# Ecocomposites

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Human history is often marked by the materials and technology that reflect human capability and understanding. Many time scales begin with the Stone Age, which led to the Bronze, Iron, Steel, and Plastic ages as innovations and improvements in refining, smelting, manufacturing and science made these materials available at reasonable prices. In the 1980's the Composite Age began, represented at its extremes by the Stealth bomber and the sun powered Solar Challenger.

A composite material combines two or more materials that work together to improve overall performance of the material. Innovative developments and market forces now herald the beginning of the **Ecocomposite Age** using biological fibers and natural or synthetic matrix materials. Ecocomposites can be very strong and selections can be made for ultimate strength, elastic modulus, fracture resistance or impact resistance. Ecocomposites are also more environmentally friendly and less hazardous to human health. The ideal ecocomposite material will be made of all natural materials that are non-toxic, fully biodegradable and renewable. The term ecocomposite is also used for materials that are made of natural materials and recycled materials, or made entirely of recycled materials.

Over the millennia evolution has helped select the most efficient and elegant uses of materials. Anyone who has attempted to open a macadamia (*Macadamia ternifolia*) nut can attest how tough natural materials can be. These nuts resist twice the force needed to fracture annealed aluminum yet have comparable hardness (Niklas, 1992). Plant cell walls and plant structures are natural composite materials with regular arrangement of reinforcing materials. One of the great challenges of developing new ecocomposites is learning to use plant structures effectively, rather than breaking materials down to small fibers or particles. Slitting straw rather than chopping it is a good example.

Composite materials combine more than one material or substance that remain identifiable but are stronger than either material alone, most commonly there is a matrix material with high strength fibers. Glass fibers have been the most common reinforcing materials for composites, but pose health and environmental problems and are energy intensive. Carbon fibers are even more expensive and itchy. Biological fibers and structures and natural or synthetic matrix materials can be used to make ecocomposites that are equally strong, but environmentally friendly.

Plant fibers are low cost, light, and surprisingly strong on a weight basis -- often 5-10 times steel.. They also have more reactive surfaces and bond better, but they can degrade with water and heat. Starch and paper construction (Appropriate Paper Technology) has been encouraged in Zimbabwe for a wide range of uses, and shows what can be done with a little inspiration and research and testing (Packer, 1995). APT products are very strong, the process can creates woodlike grain and strength.

Some very promising areas for research where we haven't yet managed to figure out how nature works include chitin, the polysaccharide made by many crustaceans. This is hard, insoluble, yet flexible. Like chicken waste plastic there are many millions of pounds of chitin disposed of every year. We are also still working to unravel the mysteries of spider web materials, which come in many formulas with often remarkable properties. Spider dragline silk is five times stronger than steel on a weight basis, five times tougher than Kevlar and elastic (Benyus, 1997). If you hang weight on equivalent diameter spider silk and steel threads they will break at about the same time, but the spider silk will stretch to 40 percent longer than its original length and bounce back if the weight is removed.

In the area of new products from renewable resources we find sugar based epoxies that outperform petroleum based products for binding concrete, wood, metals, and plastics. Depending on the formula used these epoxies set clear, glassy or rubbery and flexible. The production process leaves only vinegar and salt. These are now being evaluated in composite board production by Acadia Board and CMGI companies. These might provide a use for genetically contaminated agricultural products such as Star-link tainted corn. Research in India has explored bamboo and epoxy and bamboo and polyester resin composites. The authors note this material could be used in crash helmets, windmill fins and low cost housing. Unavailable in 1993, the sugar epoxies should provide comparable performance with bamboo if the materials were retested today. Gregory Glenn has developed starch based microcellular foams and lightweight concrete (Glenn and Irving, 1997).

**Summary**

The age of ecocomposites has begun. Agricultural and industrial ecology should make it possible to grow plastic resins and reinforcing materials economically and safely. These materials can be used to make lighter, stronger and more durable products that save resources and energy. Long life and eventual recycling can be engineered into these products. The potential economic benefits include production of biofibers in farming areas beset with economic and environmental problems. The introduction of straw based building materials can reduce air pollution problems, absorb some of the plastic waste stream, and improve the energy efficiency of the homes and commercial buildings. The use of current wastes such as feathers and nut shells is also important. The can reduce the increasing impact of agricultural operations on the environment.

This is an exciting new frontier that requires the talents, skills and enthusiasm of engineers, hobbyists, builders, farmers, chemists, botanists, ecologists, mycologists, agronomists, anthropologists, historians and economists. Integrated, holistic, systems oriented development will be needed to recognize the full potential of these materials in the development of Industrial Ecology based on ecocomposite materials. We can hasten this transition and improve the performance of ecocomposite materials by learning from past uses, successes and failures.

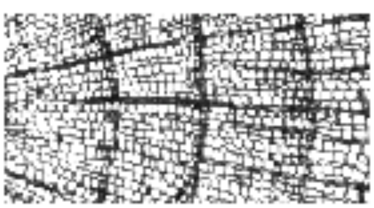
**References**

Benyus, J.M. 1997. Biomimicry. William Morrow, NY 308 p.

Glenn, G.M. and D.W. Irving. 1997. Starch based microcellular foams. Cereal Chemistry 72:155-161.

Niklas, K.J. 1992. Plant Biomechanics. University of Chicago Press, Chicago, IL 607 p.

Packer, B. 1995. Appropriate Paper-based Technology APT. IRED, Harare, Zimbabwe 176 p. (available from styluspub@aol.com)



**Further Reading**

Although **ecocomposites** are just developing as a field for research and development there are several books that will help you understand and participate in this materials revolution. The most accessible information on small scale composite manufacturing and design can be found in magazines such as Professional Boatbuilding, Primitive Archer, kit and experimental aircraft magazines, and advanced auto racing magazines such as Race Car Engineering. The beauty of working with ecocomposites is that everyone can play. They are non-toxic and user friendly. Paper maché is a good starting point. Keep notes of your experiments and send them to me.

**Suggested reading**

Benyus, J.M. 1997. **Biomimicry**. William Morrow, NY. 308 p. ISBN 0-688-16099-9

A delightful look at the applications of nature in materials and structures. A very good introduction to the field.

Packer, B. 1995. **Appropriate Paper-based Technology APT**. IRED, Harare, Zimbabwe 176 p. ISBN 1-85339-268-5

This is a hands on manual of making things with little more than waste paper and starch. From bookcases, to desks to facilities for handicapped children. Comprehensive instructions and suggestions for working with APT. *****

Vogel, S. 1998. **Cats' Paws and Catapults**. W.W. Norton, NY 382 p. ISBN 0-393-04641-9

A delightful and well illustrated introduction to the workings of nature and biomechanics. Clear explanations, broad vision and specific examples make this a must read. *****

Niklas, K.J. 1992. **Plant Biomechanics: An Engineering Approach to Plant Form and Function.** University of Chicago Press, Chicago, IL 607 p. 0-226-158641-6

A fairly technical book with clear descriptions of engineering principles, limitations on organisms and test data. Niklas shows how basic physical laws apply to plant form and function. Chapter 2: The Mechanical Behavior of Materials is required reading for non-engineers and may inspire mechanical and civil engineers to explore natural materials. ****

McBeath, S. 2000. **Competition Car Composites**. Haynes Publishing, Newbury Park, CA 208 p. ISBN 1-85960-624-5

Much of the most interesting work on composite materials is being done in race car engineering. This book provides a clear description of composite materials and design and describes simple testing and layout procedures useful for ecocomposite experimenters. ***

Perkowitz, S. 2000. **Universal Foam: From Cappuccino to the Cosmos**. Walker and Company, NY 194 p. ISBN 0-8027-1357-2

Wood can be thought of as a fiber reinforced foam and many of the promising materials for ecocomposite use are foams. . ***

Volhard, F. 1983 **Leichtlembau--alter baustaff-neue technik**. Verlag C.F. Mueller, Karlsruhe, GDR 158 p. **

An early look at straw clay construction. The U.S. lags far behind despite pioneers like Pliny Fisk III, Bill and Athena Steen and Robert Laporte (see Natural Home Aug. 2001.

For more information:

**www.ecocomposite.org**