Sustainable Composite Structures

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Project Objectives

- Design a manufacturing and processing method that improves the efficiency and properties of composite panels made from HexPly Nature Range NR-M78.1-LT/48%/UD210P/Flax (flax fiber, bio-epoxy resin)
- Prepare a STEEP (Social, Technological, Economic, Environmental, Political) analysis to obtain a more complete understanding of sustainability for this material

Background

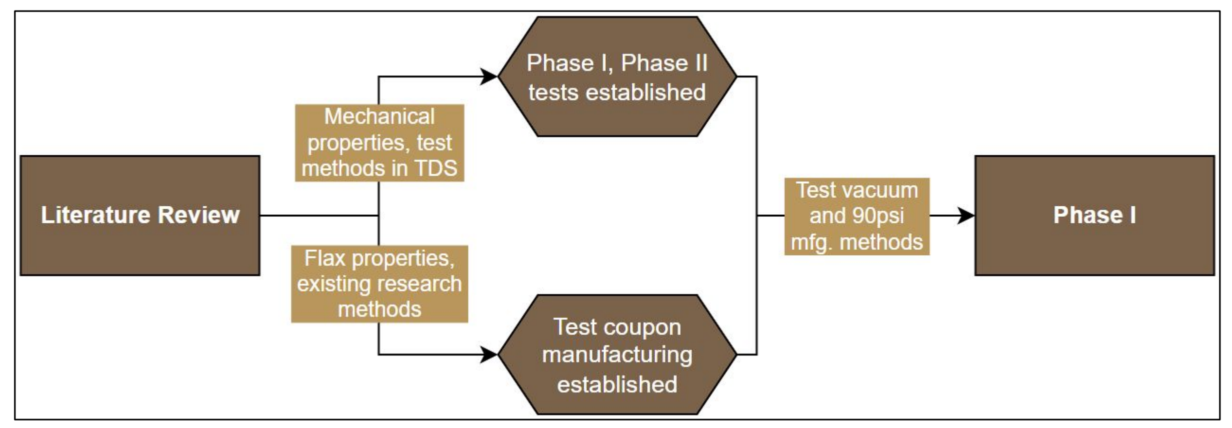
- Flax/bio-epoxy prepreg offers sustainability advantages through renewable feedstock, biodegradability, and lower energy costs/emissions
- Optimizing processing conditions can make flax/bio-epoxy composites more viable in industry
- Flax/bio-epoxy prepreg has lower mechanical properties than comparable low-temp cure carbon fiber prepreg (HexPly M79)
- Flax fibers are very susceptible to moisture absorption—creating processing and storage challenges—and thermally degrade above 220°C
- HexPly Nature Range flax fibers are sourced from Normandy, France and go through four steps: cultivation, scutching, hackling, refining

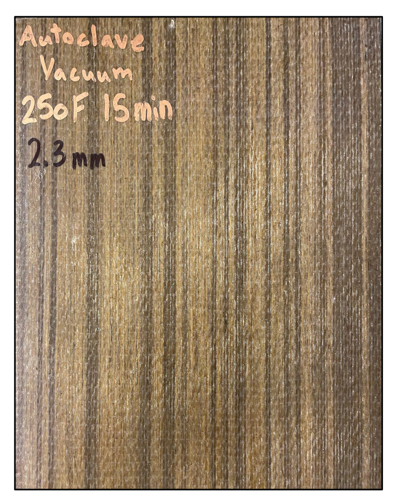
Picture from Depestele brochure

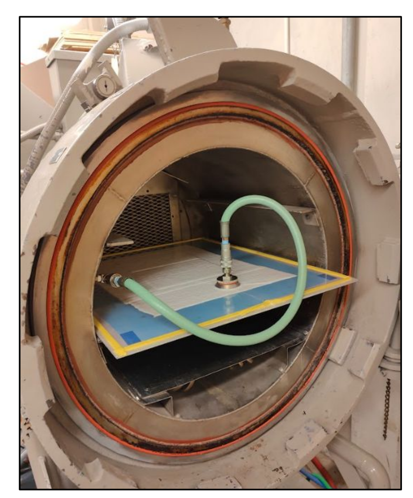
Phase I

Design Process

- Test tensile mechanical properties, degree of cure, visual inspection for flaws. 250°F, 5°F/min ramp, 10min soak

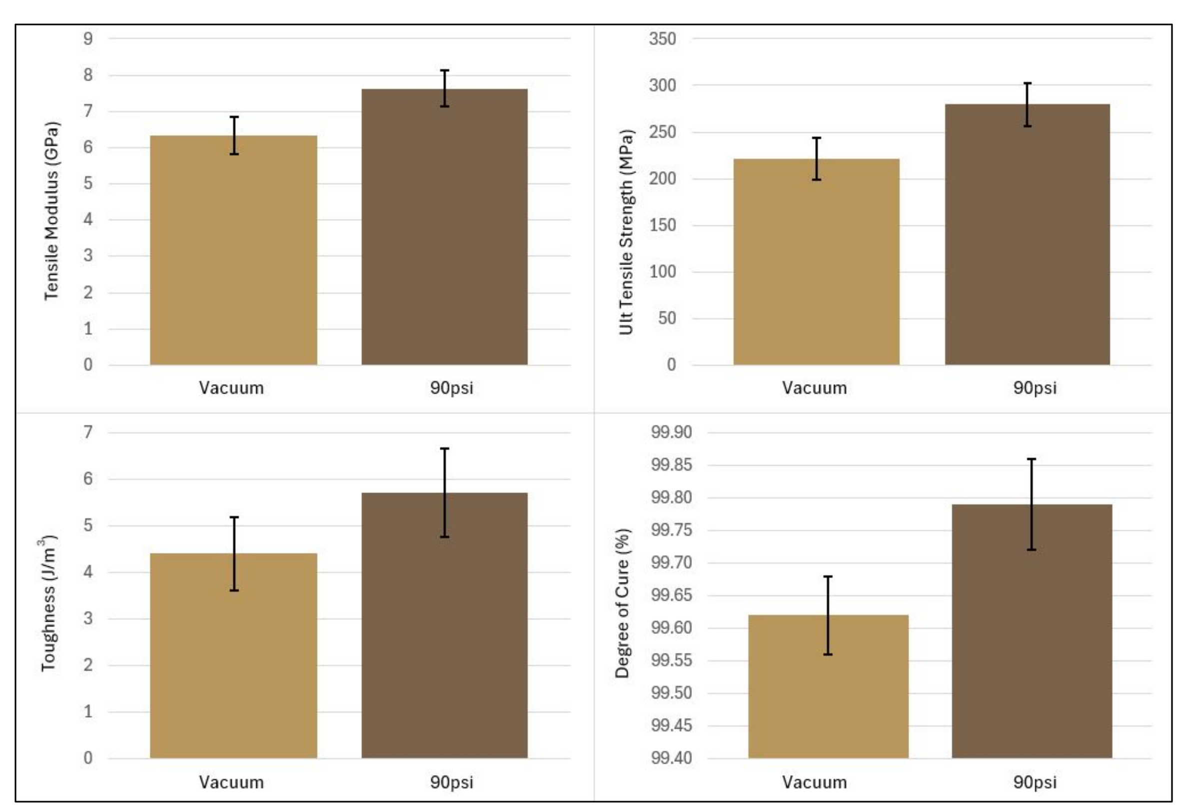






Data Analysis

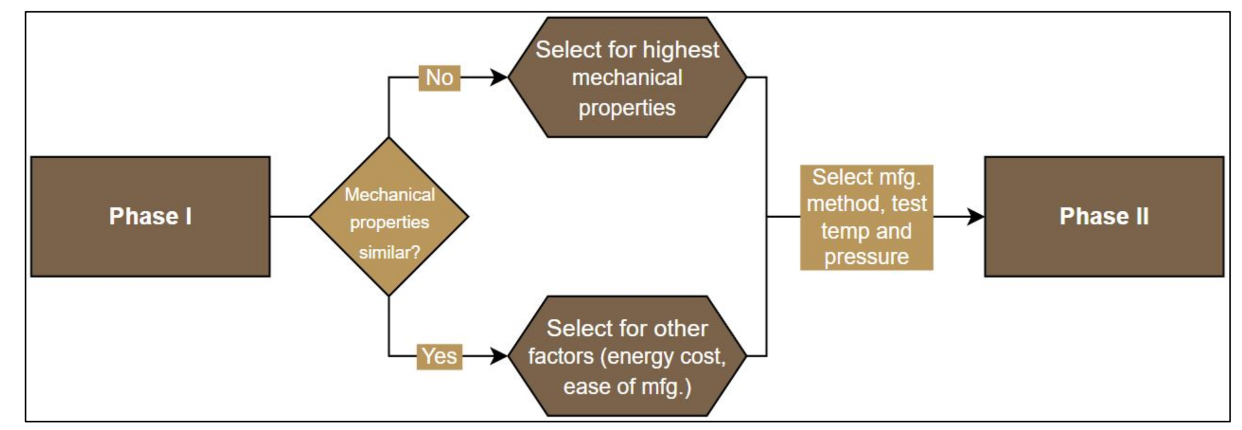
- 90psi samples had higher mechanical properties but values from both manufacturing methods nearly or completely overlapped when accounting for error
- As such, vacuum method was selected for Phase II for closer alignment to sustainability goals (more accessible, lower energy cost)



Phase II

Design Process

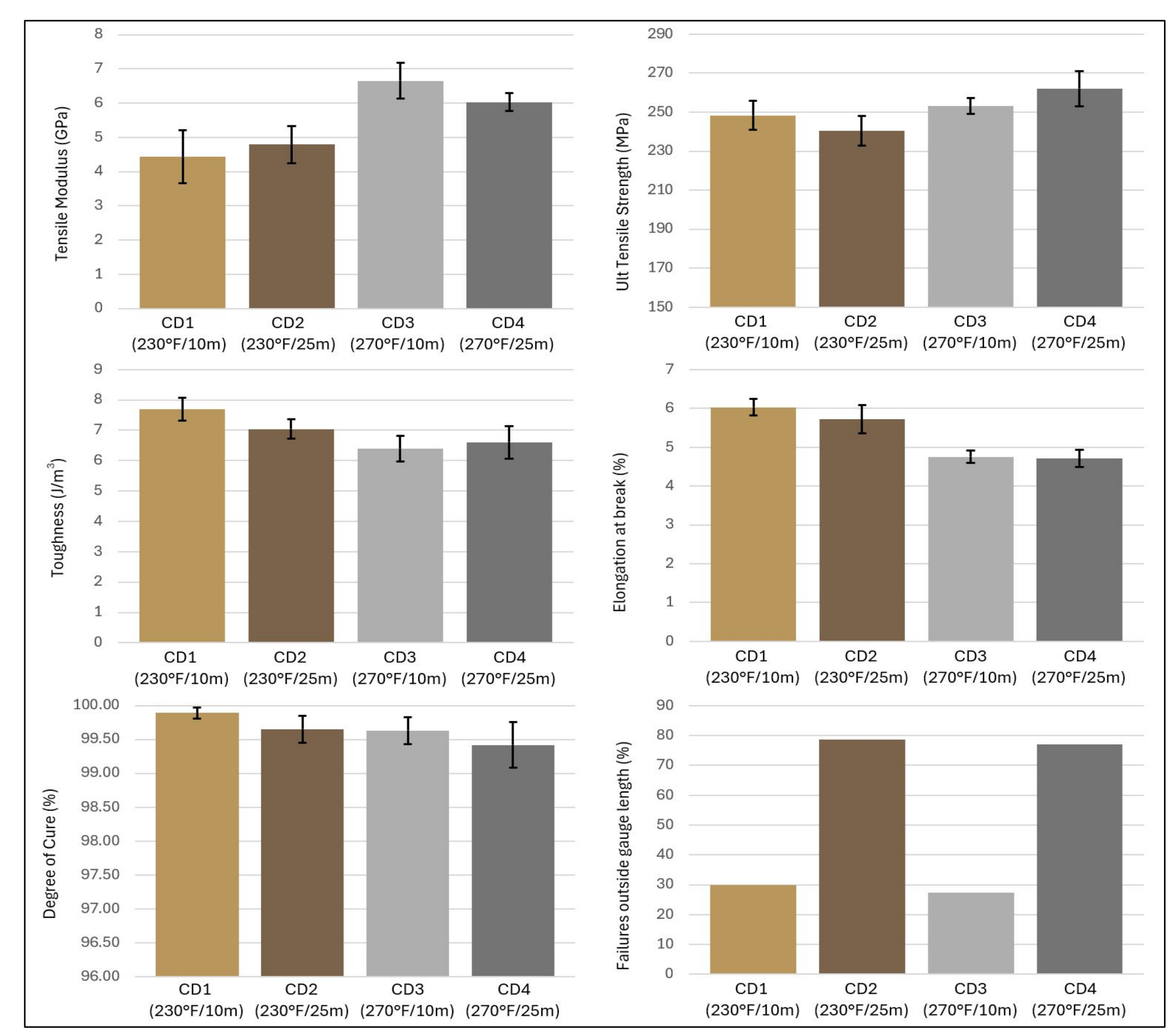
- Test tensile mechanical properties, degree of cure, visual inspection for flaws
- Due to small property differences between methods, vacuum method was selected for closer alignment to sustainability goals (more accessible, lower energy cost)



	Temperature (°F)	Soak time (min)	Ramp rate (°F/min)
Cure Design 1	230	10	5
Cure Design 2	230	25	5
Cure Design 3	270	10	5
Cure Design 4	270	25	5

Data Analysis

- Higher temperature samples had higher tensile modulus but lower elongation at break than lower temperature samples
- Higher soak time samples had significantly more test failures outside of gauge length—panels likely had flaws due to excessive soak time



STEEP Analysis

Background

- Social: health, wellness, education, workplace factors
- Technological: physical properties, manufacturing, innovation
- Economic: costs, return on investment, risk, brand reputation
- Environmental: life cycle, ecological footprint
- Political: regulations, legislation, policy

Results

- Flax/bio-epoxy composites offer strong sustainability benefits, particularly in social safety, environmental impact, and political alignment with global goals such as the UN Sustainable Development Goals
- Other benefits include safer workplaces, lower emissions during manufacturing, and greener supply chains
- Current challenges: limited recyclability due to thermoset resin and cost of developing new materials

Impact Chart

Life Cycle Stage	Stakeholder	Social	Tech.	Econ.	Envir.	Political
Manufacturing	Technicians	Safe resin handling	Low-temp curing	Local sourcing	Low emissions	Policy aligned material
	Environmental Regulators	New material uncertainty	Process oversight needed	Tariff implications	Bio-based advantage	Sustainable alignment
Operation	Industry Partners	Positive brand alignment	Scalable process	Cost-effective potential	Energy saving use	Meets ESG priorities
	End User	Durability concerns	Usable design	Premium cost	Lower footprint	Limited policy awareness
End-of-Life	Community/Public	Better aw ko areness	Recycling limits	Low recovery value	Biodegrad able fibers	Lacks circular compliance
	End User	Disposal confusion	Basic handling	No resale/reuse	Composta ble fiber	Thermoset not recyclable
Key: Pos, Mod, Neg, Neutral						

Conclusion

- For optimal panel production, we recommend applying vacuum to the panel in an autoclave or oven, a 10-15 minute soak time, and a cure temperature between 230°F-270°F, with higher cure temperature resulting in higher stiffness and lower cure temperatures resulting in higher elongation.
- Next steps: flammability testing, fractography, further analysis of mechanical properties