Recyclability of Flax Fiber Reinforced Polymer Composites with a Covalent Adaptable Network Matrix

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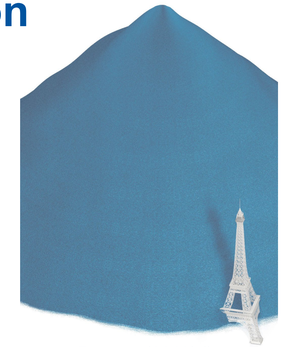
Motivation

- Glass and carbon fibers contribute to CO2e emissions
- Nearly 700,000 tons of composite waste will be accumulated in the next five years: that's over 65 Eiffel Towers! [1]
- Challenges arise in recycling composites with thermosetting matrix



Reuters (2019) [2]

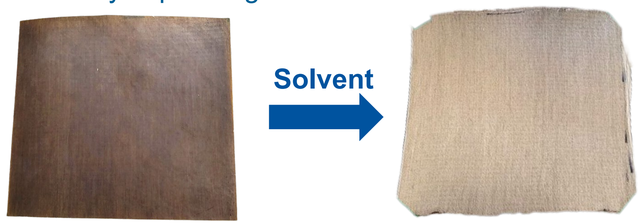
Approach and Objectives

- Flax fibers to reduce cradle-to-gate emissions
- Recyclable and self-healing Covalent Adaptable Network (CAN) matrix to reduce gate-to-grave environmental impacts

- **Primary Objective**—Investigate the performance of a CAN matrix composite with recycled flax fibers

Solvolysis

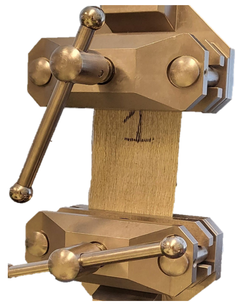
- Solvent (dimethylformamide + 2-mercaptoethanol) cleaves the disulfide bonds of CAN matrix, effectively separating flax fibers from the matrix



Composite of Vitrimer and Flax

Extracted Flax Fibers

Effect of Solvolysis on Flax Fiber Fabric



Flax Fabric Tensile Test (ASTM D5034)

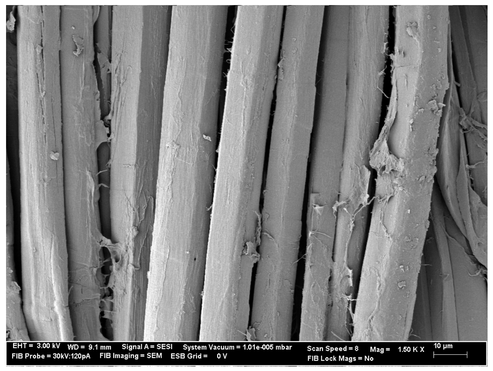
Test Group	Max Force (N)	Stiffness (N/mm)
Virgin Flax Fabric	3792 ± 421	1144 ± 100
Treated Flax Fabric	4985 ± 441	1133 ± 50
	31% Increase	No difference.

Composite Mechanical Properties

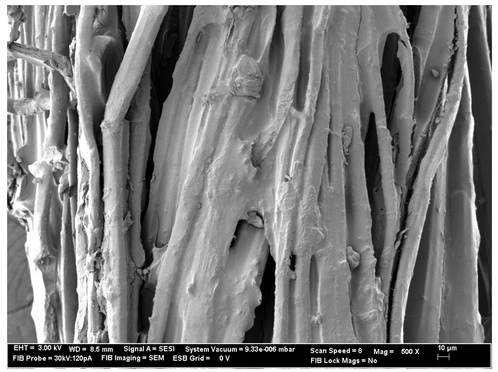
Tensile Test (ASTM D3039)

Test Group	Area (mm^2)	Modulus (GPa)	Strength (MPa)	"Yield" (MPa)
Virgin Flax Fabric	10.7 ± 0.3	20.5 ± 1.3	234.7 ± 12.1	106.4 ± 7.3
Recycled Flax Fabric	16.8 ± 1.3	17.9 ± 1.6	182.6 ± 14.1	133.8 ± 10.8
	↑ 57%	↓ 13%	↓ 22%	↑ 26%

Scanning Electron Microscopy



Virgin Flax Fibers

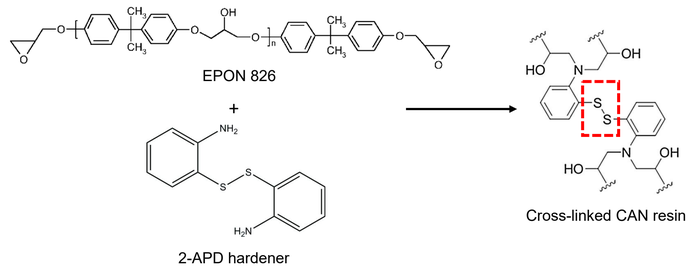


Recycled Flax Fibers

Flax Fibers

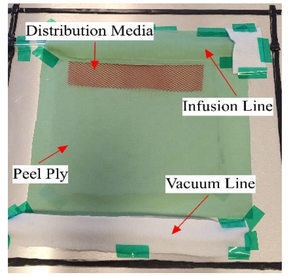
- 275 g/m2 UD flax fiber fabric
- 106 tex spun yarn

CAN Matrix



Composite Fabrication

- Vacuum assisted resin transfer molding
- 2 plies of unidirectional flax fabric infused with CAN epoxy resin
- Cured at 125 C for 5 hours and then 150 C for 1 hour



Conclusions

- Solvent treatment increased force capacity of flax fabric by 31%
- Tensile modulus and strength decreased by 13% and 22% with recycled fibers
- Thickness of the composite with recycled fibers increased by 60%, likely due to reduced permeability of recycled flax fabric

References:
[1] Shehab, E., et. al. (2022). Cost Modelling for Recycling Fiber-Reinforced Composites: State-of-the-Art and Future Research.
[2] Drowning in plastic (2019) Reuters. Available at: https://www.reuters.com/graphics/ENVIRONMENT-PLASTIC/0100B275155/index.html

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