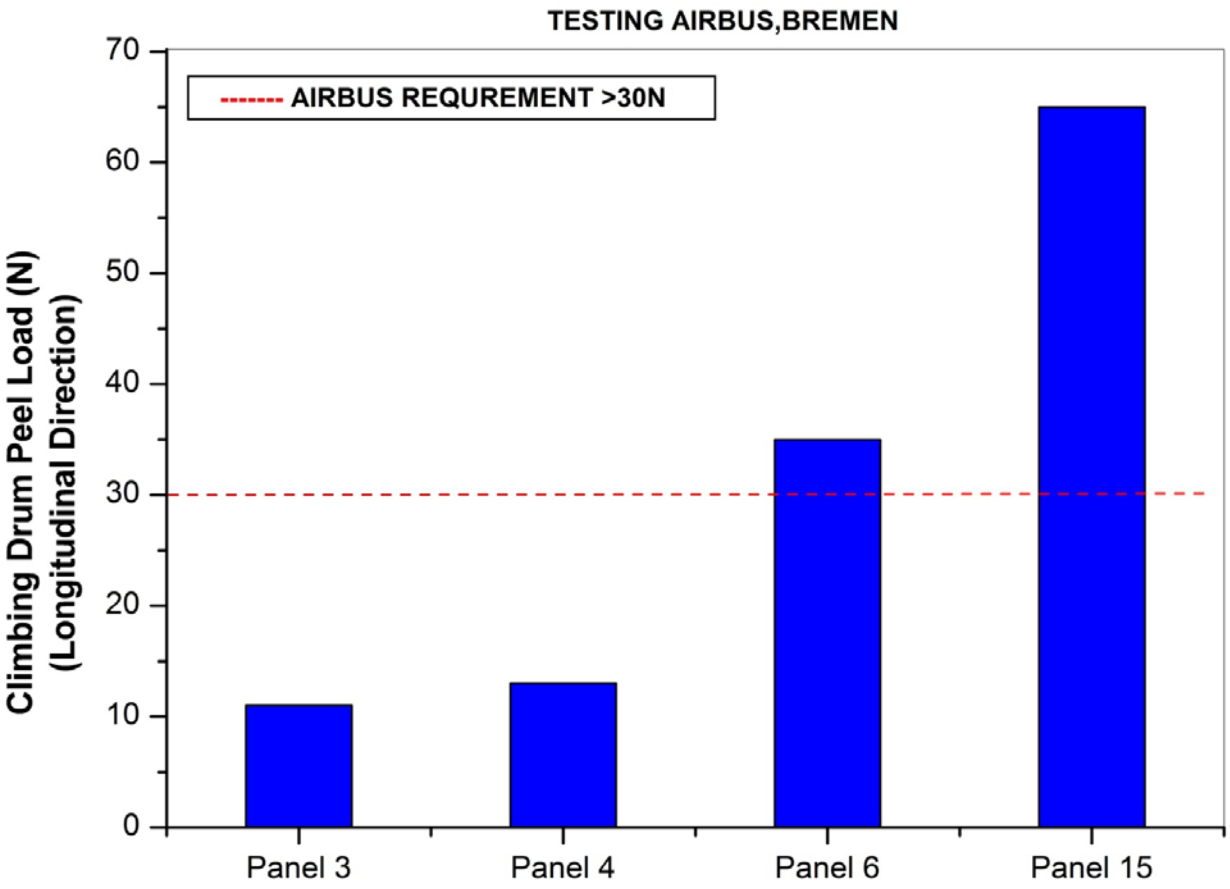
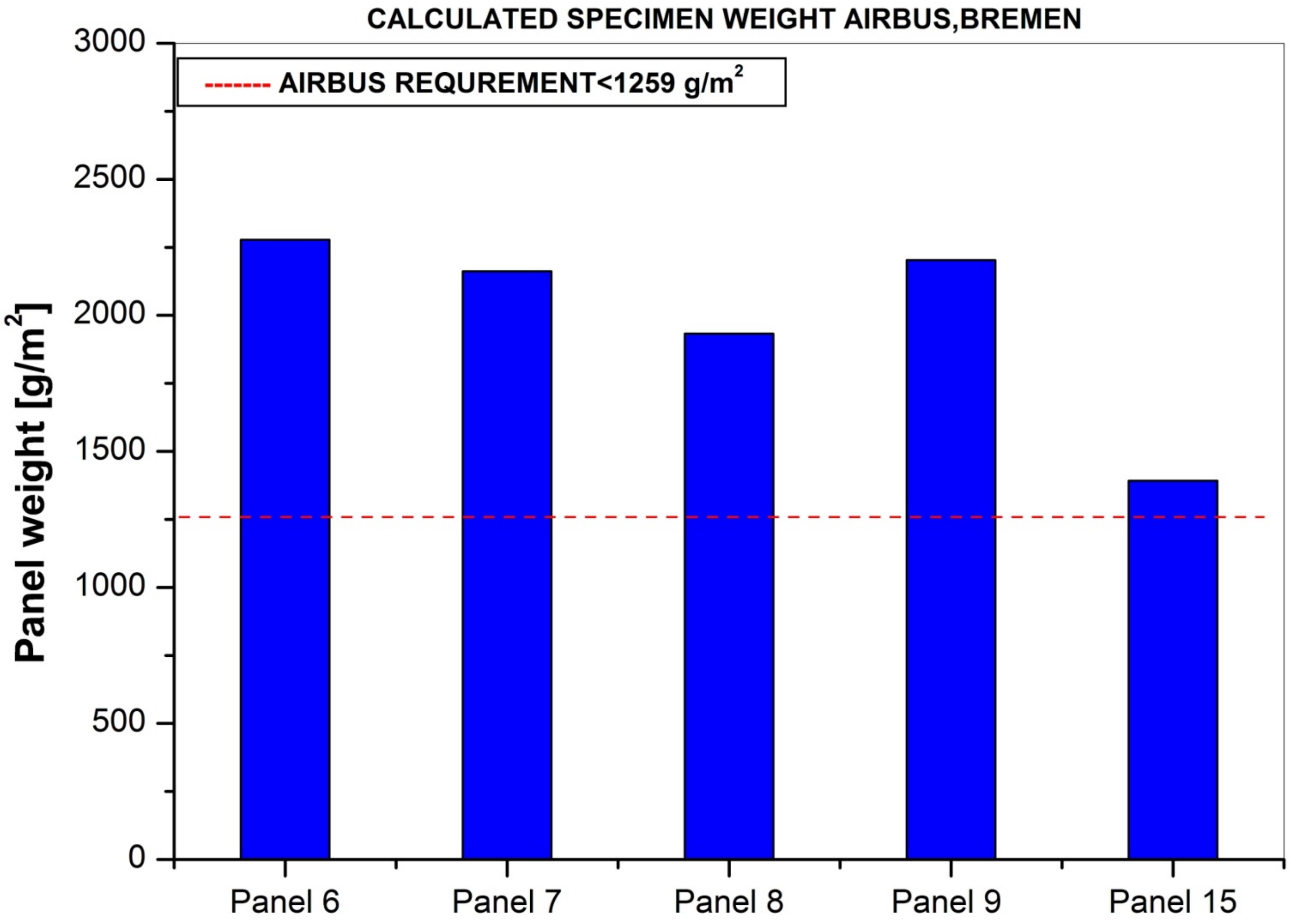
Optimization of Flexure Properties



Optimization of Peel-off Strength



Optimization of Weight



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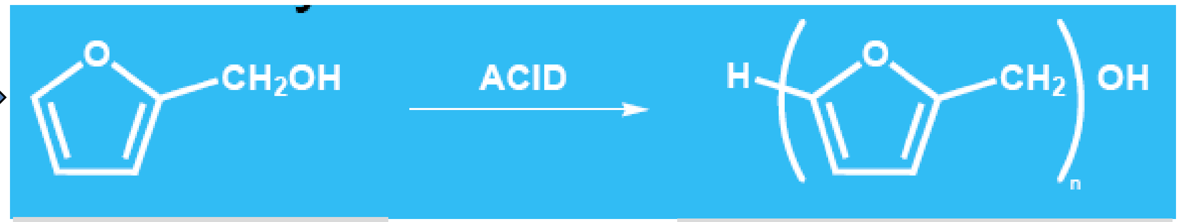
New Biobased Plastic

Objectives are to add value to locally available resources

To make affordable products so as to ensure its commercial viability

Furfural

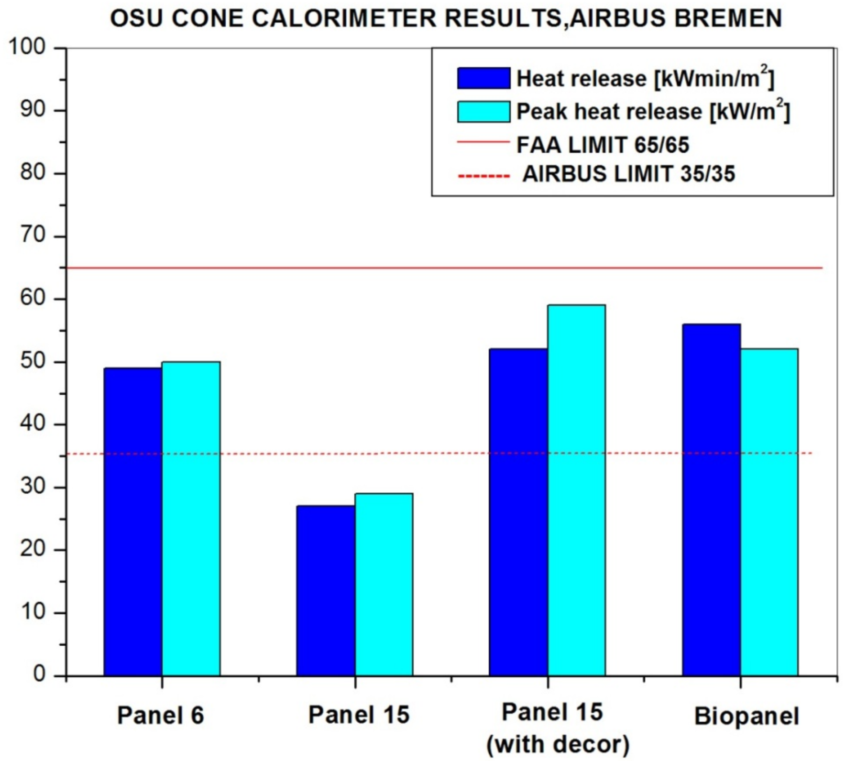


Furfuryl Alcohol (FA)

Polyfurfuryl Alcohol (PFA)

We have successfully prepared bioplastic and we have successfully moulded various applications.

Is it Suitable for Aircraft Interior?



Phenolic sandwiched panels

The Figure indicates the possibility of using PFA based bipolymer in Aircraft interior because of low heat release and peak heat release. However the mechanical properties of the biopanels should also fulfil the criteria recommended by Aerospace industries..

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Bioplastic - Prototypes

Flat Panel

Flower Pot

Calculator – Cell Phone Cover

Photo Frame – Window Frame

What Are We doing?

Fruit Packaging

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Bio-composites for Post Harvest Packaging

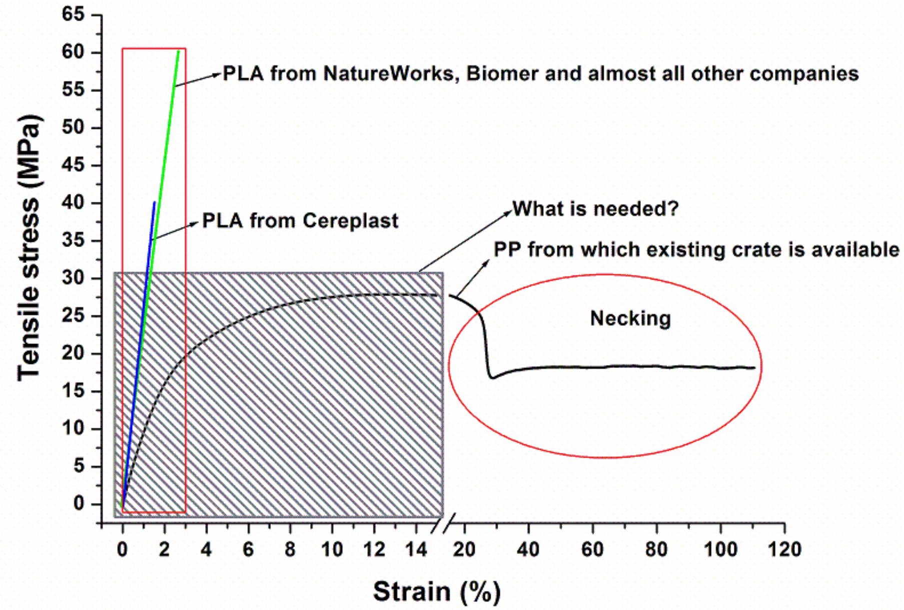
Objectives

•Develop natural fibre reinforced biocomposites through injection moulding as per the design of the modular returnable and non-returnable bio-plastic crates.

•In addition, efforts will be made to make existing one way disposable crates environmentally more friendly and increase the biodegradable content by replacing or reducing harmful and toxic adhesives used in preparing such boxes.

Some Important Considerations

- **PLA is expensive – mixing additive can help in reducing cost**
- **Macademia nutshell powder is available in South Africa**
- **Existing crate manufactured from polypropylene (PP) has lower tensile strength than PLA but has high flexibility/elongation or elasticity.**
- High flexibility/elongation or elasticity helps in easy processability i.e., without breakage of components during injection from the mold.
- Moreover till 8-10% of strain, modulus is reasonably elastic in nature for PP.



Problems – From Laboratory to Commercial Trial

- The material developed by us was soft and could not be successfully moulded .
- The crate coming out of the mould is very soft and wobbly.
- When the crate has cooled off, it becomes too brittle and the hinges break.
- **Way Forward: Establish Mouldability and suitability of the developed biodegradable material.**

Bio-Whiskers Reinfroced PLA Filaments (SA – Sweden Project)

- Development of cellulose and chitin based bio-nanocomposite fibres for textile and biomedical applications. This project is in collaboration with **Lulea University of Technology, Sweden**
  - Processing of cellulose whisker reinforced poly (lactic acid) (PLA) nanocomposite fibres by melt spinning in filament extruder

PLA

PLA-CNW-1%

PLA-CNW-3%

Extruded PLA and cellulose whisker reinforced pellets

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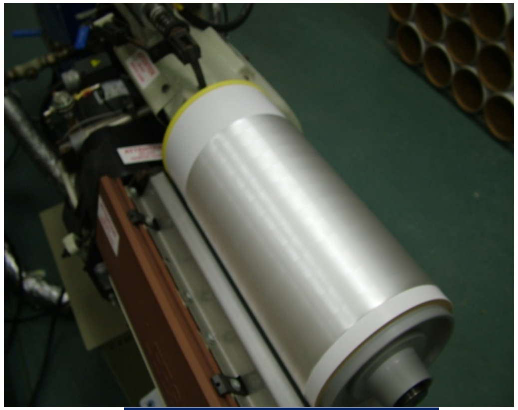
Bio-nanowhiskers Reinforced PLA Filament



PLA fibres

Nanocomposite fibres

Our Output

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Our Intellectual Property

- **CSIR – Airbus joint IP** on “A Flame-proofed Artefact and a Method of Manufacture Thereof”, Application No: PCT/IB2011/055458P filed, 5th December 2011.
- **CSIR has filed a PCT** on bio-plastic from polyfurfuryl alcohol - PCT/IB2012/051201, Priority Date: 14-03-2011, Filing Date: 14-03-2012.

Our Publication Records (2011)

- **<u>7 Presentations</u> in National and International Conferences**
  - 18th International Conference on Composite Materials, 22-26 August 2011, Jeju, Korea.
  - Eastern Cape Development Corporation's Bamboo Symposium, 11-12 August 2011, East London, South Africa.
  - 19th BEPS Annual Meeting, Vienna, Austria, September 28-30, 2011.
  - International conference on Nanotechnology & Functional Materials, Sreenidhi Institute of Science & Technology, Hyderabad, India, January 4-7 2012.
  - Coir India Fair and Conference, Invited Presentation, Allepey, India, February 2012.
  - Plastic Institute of South Africa conference: Fire Safety of Plastic Materials - The Burning Issue, Midrand, 21 February 2012
  - Third International Multicomponent Polymer Conference, Kottyam, Kerala, India, 23-25 March 2012
- **13 Publication equivalents in peer-reviewed journals**

The Team – Real Contributors!

Thank You

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