Natural Fibers: Nature Providing Technology for Composites

Dr. Scott W. Beckwith, SAMPE International Technical Director
and President, BTG Composites Inc., Taylorsville, UT

Natural fibers are rapidly emerging in composites applications where glass fibers (predominantly E-glass) have been traditionally used. This is particularly true within the automotive and construction industries. These natural fibers provide several benefits: low cost, “green” availability, lower densities, recyclable, biodegradable, moderate mechanical properties, abundant. Their uses have found entry into booth the thermoset and thermoplastic composites market places. Industries are rapidly learning how to effectively process these natural resources and use them in numerous composites applications. Typically they are used with well-recognized thermoset resin families: polyesters, vinyl esters and epoxies. Thermoplastics resin matrices also are those commonly seen within the commercial markets: polypropylene, low density polyethylene (LDPE), high density polyethylene (HDPE), polystyrene, Nylon 6 and Nylon 6,6 systems. Soy-based resin systems also are coming into vogue in some applications as we learn more about its chemistry and processing. Natural fiber systems tend to fall into several categories as noted in Table 1, with the most commonly used ones noted in **bold** type.

Table 1. Natural fiber types and general families.

Plant and Cellulose Fiber Types	
Bast Fibers	***Flax***, ***Hemp***, ***Kenaf***, ***Jute***, Mesta, ***Ramie***, Urena, Roselle
Leaf Fibers	Pineapple, Banana, ***Sisal***, Srew Pine, ***Abaca***, Curaua, Agaves, Cabuja, Henequen, Date Palm, African Palm
Seed Fibers	***Cotton***, Kapok
Fruit Fibers	Coconut, ***Coir***
Wood Fibers	Hardwoods, Softwoods – many numerous types (~10,000 varieties)
Grasses and Reeds	Wheat, Oat, Barley, Rice, Bamboo, Bagasse, Reed, Corn, Rape, Rye, Esparto, Elephant Grass, Cannary Grass

There is insufficient space and time to discuss all of the processing pros and cons of natural fibers within this short technical note. However, it is worthwhile looking at a least a few of the more common natural fibers and make some comparisons with traditional commercial fibers (such as E-glass) and aerospace fibers (S-glass and Aramid). However, Table 2 presents a number of the critical mechanical and physical properties of common natural fibers compared to E-glass, S-glass, commercial Aramid and standard modulus PAN-based carbon fiber materials. While the strength properties, and often the stiffness properties, are not on comparable levels to S-glass, Aramid and carbon fibers, the natural fibers do provide a wide range of workable strength and stiffness properties when compared with E-glass fiber.

Natural fibers are very typically about 30-50 percent lower in density when compared to E-glass fibers, and roughly the same as the Aramid commercial grade systems. This advantage has made natural fibers quite attractive to use within the automotive industry across a wide range of applications with both thermoset and thermoplastic resin matrices. In fact the stiffness of some of these natural fibers can be higher than or equivalent to that of E-glass (see, for example, Hemp and Ramie). Flax, Sisal and Kenaf fibers also tend toward a higher stiffness. Hence, for stiffness driven designs, these fibers are reasonable options. Their abundance, and a growing understanding of their processibility, makes them attractive to engineers.

Table 2. A few typical mechanical and physical properties of natural fibers compared to their commercial and aerospace counterparts (Ref. 1, 2, 3 in part).

Fiber	***Density (gm/cm²)***	***Tensile Strength (ksi)***	***Tensile Modulus (msi)***	***Range of Elongation (%)***
Flax	1.50	75 – 215	4	2.7 – 3.2
Hemp	1.47	100	10	2.0 – 4.0
Kenaf	1.45	135	7.7	1.6
Jute	1.30	55 – 110	3.8	1.5 – 1.8
Ramie	1.50	60 – 135	8.9 – 18.6	3.6 – 3.8
Sisal	1.50	75 – 90	1.4 – 3.2	2.0 – 2.5
Coir	1.20	85	0.6 – 0.9	~30
Cotton	1.55	60	0.8 – 1.8	3 – 10
E-Glass	2.56	290 – 350	10	3.0
S-Glass	2.57	665	12.5	2.8
Aramid (Commercial)	1.44	435 – 455	9 – 10	3.3 – 3.7
Carbon (PAN Std. Mod.)	1.67	580	33 – 35	1.4 – 1.8

References

1. Natural Fibers, Biopolymers and Biocomposites, Edited by A.K. Mohanty, M. Misra and D.T. Drzal, CRC Press/ Taylor & Francis, 2005.

2. Natural Fibers, Plastics and Composites, Edited by F.T Wallenberger and N. Weston, Kluwer Publications, 2004.

3. Natural Fiber-Reinforced Polymer Composites in Automotive Applications, *Journal of Materials*, J. Holberry and D. Houston, 58, 11, Nov 2006.