DEVELOPMENT OF NATURAL FIBER SANDWICH COMPOSITES WITH IMPROVED STIFFNESS

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Abstract

The use of natural fiber composites is increasing in the automotive industry as well as in other industries. One of the key design issues in many of the applications for which natural fiber composites are considered is the stiffness. In this study, we consider combining a natural fiber/polypropylene composite with either directional polypropylene or carbon fibers with the objective of improving the stiffness. Compression molded plates were prepared with various combinations of these materials. Tensile and flexural moduli of the combined materials were determined and are reported in this paper.

Background

Natural fiber composites have great potential in many automotive applications [1, 2] for the following reasons [3]:

1. Natural fibers are environment-friendly, meaning that they are agricultural products, they are biodegradable, and compared to glass and carbon fibers, the energy consumption to produce them is very small.
2. The mass density of natural fibers is in the range of 1.2 to 1.5 g/cm^3, which is much lower than both glass and carbon fibers.
3. The modulus-to-density ratio of many natural fibers is higher than that of glass fibers.
4. Natural fiber composites can provide higher acoustic damping than glass or carbon fiber composites, and therefore, they are more suitable for noise attenuation.
5. The price of natural fibers is less than that of glass fibers and much less than that of carbon fibers.

Since natural fibers have many advantages over the conventional fibers, a large number of research has been done to incorporate them in both thermoplastic and thermoset polymers. Several applications of natural fiber composites have also been developed, but most of them are for non-structural applications. One reason for this is that natural fiber composites have relatively low modulus compared to glass and carbon fiber composites. In this paper, we report an exploratory study to develop natural fiber composite sandwich constructions with the goal of achieving higher modulus, and therefore, higher stiffness.

Experimental

Materials

The materials used in this study were as follows:

1. Natural fiber mats containing 50% jute fibers and 50% polypropylene fibers, designated here as NL, NF and NH for low density, low density with an additional coating of polypropylene, and high density, respectively. Both NL and NF mats were 10 mm thick and the NH mat was 2.6 mm thick. All three natural fiber mats were supplied by Flexform, Inc.
2. Geotextile woven fabrics containing polypropylene filament (Propex 2033, designated here as P and Propex 2044, designated here as Q). The geotextile fabrics were 0.93 mm thick and were supplied by Propex Fabrics, Inc.
3. Unidirectional carbon fiber reinforced polypropylene prepreg, designated here as C. The prepreg sheet was 0.85 mm thick and was purchased from Baycomp.

Compression Molding

Compression molding was carried out using a hydraulic press with heated platens. The platens were preheated to 200°C. The material was placed between two flat plates separated by steel spacers. The assembled stack was then placed between the preheated platens and the press was quickly closed. The press was held closed for 5 minutes at a pressure of 2.75 MPa. This was followed by cooling at approximately 22°C/min while holding the pressure at 2.75 MPa.

Mechanical Tests

Tensile and 3-point flexure tests were conducted on an Instron testing machine at a cross head speed of 10 mm/min. Dog-bone shaped tensile specimens were prepared using a high speed router. The total length of the tensile specimens was 110 mm. The gage length and width were 50 mm and 12.5 mm, respectively. Straight-sided specimens, 110 mm in length and 25 mm in width, were used for flexural tests and the span length was 60 mm.

Results

Tensile Properties

Table 1 lists the tensile properties of various materials considered in this study. Figures 1 and 2 show the tensile moduli and tensile strengths of natural fiber composites, geotextile composites and sandwich constructions of natural fiber composites and geotextile composites. As can be observed from these figures, both tensile modulus and tensile strength of the sandwich constructions with geotextile composites in the skins were significantly higher than the tensile modulus and tensile strength of natural fiber composites. The elongation at failure was also improved, but only slightly. As expected, the sandwich composite CNHC, containing carbon fiber/polypropylene skins, had the highest tensile modulus.

Table 1. Tensile Properties

Specimen	Tensile Modulus (GPa)	Tensile Strength (MPa)	Elongation (mm) (Gage Length = 50 mm)
NL	0.99	12.18	1.25
NH	1.96	32.87	1.61
NF	0.94	13.5	1.72
P	1.17	31.65	106.14
Q	0.98	35.53	8.74
PNLP	2.11	41.25	1.90
QNLQ	2.44	37.78	1.96
PNHP	2.93	49.26	1.81
QNHQ	2.67	39.00	1.30
PNFP	1.58	29.45	2.58
QNFQ	1.84	28.38	2.22
CNHC	10.35	------	------

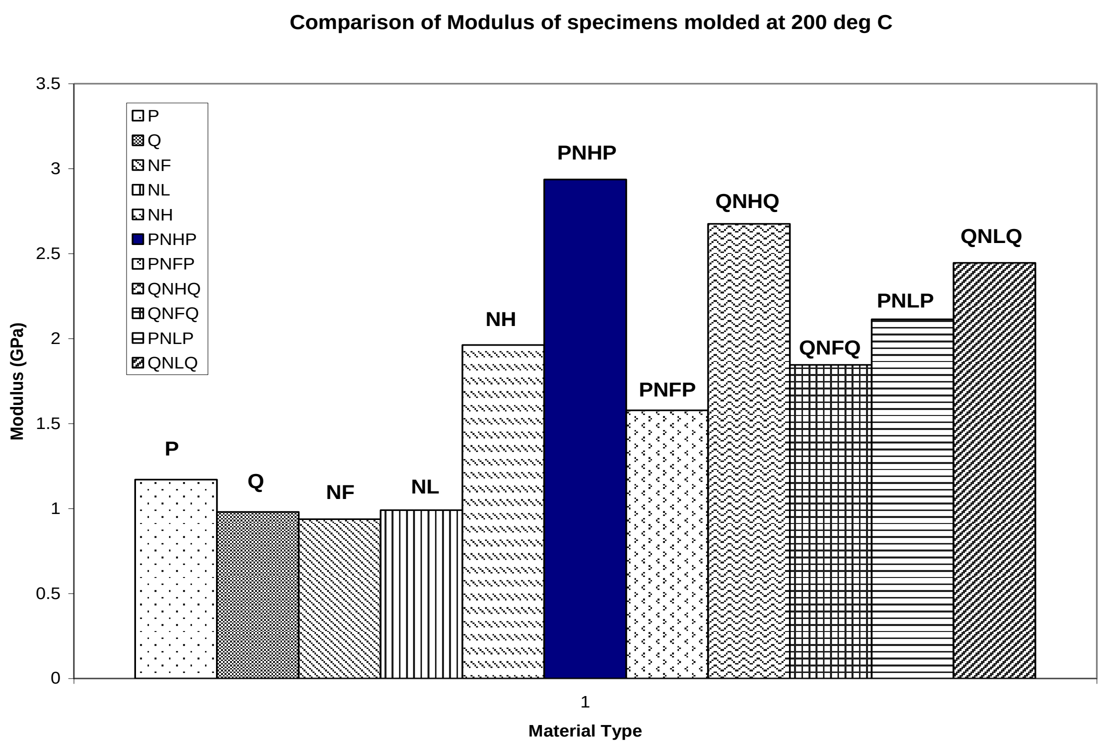

Figure 1: Comparison of tensile modulus.

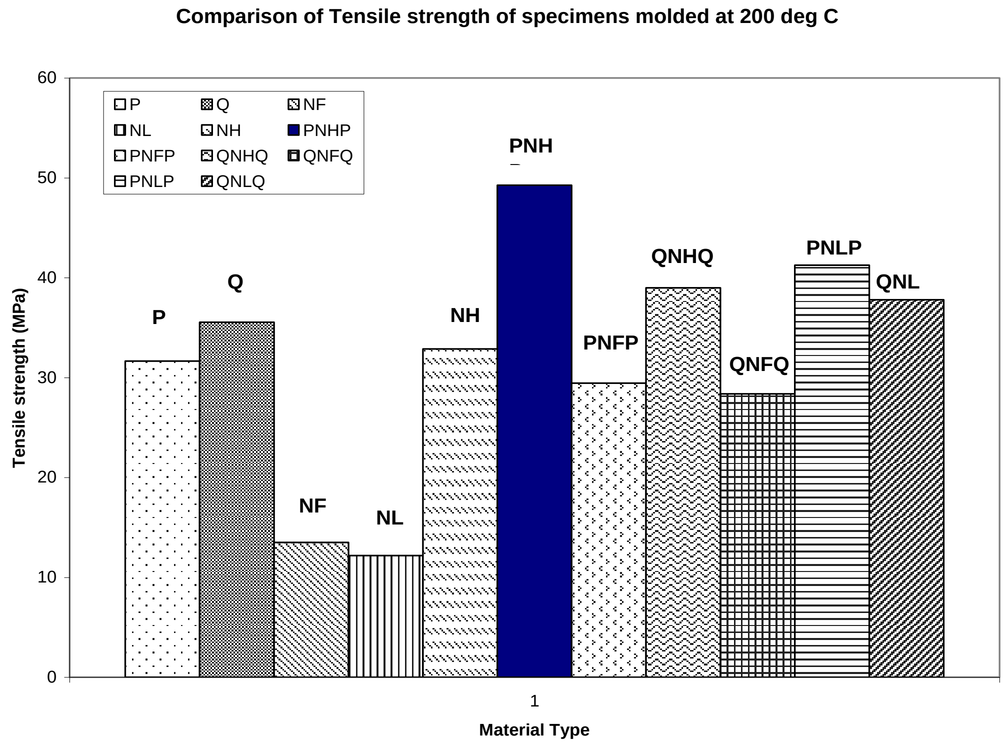

Figure 2: Comparison of tensile strengths.

Flexural Modulus

Table 2. Flexural modulus

Specimen Designation	Flexural Modulus (GPa)
NH	2.55
P	1.24
Q	2.34
C	64.2
PNHP	4.24
QNHQ	3.41
CNHC	10.72

Table 2 shows the flexural modulus of the materials tested in 3-point flexural tests. Both geotextile specimens showed a lower flexural modulus compared to the natural fiber composite (NH, in this case). However, when either of the two geotextile composites was combined with the natural fiber composite in a sandwich construction, there was a significant increase in flexural modulus. The highest flexural modulus was obtained with the CNHC specimens, which was mainly due to the contribution of the carbon fibers.

Conclusions

This exploratory study has shown that both tensile modulus and flexural modulus of natural fiber composites can be significantly improved by combining them with either geo-textile composites or carbon fiber composites in a sandwich construction. With higher modulus, it is expected that stiffness of a component can also be improved. Additionally, both tensile strength and tensile elongation of the natural fiber/geo-textile sandwich were greater than those of the natural fiber composites. More work is needed to optimize the material and process conditions that may produce even better results.

References

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Acknowledgment

The author would like to thank Flexform and Propex Fabrics for supplying the materials, and the Center for Engineering Education and Practice (CEEP) of the University of Michigan-Dearborn for providing funds to perform the work reported here. Finally, the author would like to thank two graduate students, Chinmaya Dandekar and Garun Agarwal, for conducting the tests.