



Hemp and flax fibers in load bearing structures

Designing and building the world's first biocomposite bridges

4TU.Bouw



Forest@Design



Virida



Modified Materials
innovation in polymers



C-MAX TECHNOLOGIES B.V.

Centre of Expertise Biobased Economy

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avans
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Stapper
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TU/e Technische Universiteit
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University of Technology

inholland
hogeschool

Presentation contents

- What are (bio)composites and its components?
- Biocomposite in load bearing structures
- Project teams involved
- Some biobased bridge details
- Making biocomposite
- Involving students
- Chances for industrial hemp industry

Fiber reinforced composites

- Thermoset resin + fiber

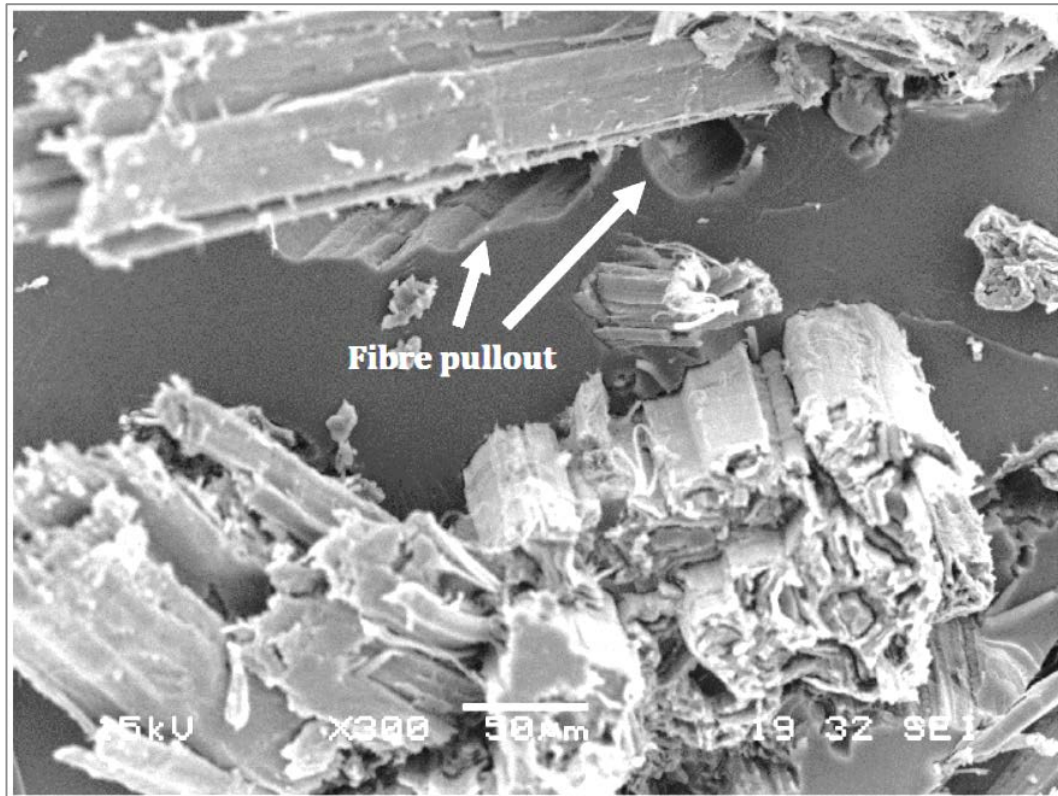
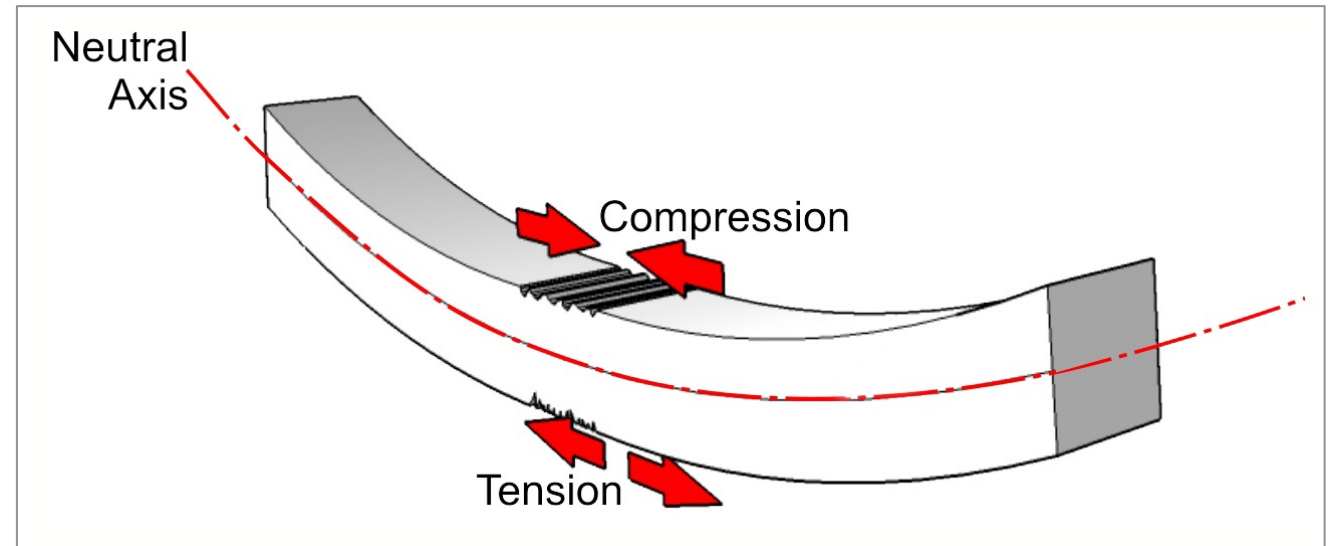
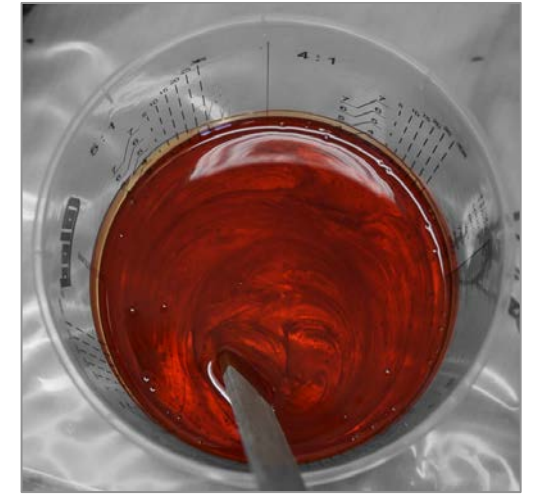


Figure 6.2. 300x SEM image of AEHO/hemp fibre biocomposite.

Image source: Manthey, N. W., 2013



Fossil based composites vs. biocomposites

- **Fossil based composites**

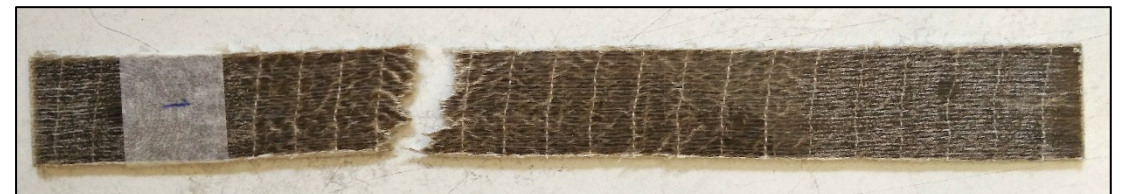
- Fossil based resin (e.g. polyester, vinyl ester, epoxy)
- Synthetic or mineral fiber (e.g. glass fiber, carbon fiber, basalt fiber)
- ✗ Sustainability fossil based resins
- ✗ End of life – carbon fiber, glass fiber

- **Hybrid composite**

- Natural fiber + fossil based resin/plastic (e.g. hemp automotive)
- ✗ Sustainability fossil based resins
- ✓ Fiber renewable

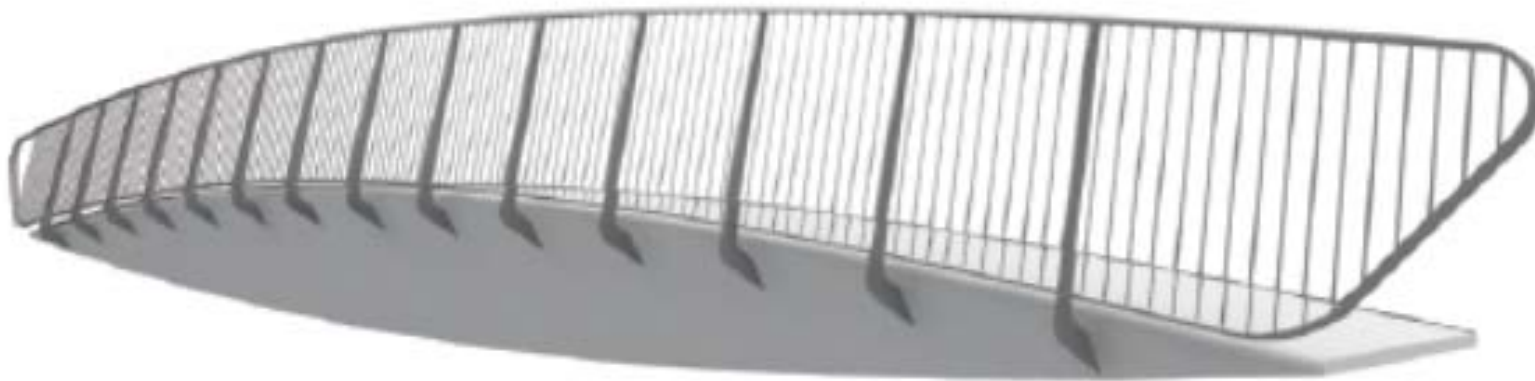
- **Biocomposites**

- Natural fiber (hemp, flax, ...)
- Biobased thermoset resin (polyester, vinyl ester, epoxy)
 - Usually from (non-food) plant oils and sugars
- ✓ Sustainability resin (if 100% biobased + positive LCA)
- ✓ Fiber renewable



Biocomposite a different material

- Biocomposite differs in construction from
 - Metal
 - Concrete
 - Wood
 - ... even fossil based composite (bulky natural fiber, hygroscopic)
- Different mindset!



Plant fibers 1/2

- **Focus on European fibers**
 - Flax & hemp
- **Strengths**
 - **Strong tensile** strength
 - Light weight
 - Renewable
 - Vibration absorption
- **Challenges:**
 - **Moderate compressive** strength
 - Hygroscopic properties
 - Swelling – shrinking > poor fiber-matrix interface
 - Rotting

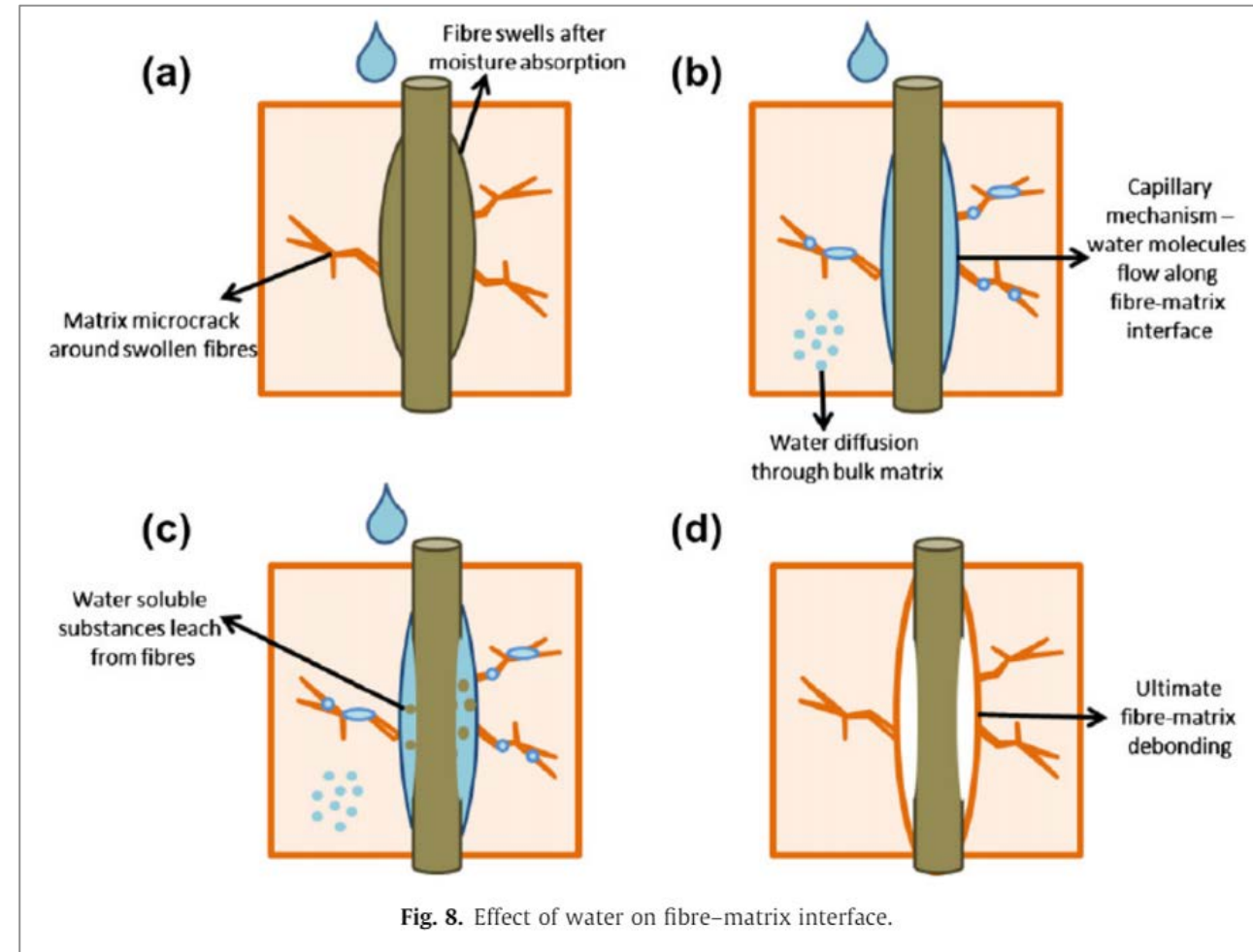


Image source: Azwa, Z.N., 2013:

Plant fibers 2/2

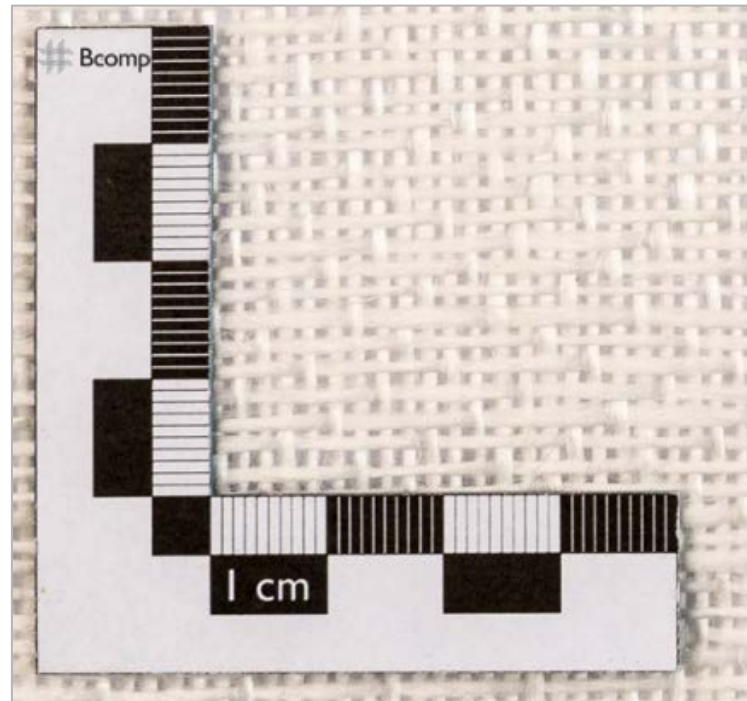
- Flax & hemp
 - Material consistency
> natural variations
 - **High price differences**

(geef prijs range aan, vragen aan Mark L.)

Non-woven (hemp)



Woven fabric (flax)



Unidirectional fibers (flax)

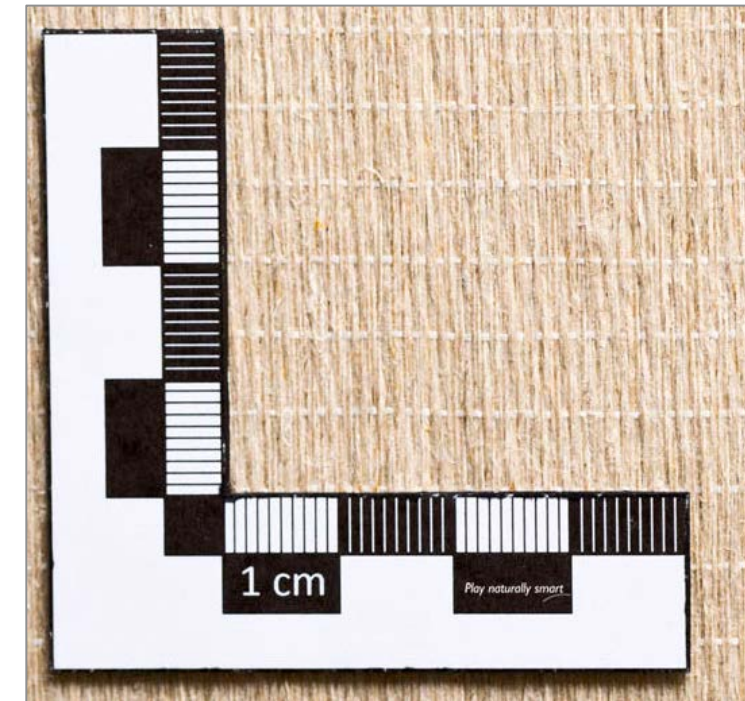


Image source: Bcomp

Thermoset bioresins

- Market research > **low availability** of high biobased content bioresins
- Average bioresin **20-50% biobased content**
- Usually high biobased content = **high viscosity** > poor infusion rate
- Biobased content $\approx$... sustainability > **LCA**
- **High costs** compared to fossil based resins
- Styrene and BPA



Biocomposites in load bearing structures

- Most biocomposites applied in **low or non-load bearing** constructions
- **Little research** done on biocomposites in **load bearing structures** such as bridges and
- Some companies make **fossil based composite bridges**



Image source: Fibercore-Europe



Spinoff collaboration

SIA Raak Biobased Bridge Project

“biocomposieten voorbouwkundige en civiele toepassingen”



ir. Alwin Hoogendoorn



4TU.Bouw project B3 Biobased bridge

4TU.Bouw



Dr.-Ing. Patrick Teuffel, ir. Rijk Blok



ir. Joris Smits



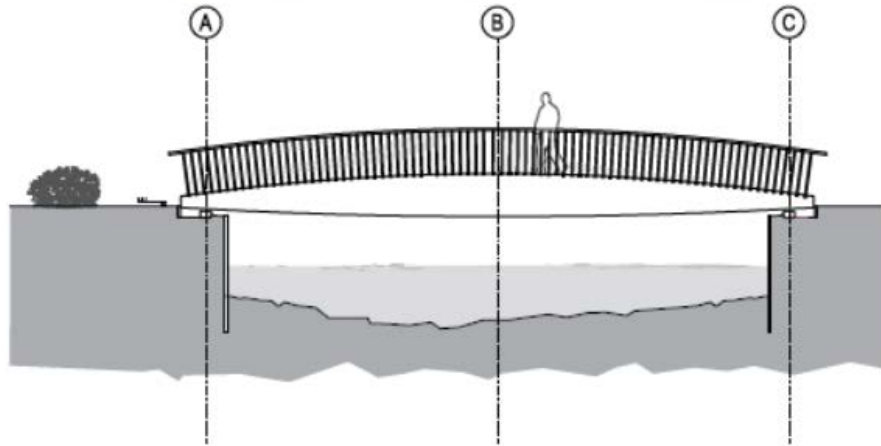
ir. Alwin Hoogendoorn



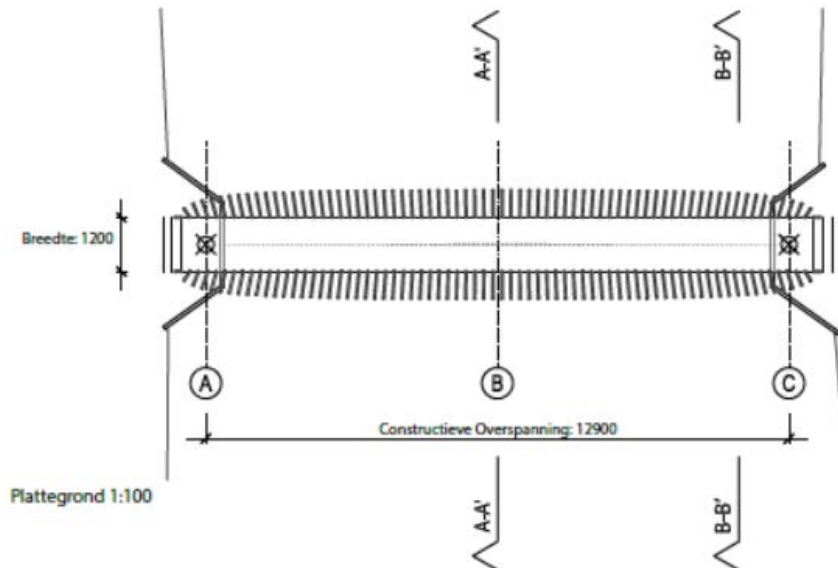
Two projects: one overarching goal

- Biocomposite bridge research
 - **Market research** biocomposites, natural fibers and bioresins
 - **Mechanical properties:** testing of various natural fibers and bioresins test samples
 - Biocomposites **production methods:** vacuum infusion, robotics
 - **Structural and architectural design** pedestrian and bicycle bridge (+ incidental vehicles)
 - Make biocomposite **bridge part** 2 m
 - **Make** full size 14 m pedestrian bridge (this year!)

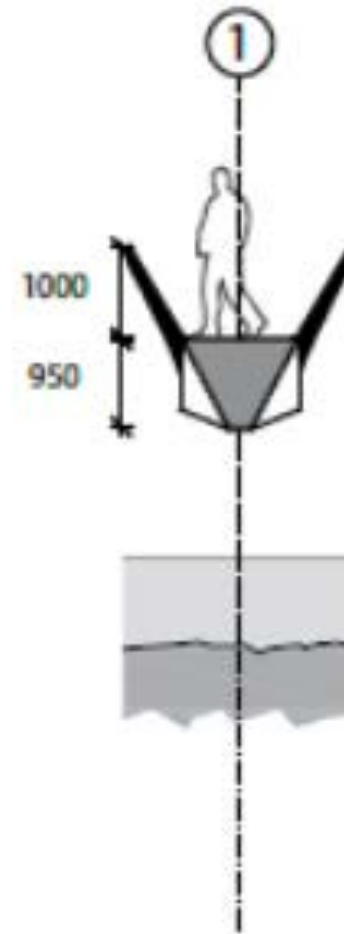
Two projects > one bridge



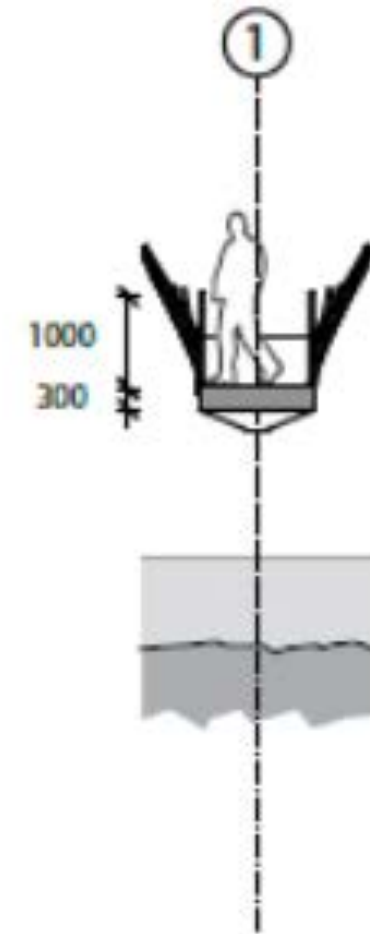
Aanzicht 1:100



Plattegrond 1:100



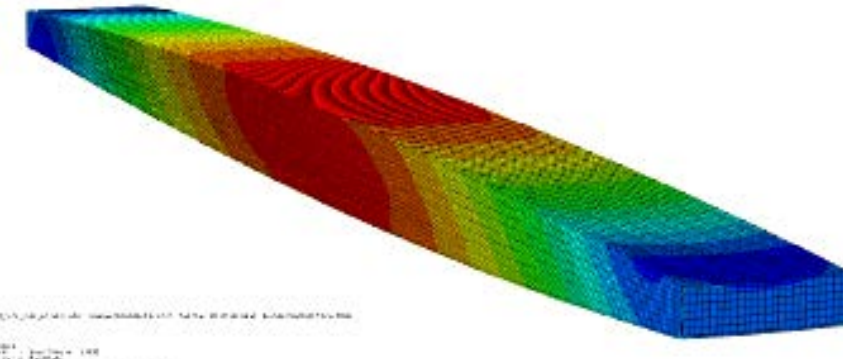
Snede A-A' 1:100



Snede B-B' 1:100

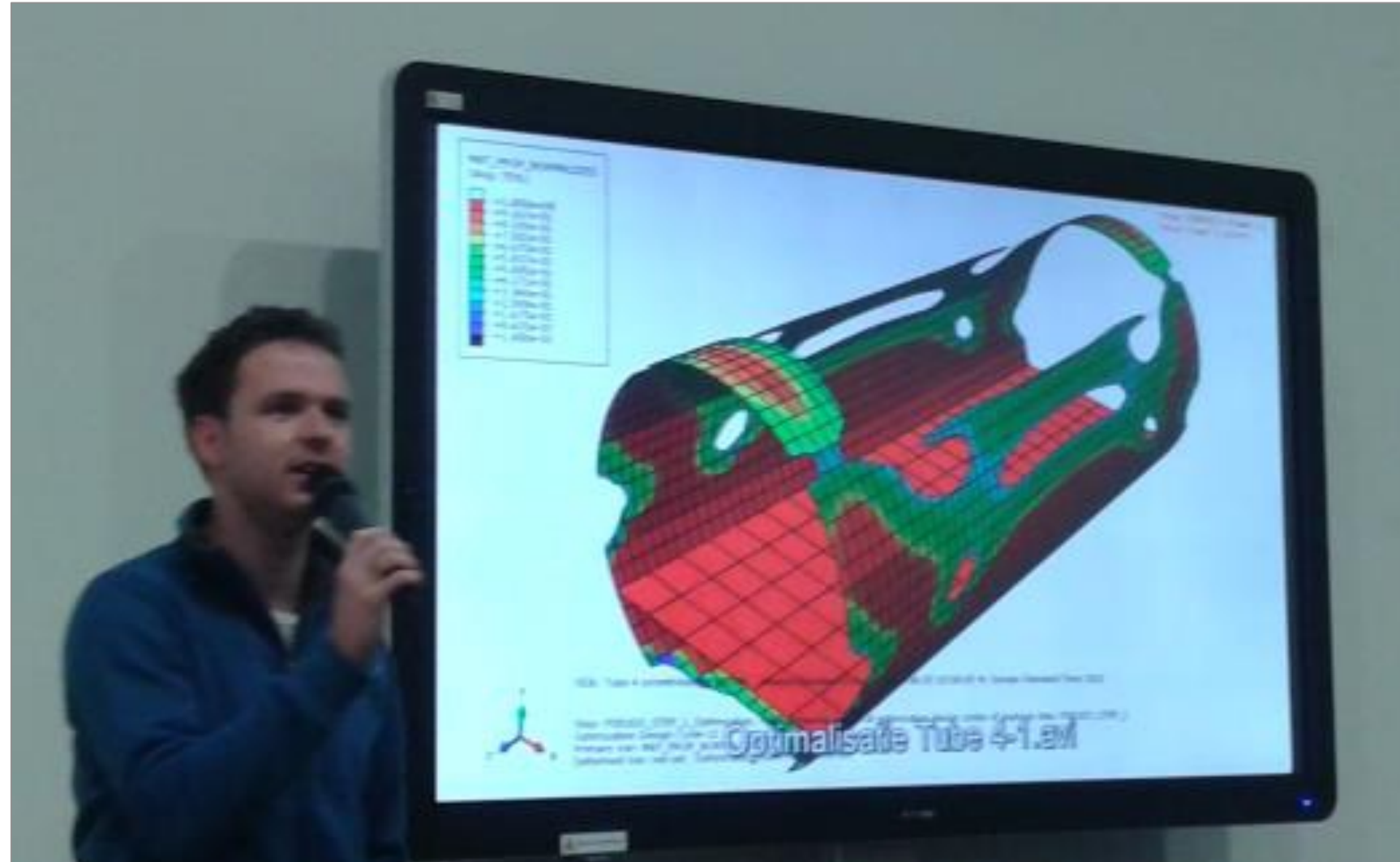


Two projects > one bridge



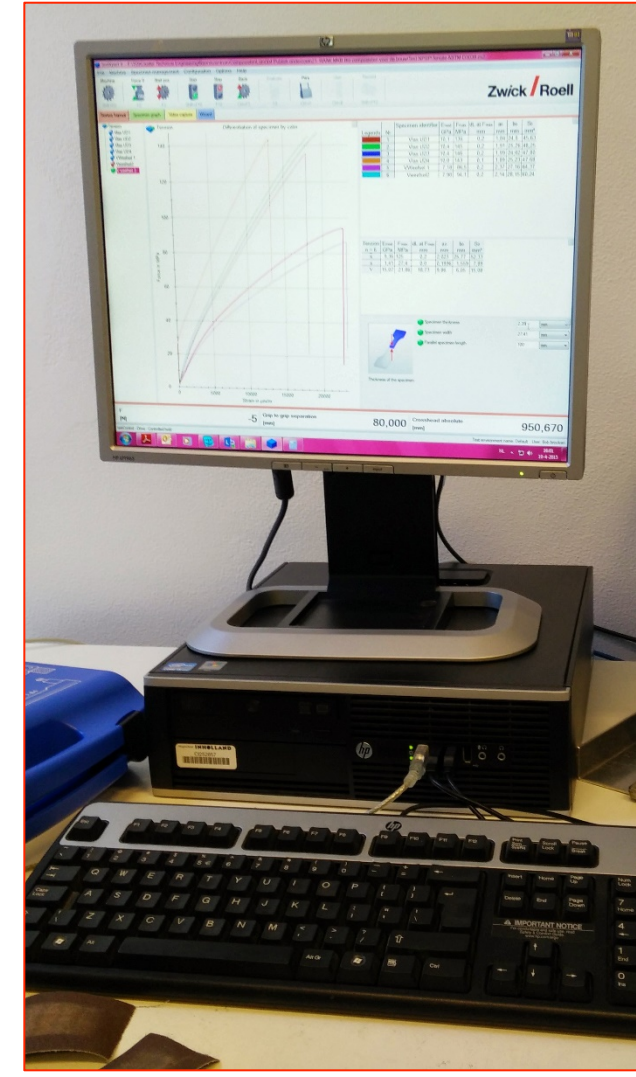
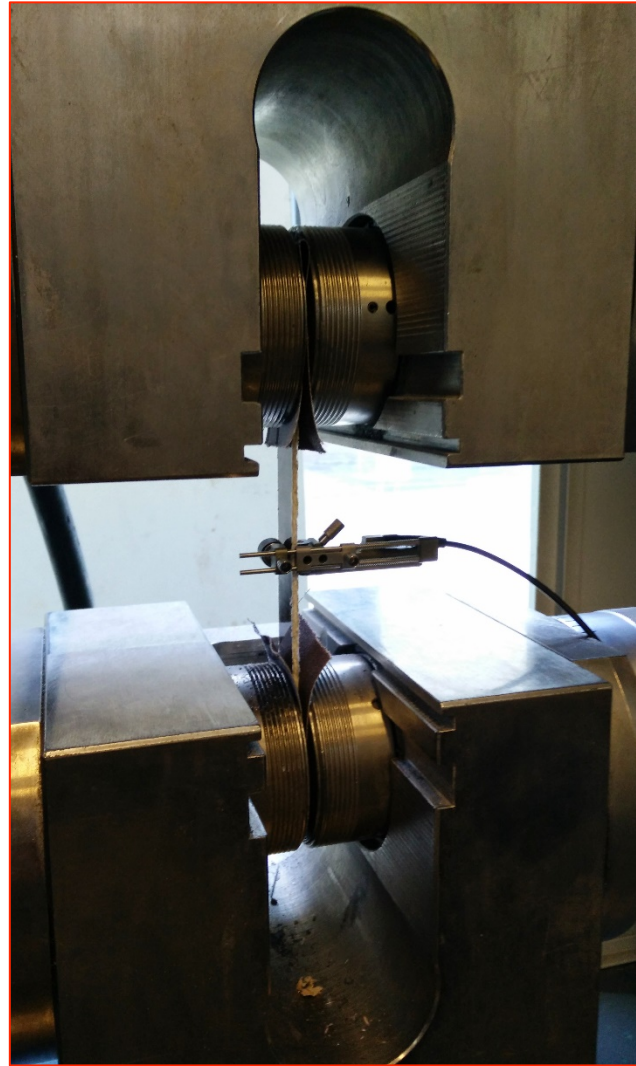
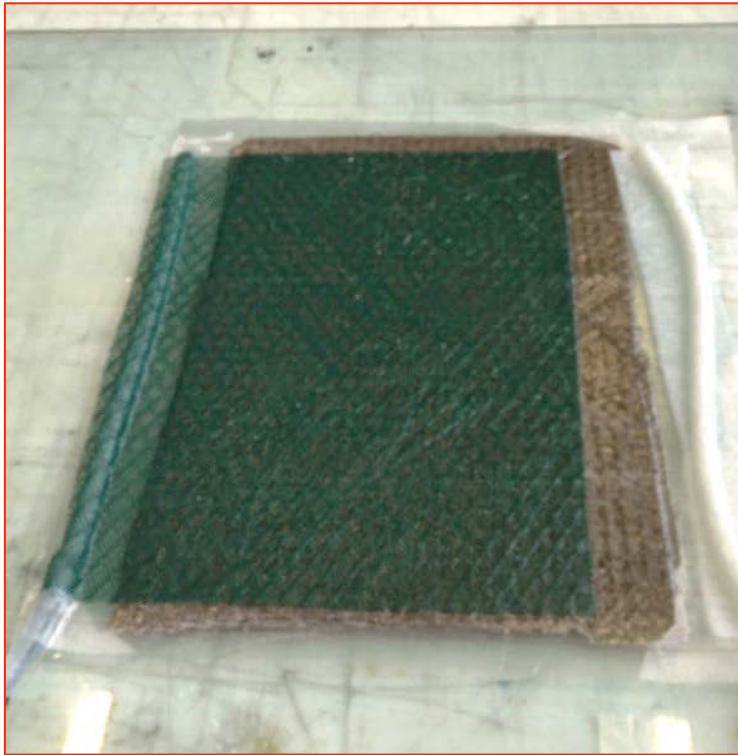
Material dimensioning optimization software

- Cuts out material
- Lowers weight
- Less resin and fibers
- Save costs + footprint
- Improves LCA score



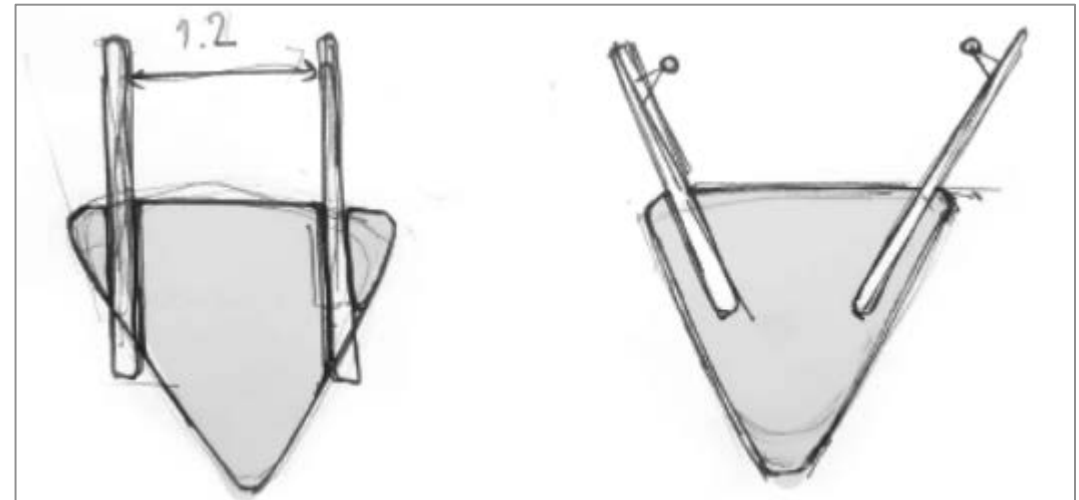
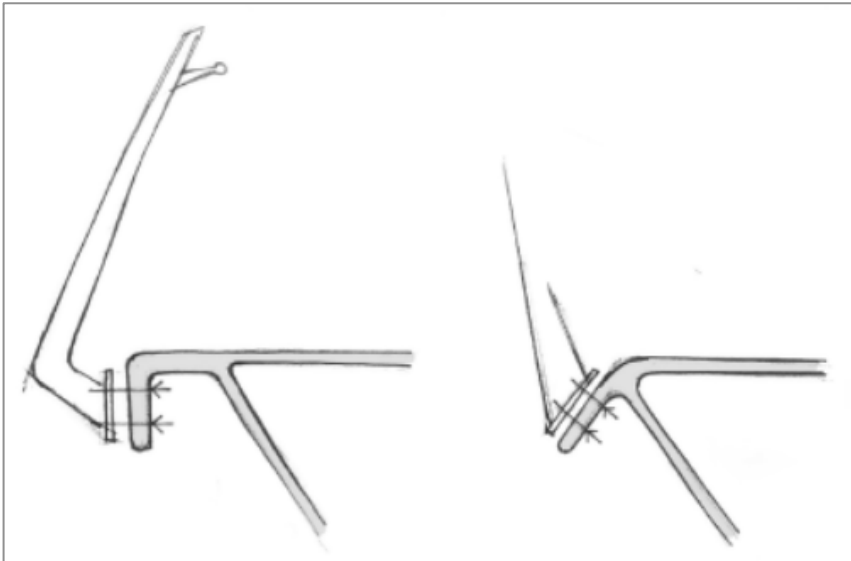
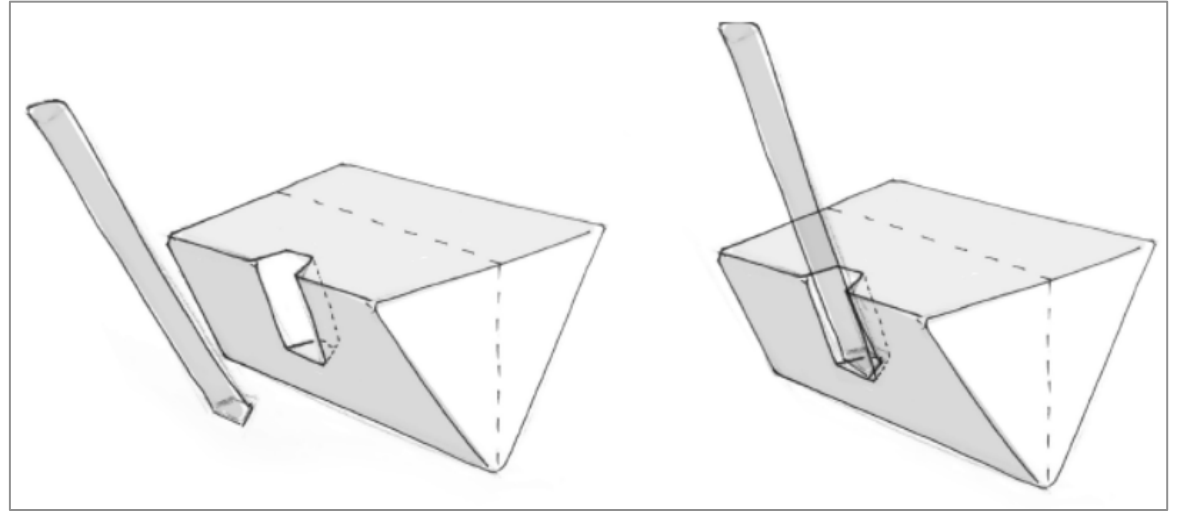
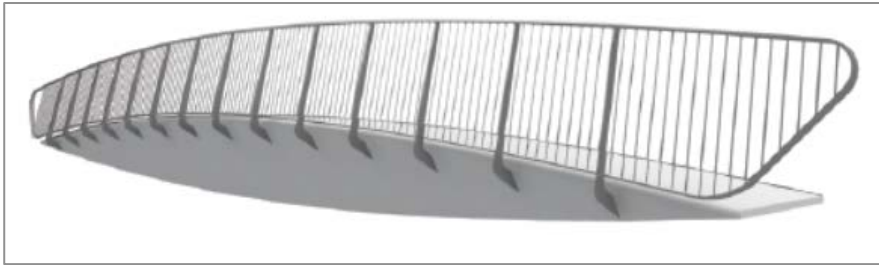
Material testing

- Various bioresins
- Various fibers



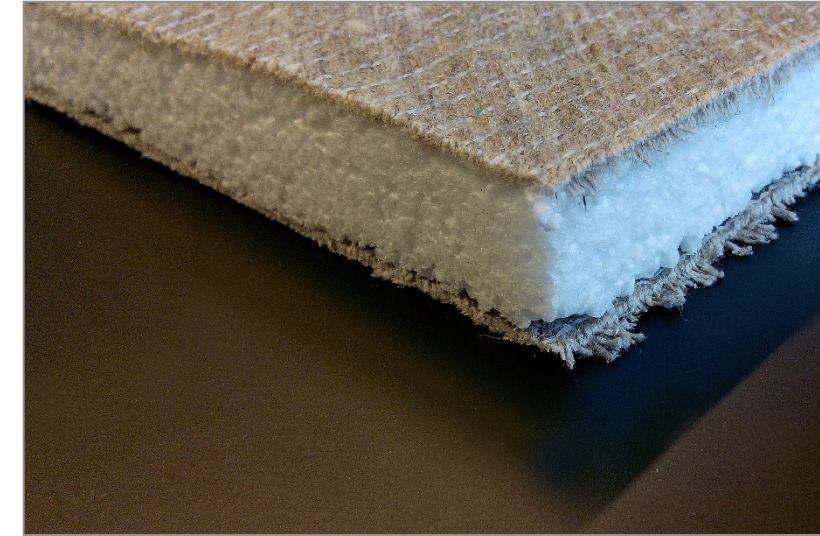
Railing Design

- Screws/bolts vs. screw less
 - Point load composite



Sandwich core material 1/4

- Stiffness + shaping
 - PLA foam (biobased alternative to EPS)
 - Cork
 - Mycelium material
 - Organic carbohydrate and protein rich source
 - Mycelium (e.g. oyster mushroom)



Sandwich core material 2/4

- Hemp as mycelium substrate
 - “Waste stream” fiber production
 - Short fibers + shives
 - Hemp dust pellets
 - Pure hemp shives

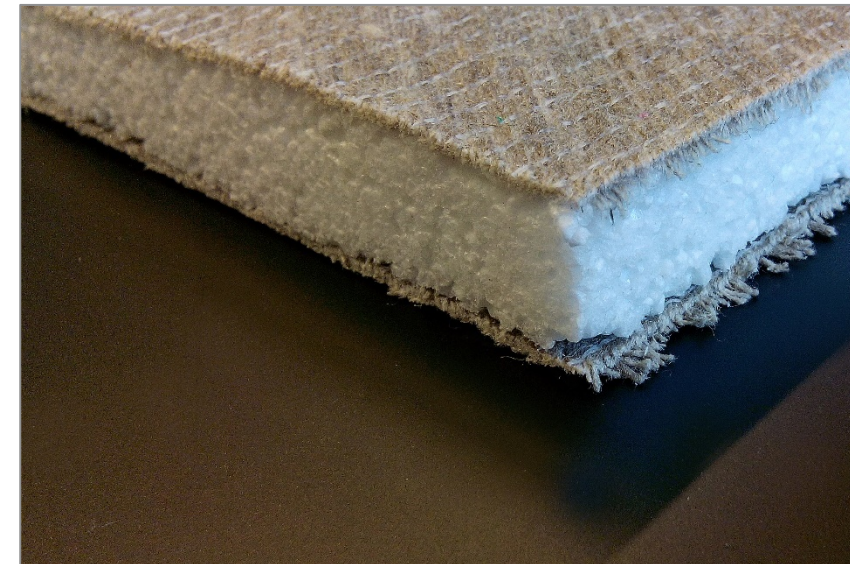
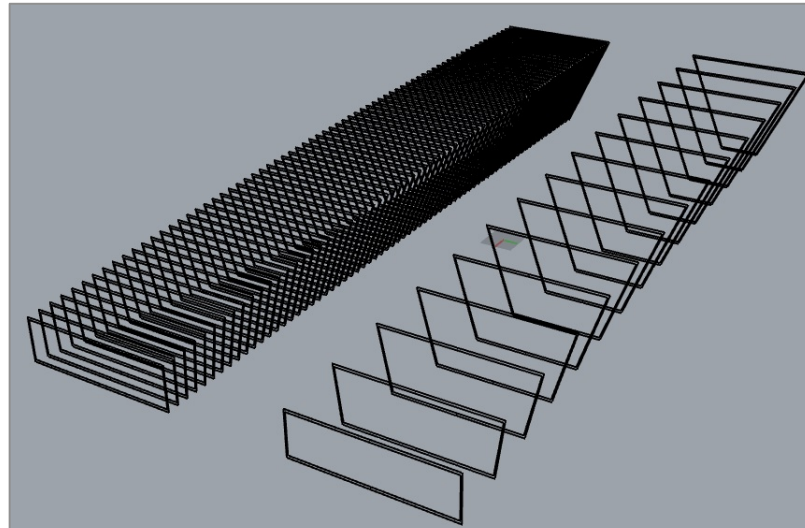
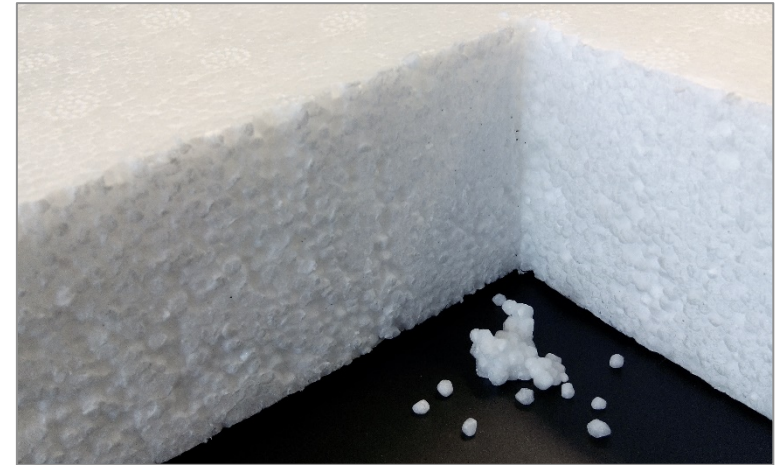






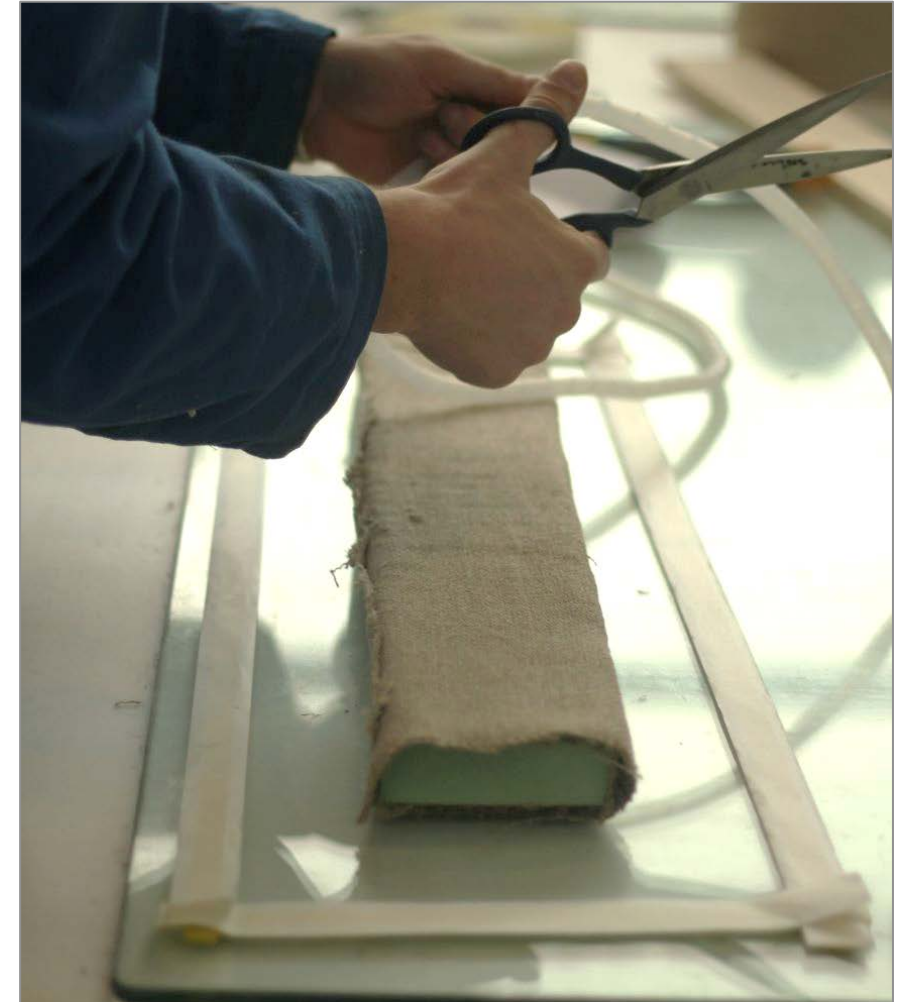
Production method 1/3

- Shaping core
- Sawing and scraping
- PLA foam
- Shaping shapes laser cut from wood/
cardboard



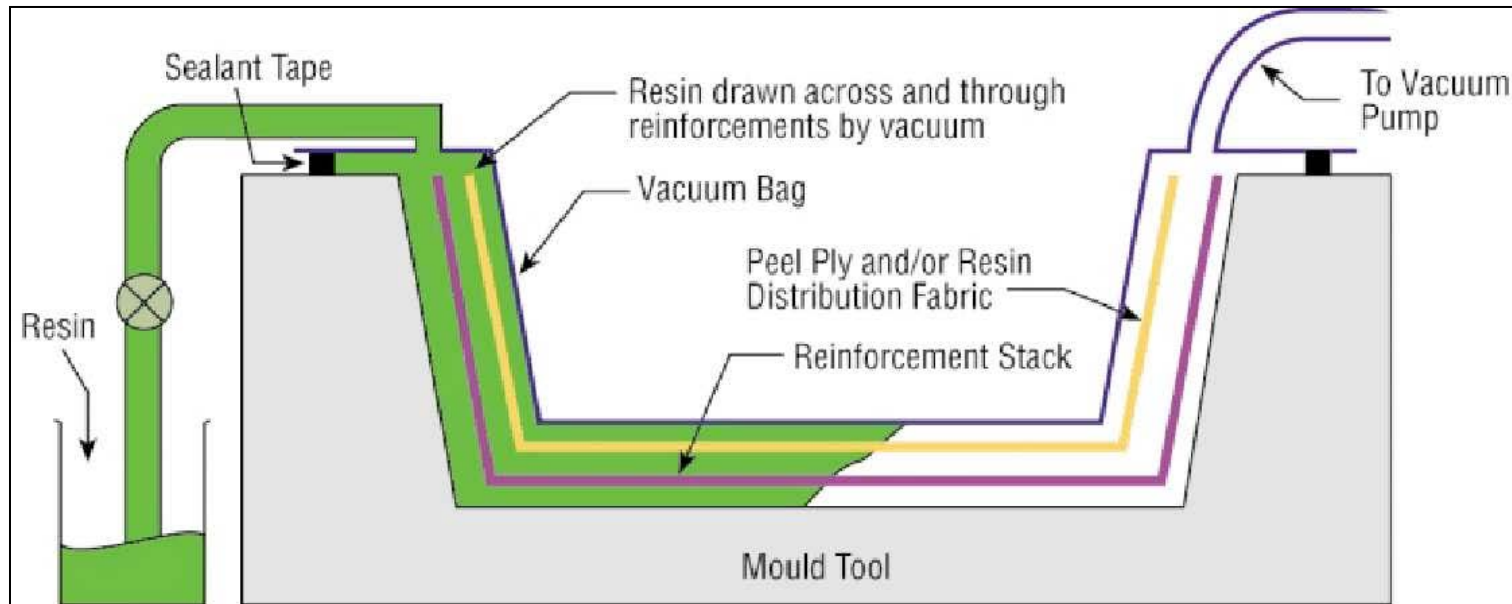
Production method 2/3

- Lay fibers on core
 - Using high strength fibers on high stress points
- Wrap in vacuum foil
- Apply vacuum...



Production method 3/3

- Vacuum infusion molding
 - High fiber/resin ratio
 - Good compression of fluffy natural fibers
 - Good wetting of natural fibers
 - Less solvent air emission during production















Student projects 1/3

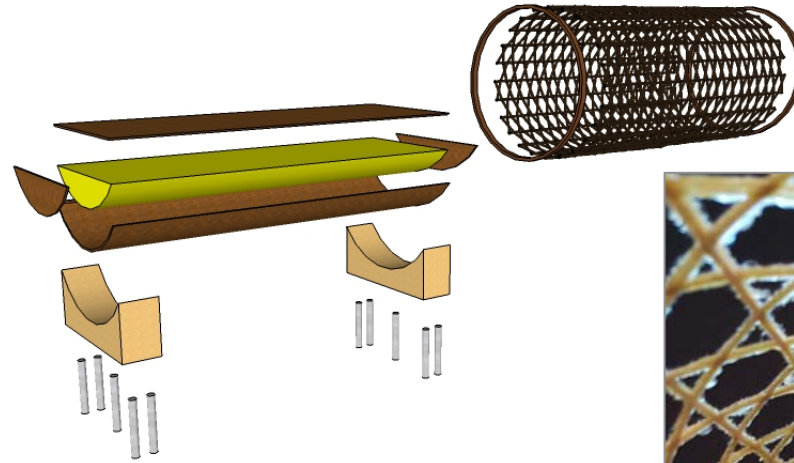
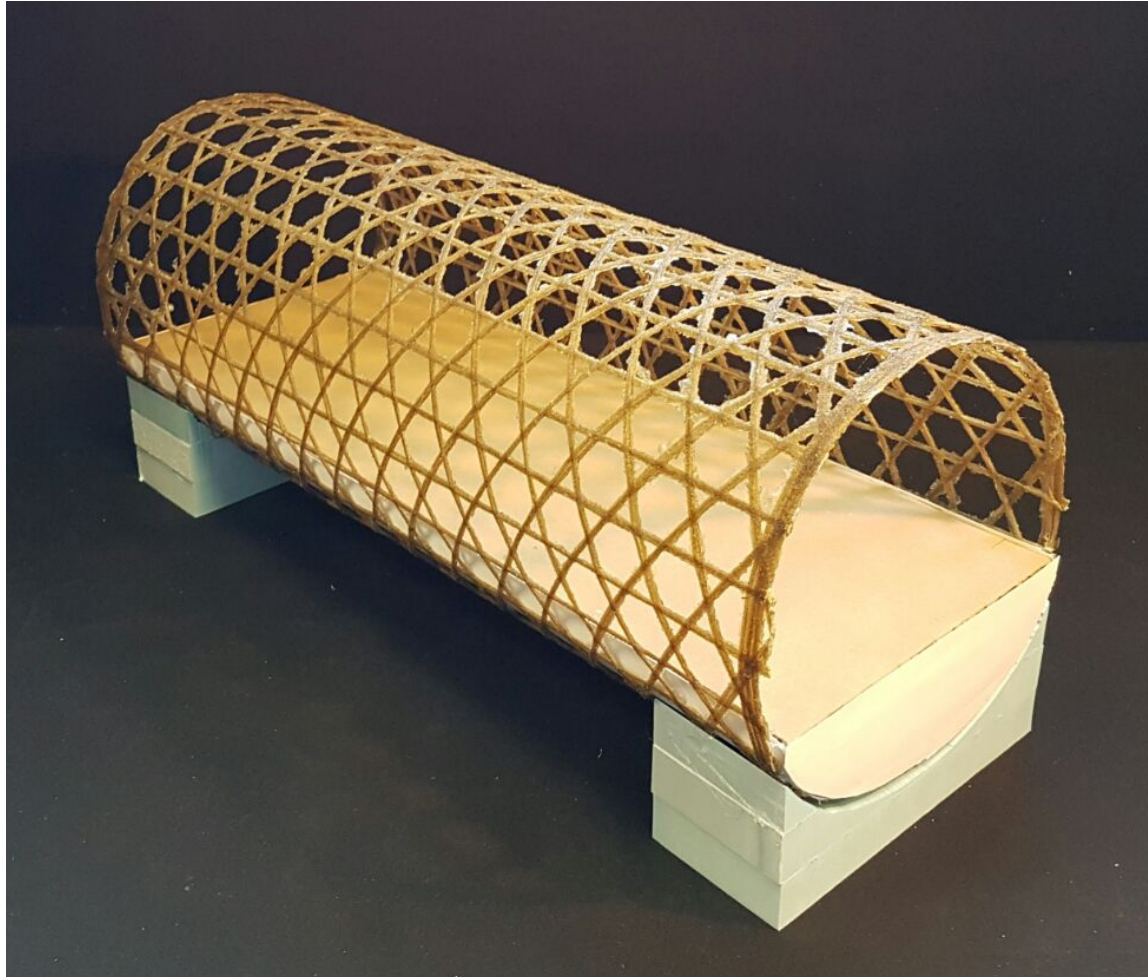
avans

University of Applied Science

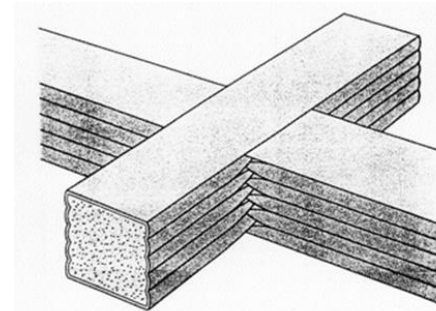
- Hyperboloid structure
- Needs vertical support rings



Student projects 2/3

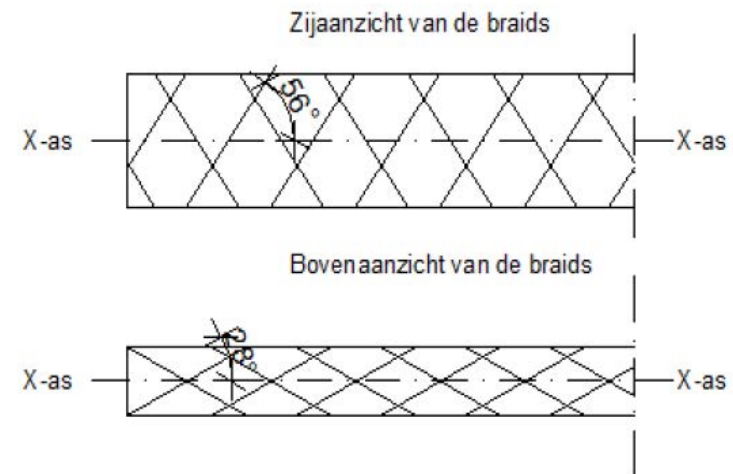
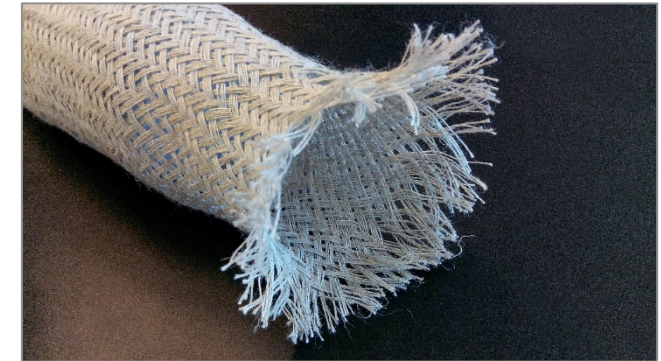
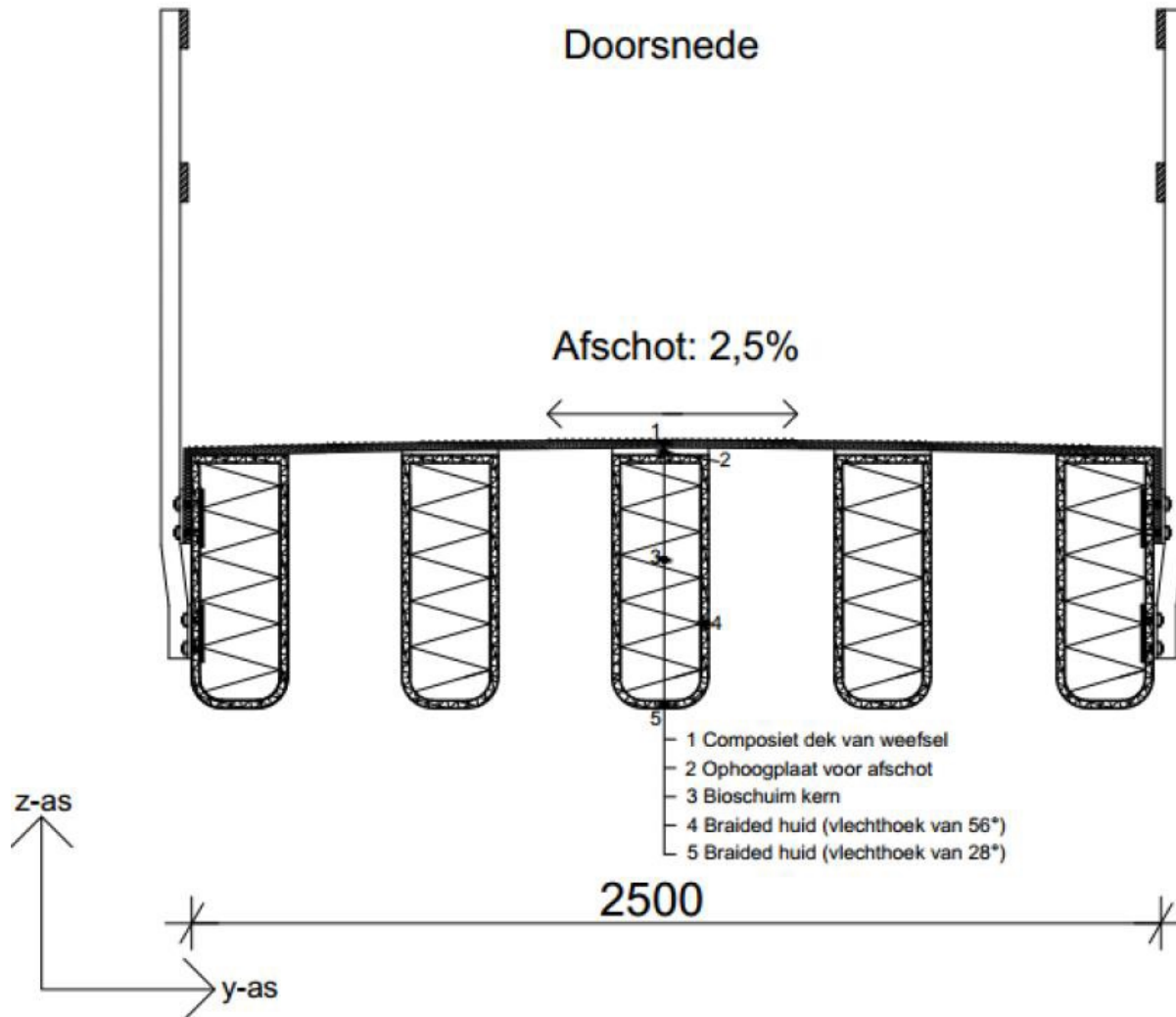


- Kagome grid
- Layering



Student projects 3/3

- Braided support beams



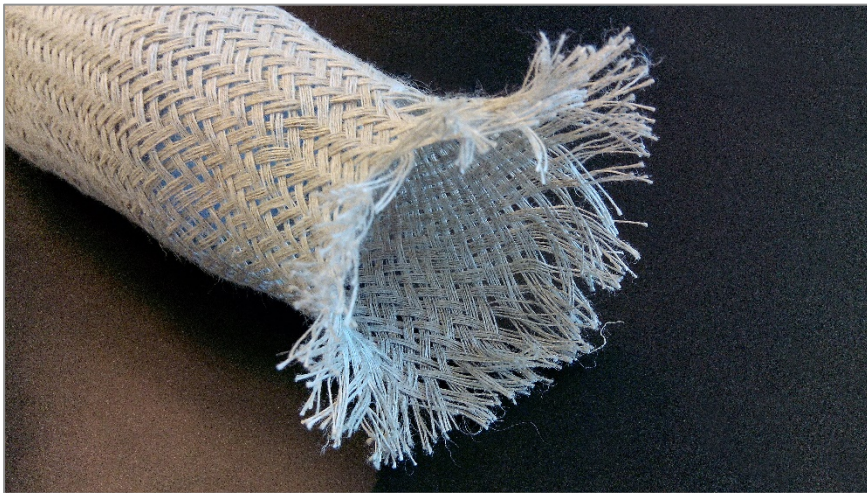
Chemical recycling

- Using **solvents** to separate the fibers and resin again.
- Not for recycling natural fibers but for **resin** (~€19/kg bio epoxy resin)
- **Reversal** of crosslinking?
- More research needed



Biocomposite research: hemp related 1/

- Affordable **price competitive hemp fiber** besides non-woven products
 - Woven
 - Unidirectional
 - Braids



- **Interesting area of R&D for the hemp composite industry**

Biocomposite research: hemp related 2/

- **Bioresins** > early harvest hemp seeds

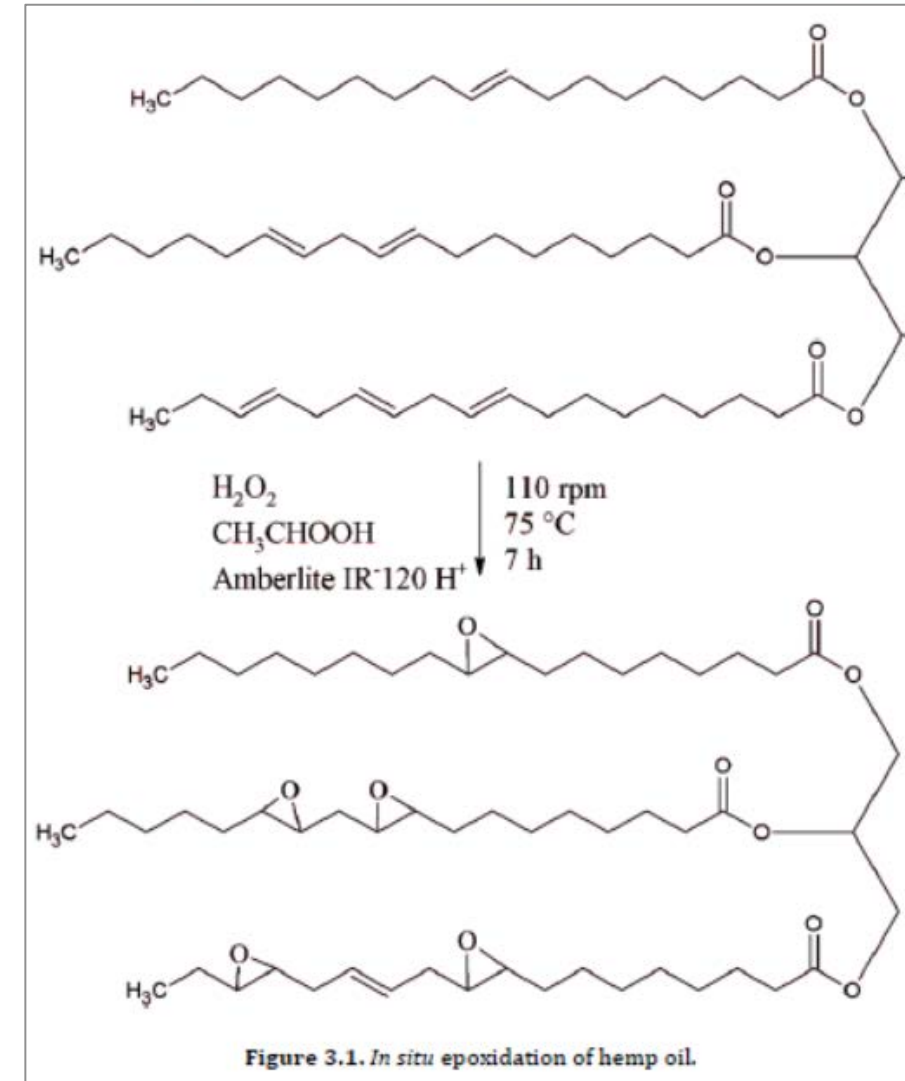
- By product fiber production
- Not fit for human consumption
- Hemp oil



- Epoxidised hemp oil
- Acrylated epoxidized hemp oil
- Multiple research papers by: Centre of Excellence in Engineered Fibre Composites, University of Southern Queensland
 - Gaston Francucci, Francisco Cardona, Nathan W. Manthey, Thiru Aravinthan.

- *“Overall from this research work it can be concluded that hemp oil based bioresins can effectively compete with commercially available bioresins and their equivalent synthetics in biocomposite applications.”*
...more research is needed.

- **Interesting area of R&D**
for the hemp composite industry





Questions? More information

SIA Raak Biobased Bridge Project

“biocomposieten voor bouwkundige en civiele toepassingen”

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<https://www.4tu.nl/bouw/en/lighthouse2016/Bio%20Based%20Bridge/>

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