The Application of Bio-Based Composites in Load-Bearing Structures

A research into the possibilities, properties and the durability of flax fibre reinforced bio-based composites

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CONTENT

Composites in load-bearing structures
Why biocomposites
Intro to bio composites
B³ Bio based bridge
Potentials and challenges
Research
Environmental impact indication
Conclusions & future
1 + 1 = COMPOSITE

A composite is a material construction, consisting of at least two microscopically distinguishable materials that work together to achieve a better result. ¹

Fossil based raw materials
Large CO$_2$ footprint
High human toxicity

Renewable materials
Low CO$_2$ footprint
Low human toxicity
NATURAL FIBRES

Bast fibres:
→ Longest fibre length
→ Highest strength & stiffness.
Woven flax yarn, 550 gram/m² produced by Lineo

Woven flax yarn, 150 gram/m² produced by Lineo

UD flax fibres, 180 gram/m² produced by Lineo

45/-45 ° flax fibres, 300 gram/m² produced by Lineo

Hemp fibre mat, 350 - 2000 gram/m² produced by Hempflax
BIO-BASED POLYMERS

Thermoset bio-based polymer

100%

Greenpoxy 56 - Sicomin (max 56%)

FormuLITE - Cardolite (max 37%)
PRODUCTION METHODS

Combination with:
- Size
- Design
- Curing pattern
- Batch size
- Equipment costs

Production methods:
- Hand lay-up
- Vacuum Assisted RTM
- RTM
- Spray-up
- Filament Winding
- BMC
VACUUM ASSISTED RTM

1. Fibre placement
2. Place peel-ply fabric
3. Place perforated foil
4. Place mesh and runners
5. Create vacuum and start resin infusion
3TU BIO-BASED PEDESTRIAN BRIDGE
THE DESIGN

Side elevation

Longitudinal section
MATERIALS

Flax fibre
UD & Woven

Hemp fibre
Random mat

PLA foam

Greenpoxy 56 resin
SD 4770 hardener
43% bio based
Curing temperature
- Low melting temperature of PLA foam
- Found solution in resin

Bio-based paint
- Linseed oil based paint
- Did not dry properly

Check production process
LASER CUTTING PLA FOAM
Prefab top and bottom elements

- Most tensile strength bottom

- Top incorporating measuring equipment
POTENTIALS

Design flexibility
- Double curvature
- Material engineering possibilities

Environmentally friendly
- Replacement glass fibre
- Bio-based and renewable

Recycling possibilities
- Chemical recycling

CHALLENGES

Production challenges
- Constant quality fibre
- Limited choice bio based resin

Thermal stability
- Degradation fibre at low temperatures (> 210 °C)

Weathering behavior
- UV radiation
- Moisture
- Temperature
POTENTIALS

Design flexibility
- Double curvature
- Material engineering possibilities

Environmentally friendly
- Replacement glass fibre
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Production challenges
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Thermal stability
- Degradation fibre at low temperatures (> 210 °C)

Weathering behavior
- UV radiation
- Moisture
UV radiation

- Brittle and cracked surface
- Decoloration
- Fibres exposed
WEATHERING

Moisture absorption by fibre

Moisture diffusion through polymer matrix

Dissolving of water-soluble substances from fibre

Moisture evaporates, damaged composite
CHALLENGE - LONG LIFESPAN

MATERIAL PROPERTIES

Coating
With UV-blocker

Weathering
By outdoor environment

MATERIAL PROPERTIES
What are the effects of weathering (UV radiation, humidity and temperature) on the mechanical properties of flax fibre reinforced bio composites?
EXPERIMENTS

Mechanical properties with different resins

- Flax fibres
- UD 180 gr/m², 10 layers

Accelerated weathering

- Artificial!
- Test impact on mechanical properties
MECHANICAL PROPERTIES

Different resins
Specimens tensile testing
ISO 527-5

FormuLITE 2501A + NX5619
Greenpoxy56 + SD4770
FormuLITE 2501A + 2401B
TENSILE TESTING

With Fred Veer
3ME faculty TU Delft
2 mm/min test speed
RESULTS TENSILE TEST

Stress/strain graph of flax fibre bio based composites

- **Greenpoxy 56**
  - E modulus [GPa]: 10.3
  - Tensile strength [MPa]: 265
  - Bio-based content resin [%]: 43
  - Bio-based content specimen [%]: 67

- **FormuLITE 2501A + 2401B**
  - E modulus [GPa]: 9.8
  - Tensile strength [MPa]: 212
  - Bio-based content resin [%]: 34
  - Bio-based content specimen [%]: 64

- **FormuLITE 2501A + NX5619**
  - E modulus [GPa]: 8.6
  - Tensile strength [MPa]: 158
  - Bio-based content resin [%]: 30
  - Bio-based content specimen [%]: 59
WEATHERING TESTING

Accelerated weathering: QUV

2, 4 & 6 weeks!

Control group

2, 4 & 6 weeks!

Week 0 test
WEEK 0

Tensile testing & 3-point bending testing

2 types of resins used:

- Greenpoxy 56 + SD4770

- FormuLITE 2501A + 2401B
RESULTS TENSILE TEST

- Greenpoxy 56
  - E modulus [GPa] 10.3
  - Tensile strength [MPa] 279
  - Bio-based content resin [%] 43
  - Bio-based content specimen [%] 67

- FormuLITE 2501A + 2401B
  - E modulus [GPa] 9.6
  - Tensile strength [MPa] 252
  - Bio-based content resin [%] 34
  - Bio-based content specimen [%] 64

- Greenpoxy56 comparable results
- FormuLITE tensile strength 19% better
3-POINT BENDING TEST
RESULTS 3-POINT BENDING TEST

- Greenpoxy56 comparable results
- FormuLITE tensile strength 19% better

Greenpoxy 56
- Flexural modulus [GPa] 24.9
- Tensile strength [MPa] 279
- Bio-based content resin [%] 43
- Bio-based content specimen [%] 67

FormuLITE 2501A + 2401B
- Flexural modulus [GPa] 9.6
- Tensile strength [MPa] 252
- Bio-based content resin [%] 34
- Bio-based content specimen [%] 64
ACCELERATED WEATHERING TEST

Difference with natural weathering
- Acceleration factor
- Freezing temperatures in NL
- UV spectrum
RESULTS ACCELERATED WEATHERING

Greenpoxy56 based composite

Tensile strength [MPa] vs. Time [hours]

- Greenpoxy 56 - Control group (individual specimen)
- Greenpoxy 56 - In QUV accelerated weathering machine (individual specimen)
- Greenpoxy 56 - Control group (mean)
- Greenpoxy 56 - In QUV accelerated weathering machine (mean)
RESULTS ACCELERATED WEATHERING

FormuLITE based composite

- **FormuLITE - Control group (individual specimen)**
- **FormuLITE - Control group (mean)**
- **FormuLITE - In QUV accelerated weathering machine (individual specimen)**
- **FormuLITE - In QUV accelerated weathering machine (mean)**

Tensile strength [MPa] vs. Time [hours]
RESULTS ACCELERATED WEATHERING

Greenpoxy56 based composite

- Greenpoxy 56 - Control group (individual specimen)
- Greenpoxy 56 - In QUV accelerated weathering machine (individual specimen)
- Greenpoxy 56 - Control group (mean)
- Greenpoxy 56 - In QUV accelerated weathering machine (mean)
RESULTS ACCELERATED WEATHERING

FormuLITE - Control group (mean)

FormuLITE - Control group (individual specimen)

FormuLITE - In QUV accelerated weathering machine (mean)

FormuLITE - In QUV accelerated weathering machine (individual specimen)
ENVIRONMENTAL IMPACT
Bio-based composite bridge

Double curved body

same amount of material

Simplified body

Glass fibre composite bridge

Double curved body

same amount of material

Simplified body

Timber bridge

Hardwood decking

Glulam beams

600 mm

Steel bridge

Galvanized steel decking

Concrete bridge

IPE 360 beams

6% steel reinforcements in C28/35 concrete

Glass masonry bridge

Casted glass bricks with PVC foil inbetween
Production phase

Bio-based composite 4 times better than regular composites!

Steel not bio-based!
CONCLUSIONS

• Possible for load-bearing structures
  - Bio based bridge is proof!
CONCLUSIONS

• Good mechanical properties
  - Tensile strength comparable with steel!
  - But choose right fibre/matrix combi

• Weathering effects tensile strength and Young’s modulus
CONCLUSIONS

- Environmentally friendly - Almost 4 times better than glass fibre composite!
- But room for improvement!
CONCLUSIONS

• Keep developing!
  - In the polymer industry
    - Through research projects
      - production methods
      - Recycling possibilities
FUTURE

• Fully bio-based resins/coatings
  - New types
  - recycled resins?

• Other fibre types

• Implementation in building industry

• Production process
  - Reducing waste material
  - Bio based materials for production?
  - Fibres in new production processes
Thank you