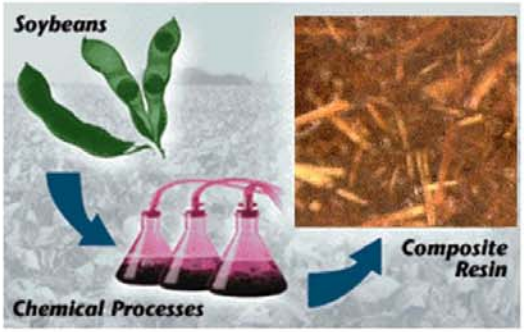
BIO-BASED COMPOSITE SANDWICH STRUCTURES FOR CONSTRUCTION APPLICATIONS

M. A. Dweib (PD), A. O'Donnell (MSChE), R. P. Wool, B. Hu (MSCEE), and H. W. Shenton

University of Delaware • Center for Composite Materials • Department of Chemical Engineering • Department of Civil and Environmental Engineering

BACKGROUND

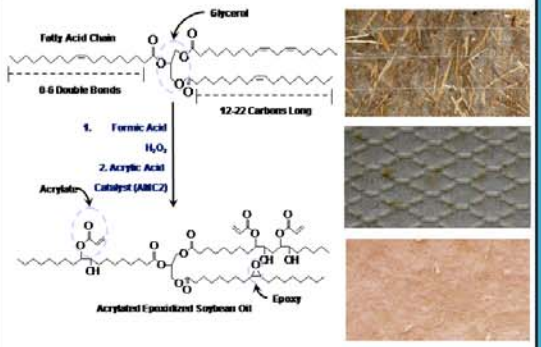


Natural bio-based composite panel showing the original material sources, soybean and flax fiber. This panel had a flexural modulus of 2 GPa and ultimate flexural strength of 44 MPa when resin was room temperature cured.

TARGET

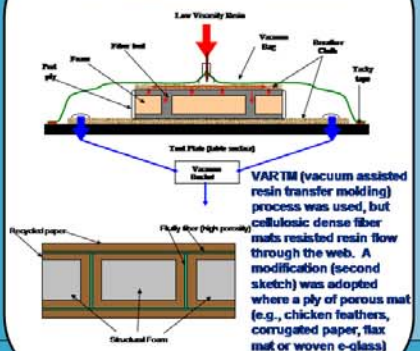
Success in manufacturing natural composites that have mechanical properties comparable to wooden structures prompted the idea of manufacturing and testing structural composites that could replace traditional construction materials. The new technology provides high strength and stiffness to weight, survivability in severe weather conditions, fatigue resistance, and design flexibility (3-dimensional formed, easy to install and replace).

MATERIALS



Resin (AESO) made of soy oil triglyceride and fiber mats made of flax, cellulose and chicken feathers

PROCESSING: VARTM



VARTM (vacuum assisted resin transfer molding) process was used, but cellulosic dense fiber mats resisted resin flow through the web. A modification (second sketch) was adopted where a ply of porous mat (e.g., chicken feathers, corrugated paper, flax mat or woven e-glass) was used for this purpose.

PROCESSING

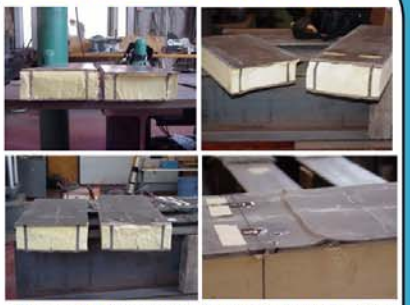
Two different preforms: (left) flax mat and recycled paper from cardboard boxes and (right) a unit beam made of recycled paper being infused with soy oil based resin.

BEAMS AFTER CURING & DEBAGGING

Beams dimensions: 3.5 ft long, 8 in wide and 3.5 in deep with a composite skin thickness of 0.25 in

Two beams: the top one is made of flax mats, and the second beam is made of recycled paper. One ply of chicken feathers mat was used as an integral distribution media in the second.

MECHANICAL FAILURE RESULTS



From top left and clockwise: flax mat beam, recycled paper with corrugated form beam, recycled paper with e-glass fiber beam, and recycled paper with chicken feathers beam after 4-point bending testing to failure.

RESULTS AND COMPARISON

Beam	Flexural Rigidity – EI (kN-m²)	Strength (kN)
Composite Beams		
Recycled paper /Chicken Feathers	12.4	24.2
Recycled paper /Corrugated Paper	14.8	25.8
Recycled paper /E-Glass Fiber	19.9	25.6
Wood Beams, "2-by-4", 3.81 cm by 8.89 cm. Wood Handbook		
Douglas Fir	18.0-30.3	15.4-29.7
Spruce	16.0-25.0	10.7-24.5
Cedar	10.0-26.4	9.5-28.8

The table shows three different beams made of recycled paper and one ply of another fiber as a distribution media compared with three different construction wood materials.

SCALING-UP: 7.5 ft LONG BEAM

All recycled paper beam, recycled paper in a corrugated form was used to provide resin channels and distribution media. The beam is 7.5 ft long, 4.5 in. deep and 9 in wide

3-POINT AND 4-POINT BENDING TEST

TIMOSHENKO BEAM THEORY

3-point bending mid-span deflection:

$$EI = \frac{PLh}{8\varepsilon} \qquad \Delta = \frac{PL^3}{48EI} + \frac{PL}{4GA}$$

4-point bending mid-span deflection:

$$EI = \frac{PLh}{12\varepsilon} \qquad \Delta = \frac{23PL^3}{1296EI} + \frac{PL}{6GA}$$

EI and *GA* are the flexural stiffness and shear stiffness respectively, *L* is span length, *P* is load

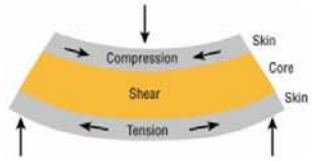
QUASI-DISTRIBUTED LOAD

$$\Delta = \frac{5qL^4}{384EI} + \frac{qL^2}{8GA}$$

STRUCTURAL BEAM BENDING

Flexural stiffness of any panel is proportional to the cube of its thickness.

The purpose of a core in a composite is therefore to increase the composite stiffness by effectively 'thickening' it with a low-density core material. This can provide a dramatic increase in stiffness for very little additional weight.



FOAM CORE INFLUENCE

	Solid Material, Solid thickness t	Solid t + Core thickness t	Solid t + Core thickness 3t
			
Stiffness	1	7	37
Flexural Strength	1	3.5	9.2
Weight	1	1.03	1.06

It should also be noted that foam could have disadvantages such as flammability, and a cause for buckling in the top composite sheet. Foam is a good heat insulation material but not necessarily sound insulator.

CONCLUSIONS

- Structural composites were successfully manufactured from soy oil -based resin and plant fiber or recycled cellulosic fibers.
- Test results show that beams made of natural composites are comparable to traditional wooden structures.
- Hurricane resistant roofing systems are possible using this technology.
- These bio-based composite materials could have other applications besides housing, including civil infrastructure and furniture.

ACKNOWLEDGEMENTS

This work is supported by the National Science Foundation and the Department of Housing and Urban Development.