Natural Fiber Composites Development and Testing

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Motivation for the Study

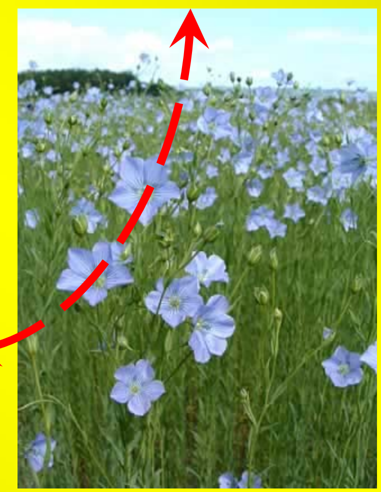
Biobased composite materials will emerge as an important engineering material as the technology evolves through strong collaboration by several facets of the entire production

Composite Manufacturers

University & Industry Researchers

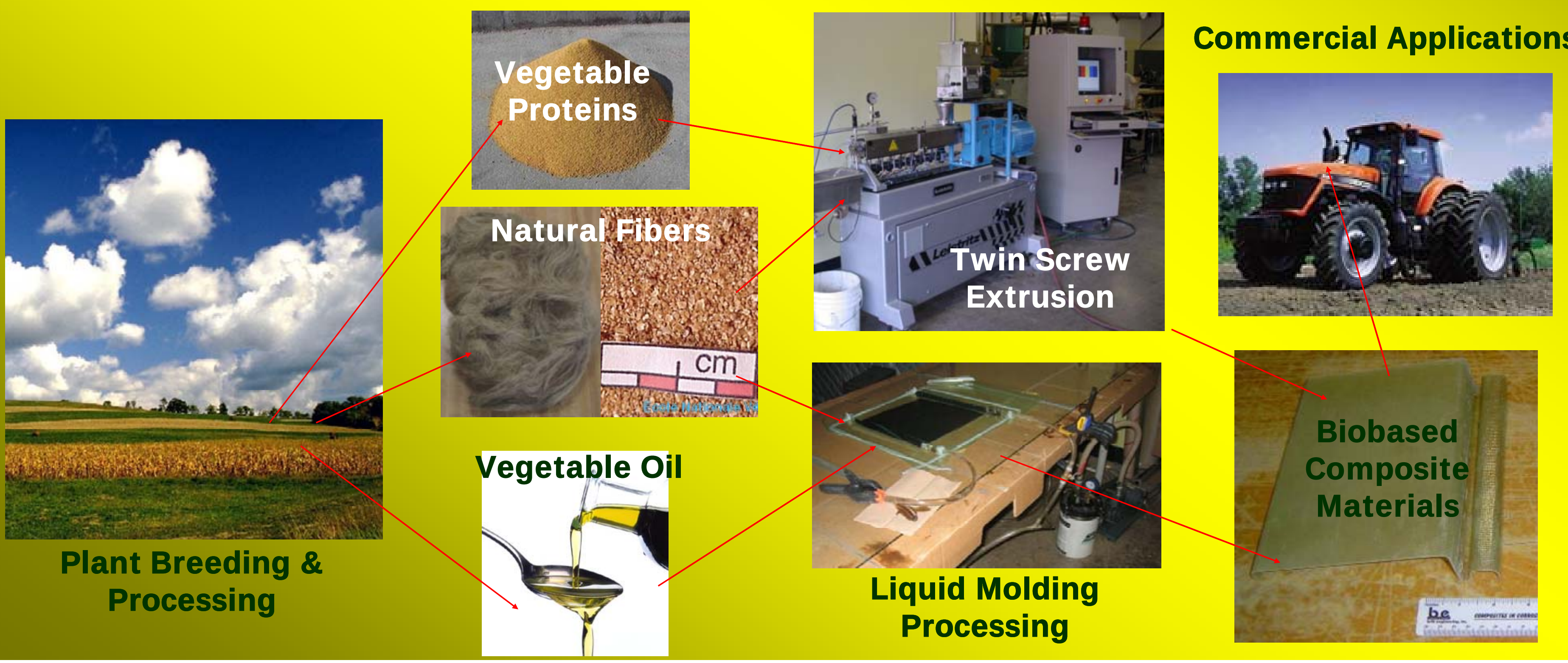
Farmers & Processors

Commodity Groups



Research Approach

A multidisciplinary team is being assembled focused on improving the growth, harvesting, treatments, and development of new agri-based precursors for processing structural biobased composites in local and regional composite manufacturing facilities for use in a wide range of applications



Flax Fiber Research To-Date

Composites Innovation Centre (CIC) Project

- Effect of Flax Fiber Fineness on Composite Properties
- Evaluation of the Pull-Out Strength of Several Flax Fiber Samples in As-Received Conditions
- Effect of Shive Content, Size, & Aspect Ratio

DoE / ND EPSCoR – SUNRISE Project

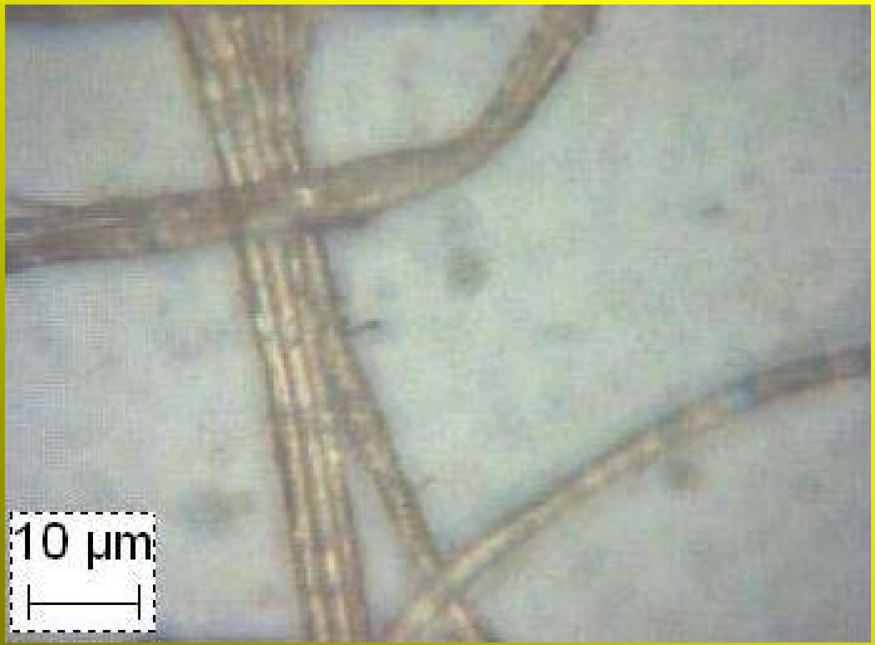
- Development of Flax Fiber Surface Treatments to Improve Flax Fiber Composite Properties

SpaceAge Synthetics, Inc. (SAS) Project

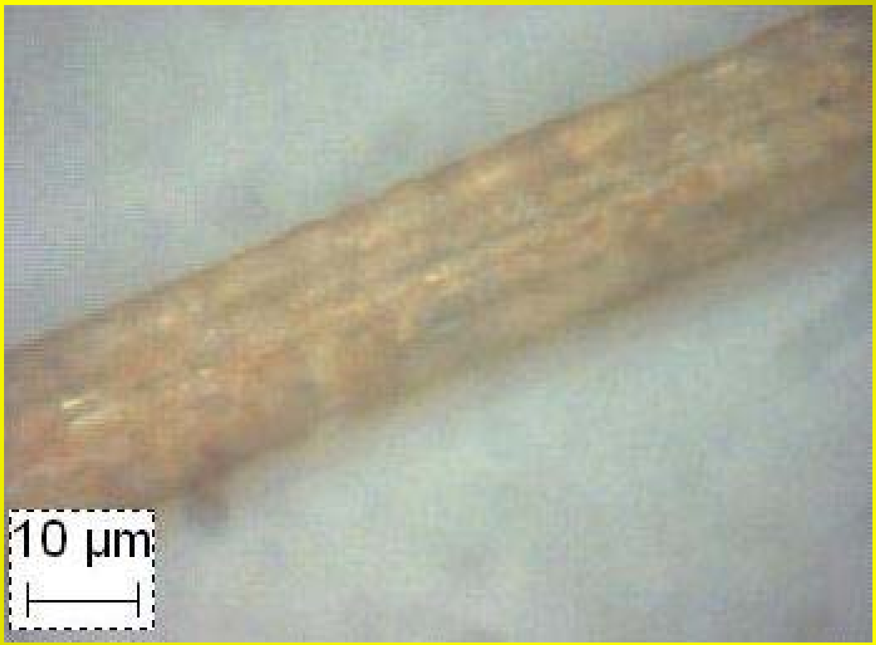
- Investigate the Feasibility of Replacing E-glass in SAS Thermo-Lite® Composite Board Product with Flax Fiber

Effect of Flax Fiber Fineness on Tensile Properties

Flax fibers with different diameters were sorted and processed into composites using a modified vacuum assisted resin transfer molding.



Individual Flax Fibers



Flax Fiber Bundle

Effect of Flax Fiber Fineness on Tensile Properties

Property	Small	Medium	Large
Average Fiber Width (µm)	19.4 ± 12.8	26.8 ± 15.0	32.8 ± 16.2
Elastic Modulus (GPa)	17.9 ± 3.1	20.9 ± 4.6	17.4 ± 3.3
Tensile Strength (MPa)	125 ± 14	135 ± 11	120 ± 6
Composite Density (g/cm^3)	1.19	1.20	1.18
Vf (%)	30.5	32.8	28.3

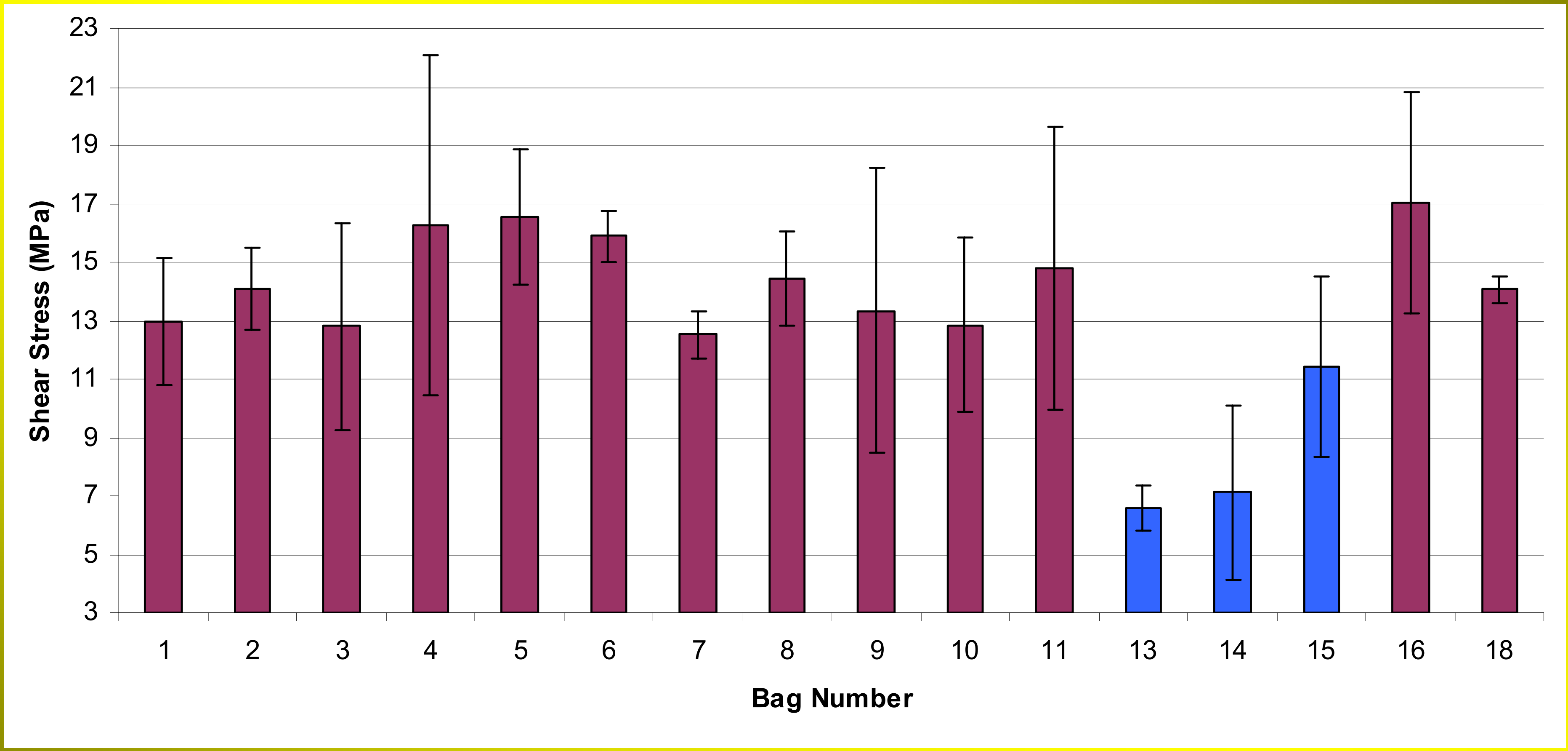
- There is statistically no difference in strength or modulus performance with varying flax fiber fineness within an appreciable range
- Good quality flax fiber composites can be produced with a modified vacuum assisted resin transfer molding (VARTM)

Flax Fiber Bundle Pull-Out Tests

$$\tau_i = \frac{F_{\max}}{CL_e + A}$$

τ_i : interfacial shear strength
F_{max} : max load at pullout
C: fiber bundle perimeter
L_e : fiber embedded length
A : area of the top surface of the fiber

Flax Fiber Bundle Pull-Out Tests



- Interfacial shear strength was less than 17 MPa for all samples
- Flax has a short critical pullout length
- Chemically retted fibers performed worse than hammer milled fibers

Effect of Shive on Flax Fiber Composite Properties

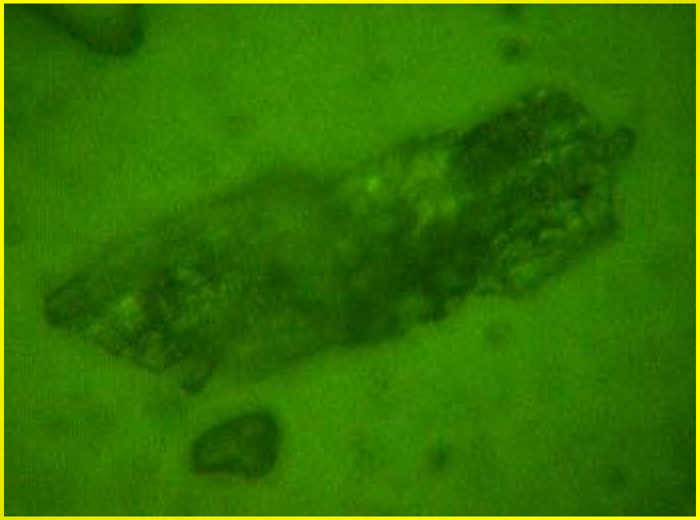
- 4 sizes of shive were separated using multiple sieves
- A 5th collection set of pod stems was also separated

Shive Characterization

	Average Size (µm)		
	length	width	thickness
small	65	20	-
medium-small	200	35	-
medium-large	6000	750	300
large	5500-18500	500-1800	300-500

iSolution DT digital imagining software to determine approximate dimensions

Medium-Small Shive - 2.5X



Small Shive - 16X

Test Matrix Design

Plaque	Shive Size					
	Small	Medium-Small	Medium-Large	Large	Pod Stems	
1	Low	Low	Low	High	High	Weight Concentration
2	High	Low	Low	Low	Low	
3	Low	High	Low	Low	High	
4	High	High	Low	High	Low	
5	Low	Low	High	High	Low	
6	High	Low	High	Low	High	
7	Low	High	High	Low	Low	
8	High	High	High	High	High	

1) All shive sizes are incorporated into each panel produced, replicating actual harvested flax
2) Shive weight concentrations do not have to remain consistent between shive sizes, so that volumetric shive yield will not be an issue and will replicate reality
3) Statistical determination of important and non-important shive size
4) Statistical determination of ideal weight concentration trend for each individual shive size

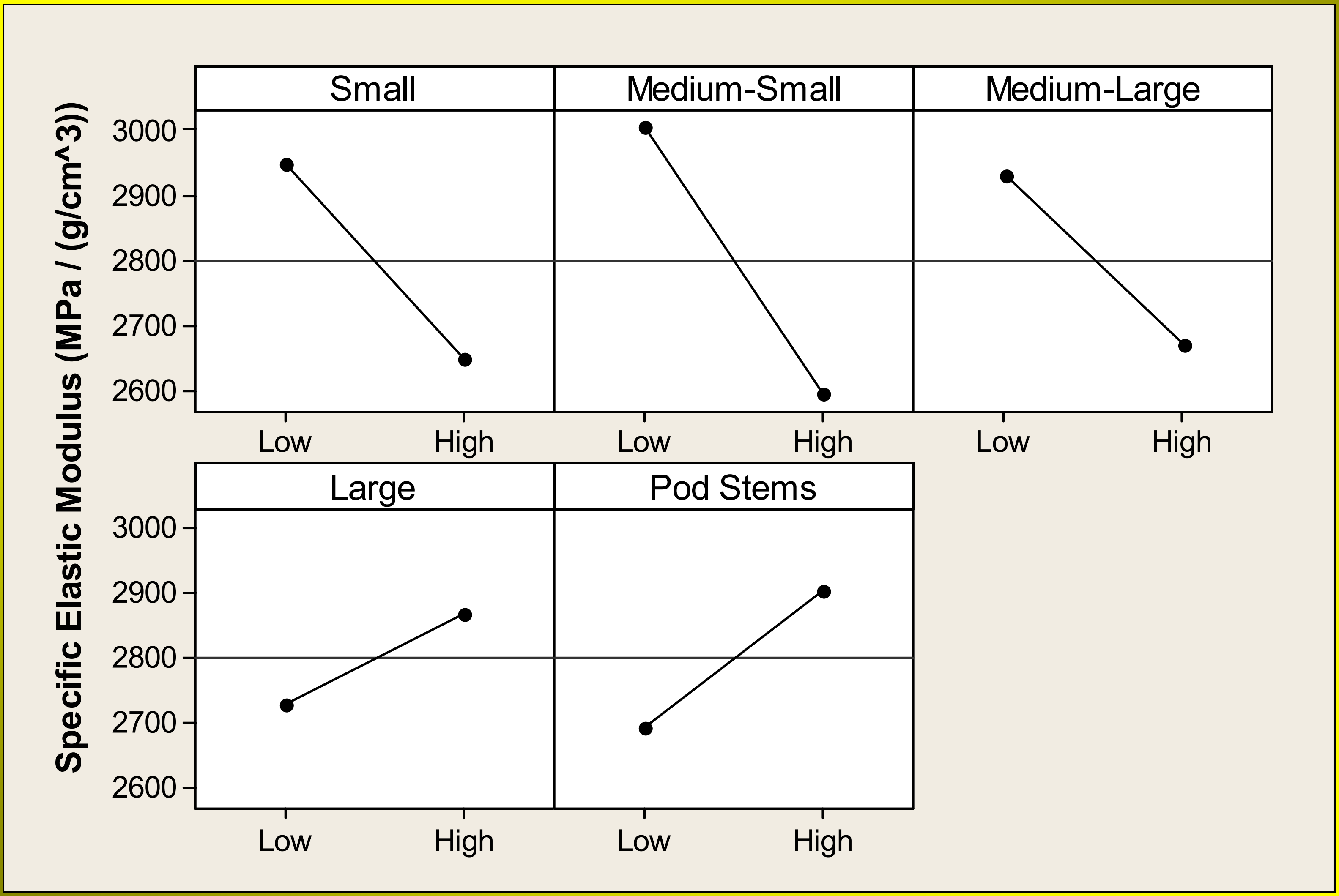
Test Weight Percentages

Concentration of shive found in a small sample

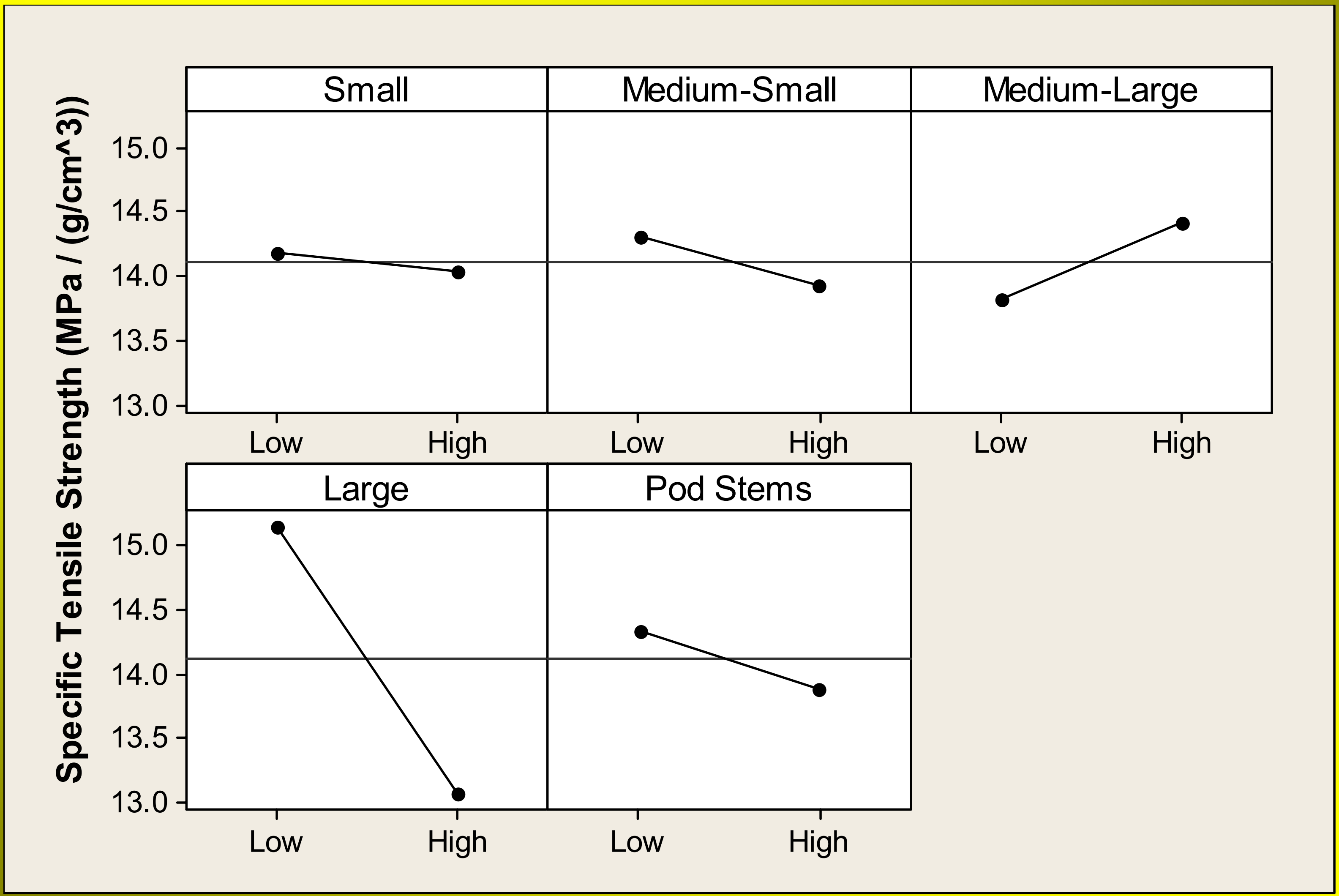
	Concentration (wt% of flax bundle)	Low Concentration (wt%)	High Concentration (wt%)
small	1.95	0.98	2.98
medium-small	3.31	1.66	4.97
medium-large	4.19	2.01	6.29
large	19.18	9.59	28.77
stems	5.92	2.96	8.88

- From this data, it was possible to determine a baseline for the shive concentrations that were chosen as high and low loadings
- These values represent a fairly accurate range of natural occurring shive content in high and low shive concentration flax bundles

Specific Elastic Modulus



Specific Tensile Strength

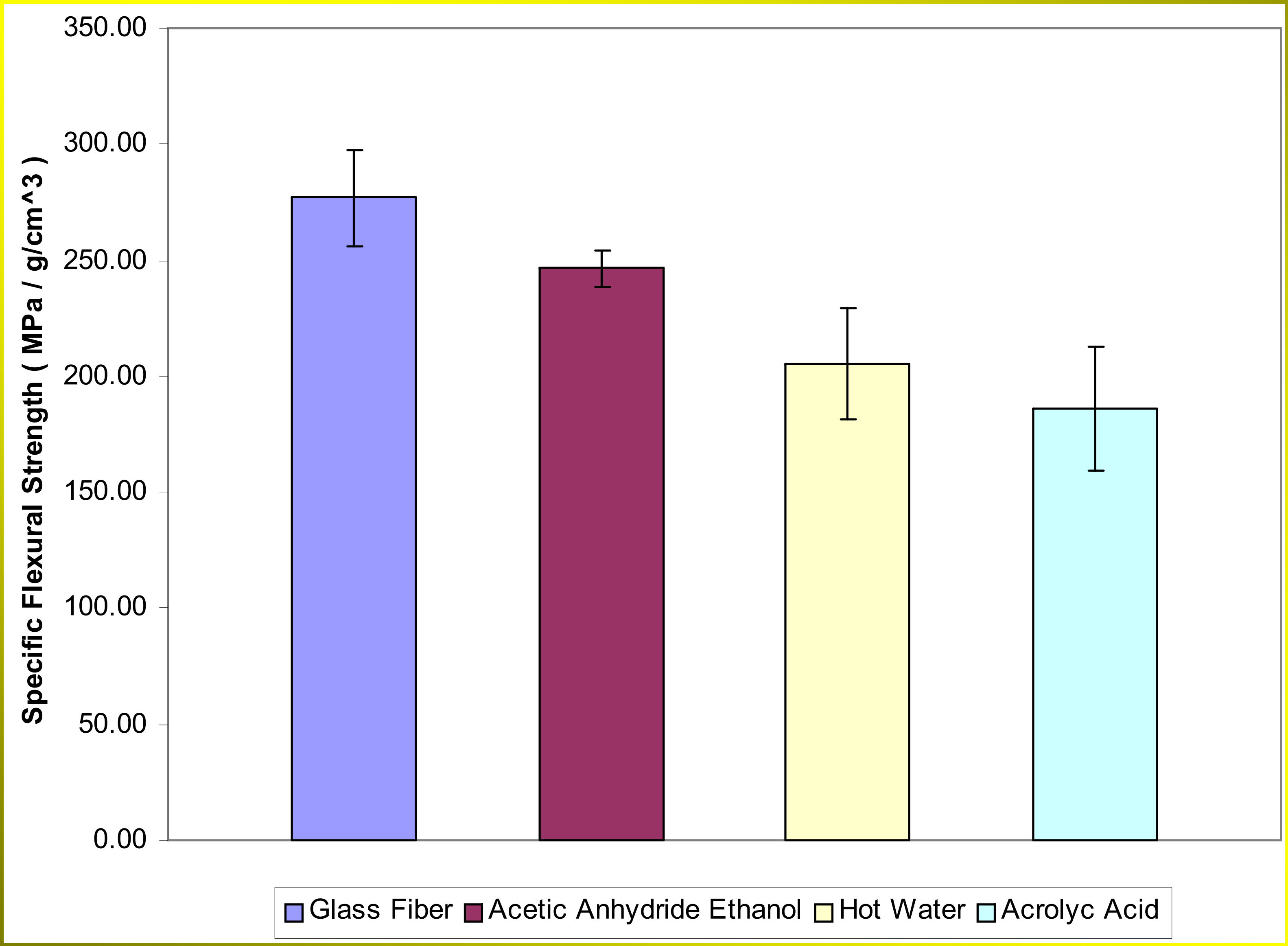


Flax Fiber Surface Treatment

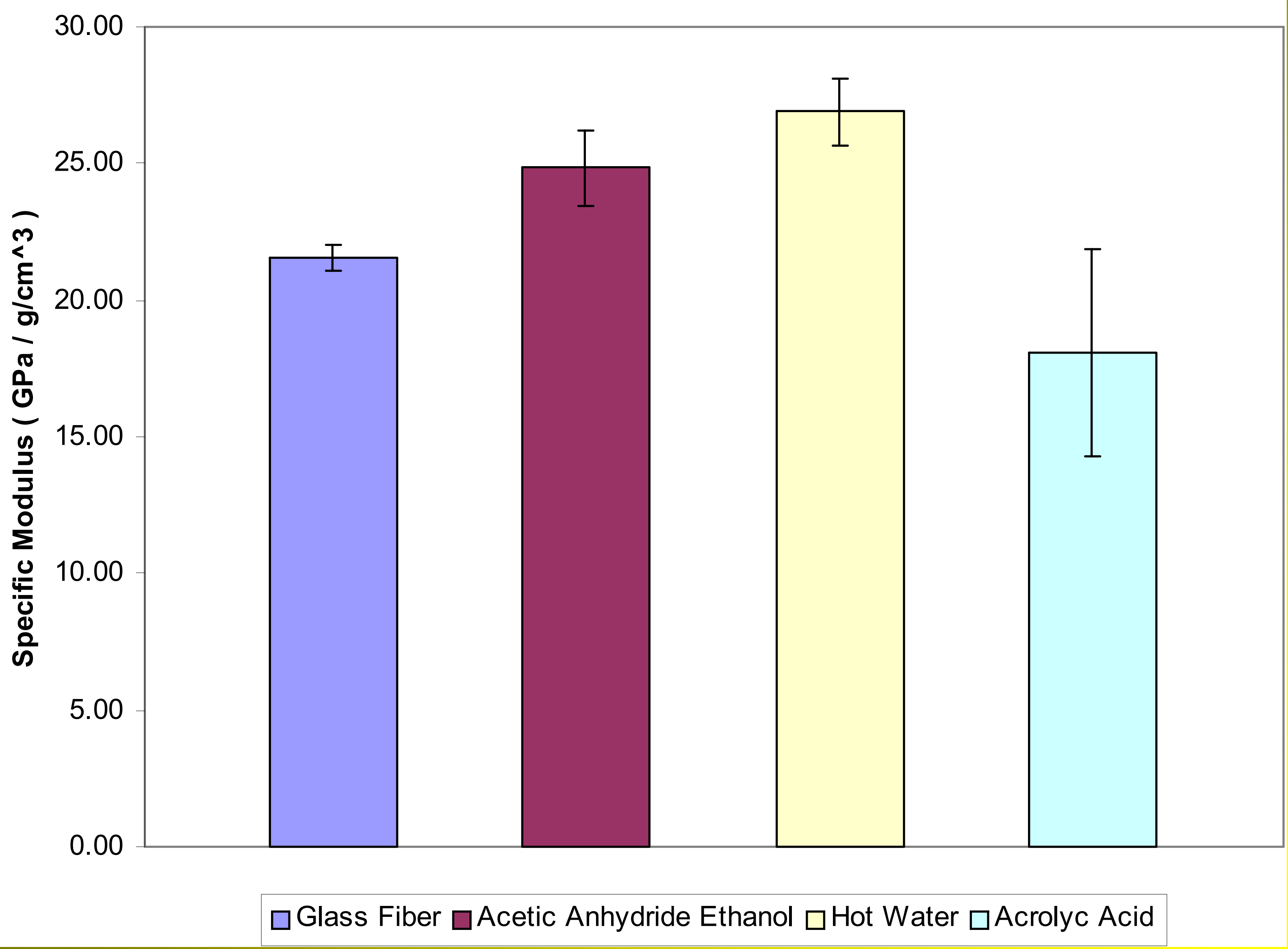
European flax fibers were chemically treated and VARTM processed using vinyl ester resin

- Flax fiber were hand-loomed for treatment
- Two sets of unidirectional flax fibers were pretreated with NaOH-Ethanol solution, then with either acetic anhydride or acrylic acid
- One sample was treated with hot distilled water
- Three flax fiber samples and one unidirectional glass fiber sample were made into composite panels for three point bend tests

Specific Flexural Strength Comparison



Specific Flexural Modulus Comparison



Effect of Fiber Surface Treatment

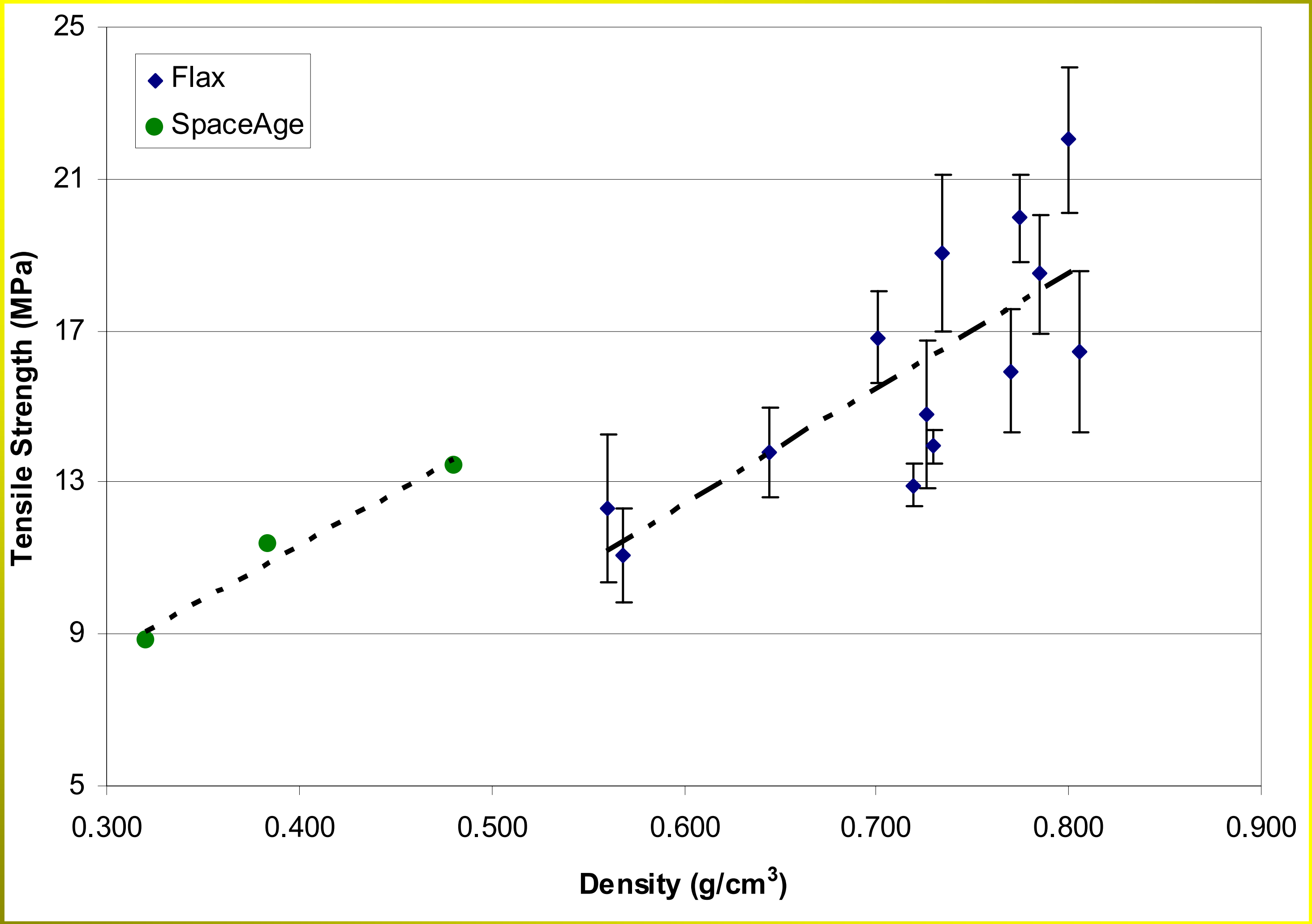
- Specific modulus of flax composites with hot water treatment were 25% higher than that of glass fiber composites
- Specific strength of glass fiber composites were only 11% higher than acetic anhydride treated flax fiber composites

ND Flax Fiber Mat / Polyurethane (PU) Foam

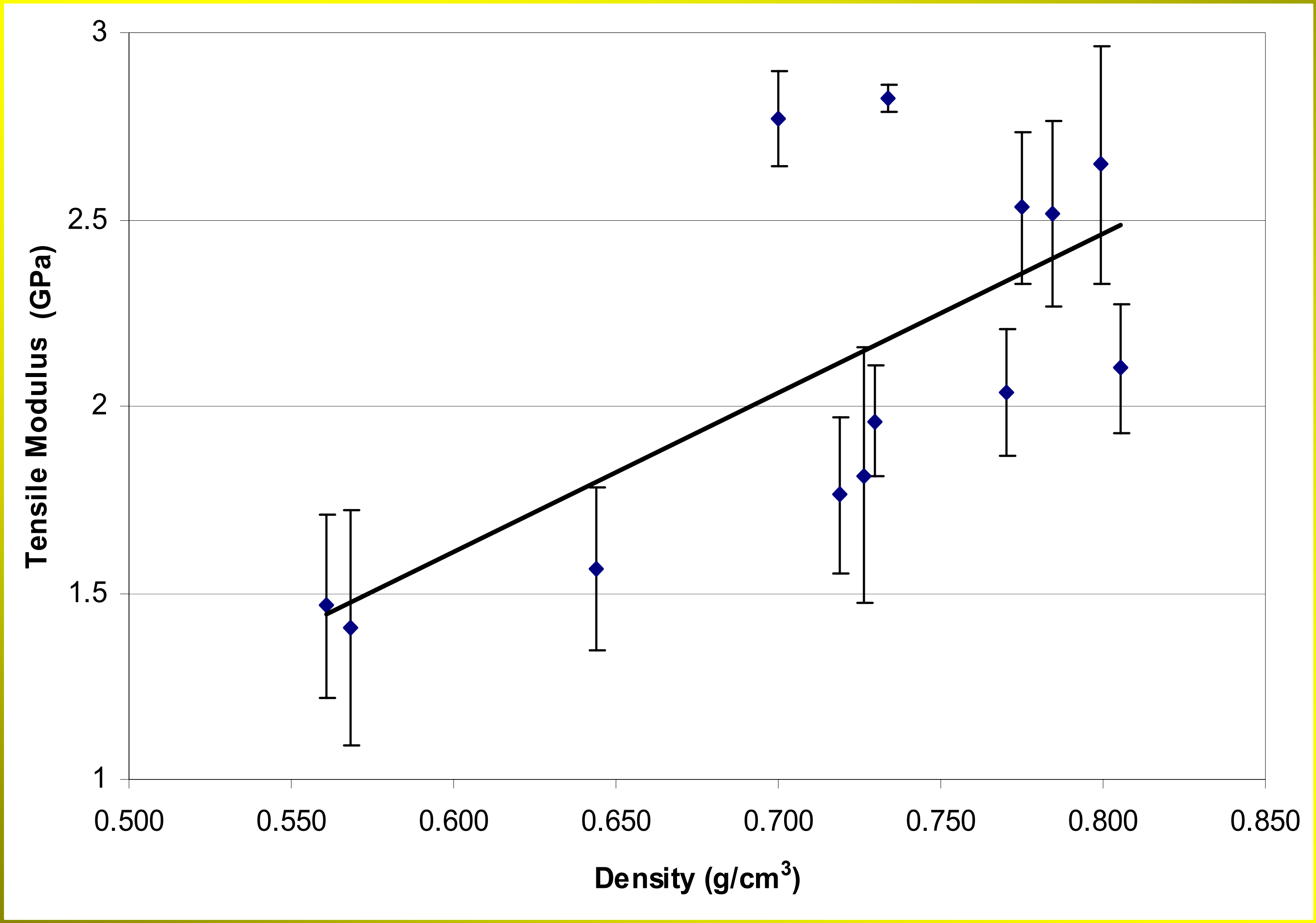
Exploratory study with SpaceAge Synthetics, Inc.

- North Dakota Flax Fiber Mat from Flax Tech, LLC
- Flax fiber weight percentage of roughly 60% with the remainder of the weight composed of shive
- Average fiber length is between 10 mm and 60 mm and average fiber diameter is between 2 μm and 5 μm
- Aspect ratio of over 2000

ND Flax Fiber Mat / Polyurethane (PU) Foam – Tensile Strength



ND Flax Fiber Mat / Polyurethane (PU) Foam – Tensile Modulus

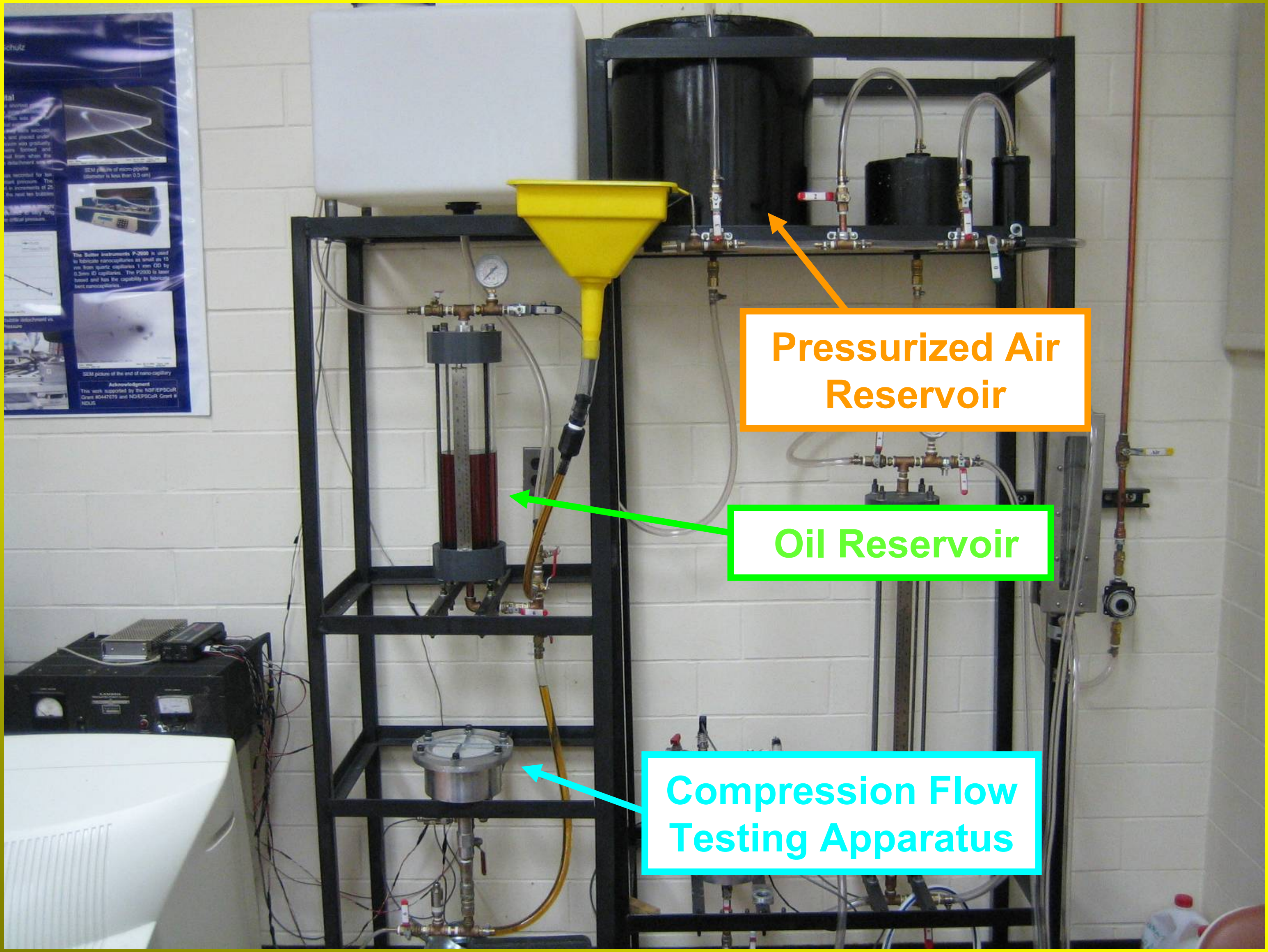


Flax Fiber Permeability

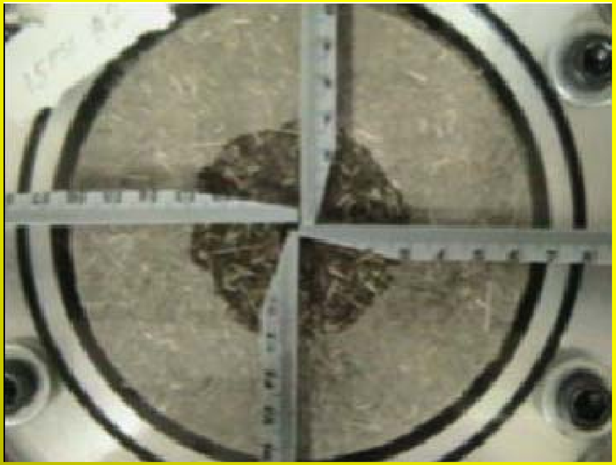
- North Dakota flax fiber mat from Flax Tech, LLC is being evaluated for permeability in-plane and transverse

- Determining the permeability will allow resin flow analysis through flax fiber mat using existing software programs (RTM-Worx, PAM-RTM, etc.)

Fiber Preform Permeability Test Apparatus

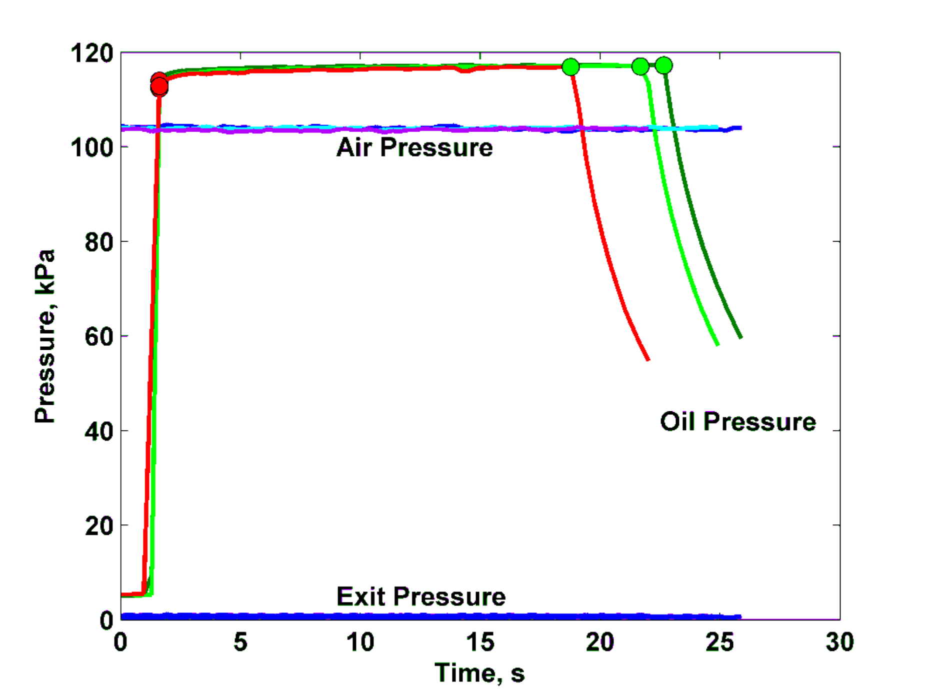


Wetting of Flax Fiber Mat

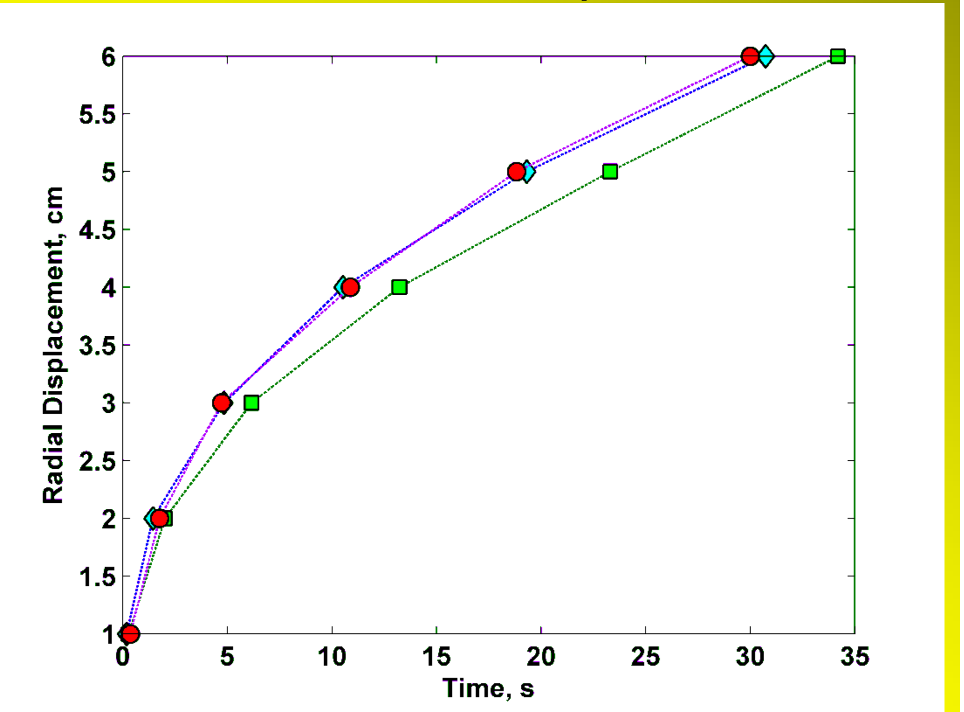


Preliminary Permeability Results

Pressure distribution in the system in three experiments



Radial displacement through fiber mat flux in three experiments



- Compression pressure on the flax fiber mat P = 250 kPa
- Fluid injection pressure P ≅ 115 kPa

Summary & Future Work

Summary:

- Flax fiber composites can compete with glass fiber composites in terms of specific modulus and strength
- Fiber treatment can play a big role in composite quality
- Processing methods dominate the mechanical properties of the composites

Future Work:

- Optimize fiber treatment for cost & ease of processing
- Study fiber pullout test on chemically treated samples
- Improve composite processing process

Acknowledgements

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