Ecocomposites

by David Bainbridge - California, USA

An adobe without straw is like a marriage without love. – Traditional saying

Human history is marked by the materials and technology that reflect human capability and understanding. The Stone, Bronze, Iron, Steel, and Plastic Ages have emerged and receded as improvements in understanding, refining, smelting, and manufacturing occurred. In the 1980s 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, typically with fibers that remain identifiable combined with a matrix that together are stronger than either material alone. Glass fibers have been the most common reinforcing materials for composites, with the extensive use of fiberglass in cars, boats and roofing panels. Carbon fibers are stronger, but even harder to work with, more expensive and itchy. Basalt fibers are a strong heat-resistant, natural material, but very challenging to work with. Biological fibers and structures and natural or synthetic matrix materials can be used to make ecocomposites that are equally strong, but environmentally friendly.

The natural building movement represents one thread of an emerging Ecocomposite Age, using biological fibers and natural or synthetic matrix materials. In some ways, this is simply a rediscovery of past wisdom. Over the long course of human history, humans have relied on ecocomposite materials to meet most of their needs. Industrial materials are a recent phenomenon, with widespread use of plastics for less than 50 years and steel for only a little more than 100. Long before the Bronze Age, skilled craftsmen and women made boats, weapons, tools and homes with ecocomposites. We can learn from their experiences and discoveries. We may not need to use sinew backed bows, using fish bladder glue and sinew fibers to dramatically improve performance (casting arrows up to 1,000 meters); the thin walled kotni (granaries) of India built with a mix of clay, cow dung and husks; or the linen/resin armor used by the Roman legions; but we may consider using straw/clay infilled timberframe homes developed in Germany; fiber reinforced plasters, adobe and cob; the thick oiled paper floors of traditional Korean homes; and a wide range of building products made with modern ecomposites.

Ecocomposites can be designed and developed for ultimate strength, elastic modulus, fracture resistance or impact resistance. During World War II, a linen and natural plastic composite was developed and tested for aircraft use in case aluminum supplies were interrupted, and there is little question that ecocomposites can be developed for virtually any use. The ideal ecocomposite material will be made of all natural materials that are nontoxic, fully biodegradable and renewable. Natural earth plasters with straw or flax fibers are a perfect example of a Noble Ecocomposite, made of materials that can easily meet the most stringent criteria of the new 4 Rs: Reduce, Reuse, Recycle and Return to Nature.

The term ecocomposite has also been used for materials that are made of natural materials and recycled materials, or made entirely of recycled materials. Many recycled plastic and natural fiber materials, such as Trex, have been developed and are now widely used in trim, window and door assemblies, and decking. These are less desirable, as most cannot be recycled or returned to nature and are not 4R compatible.

We have learned a great deal about the potential of ecocomposites by studying natural materials that have evolved over the millennia. Plant cell walls and plant structures are natural composite materials with regular arrangement of reinforcing materials. Wood can perhaps best be described as an ecocomposite with fibers in a foam matrix. 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.

We are 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. If you add weight on equivalent diameter threads of spider silk and steel, 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.

Plant fibers are more readily available, lower cost, light, and surprisingly strong on a weight basis – often 5 to 10 times stronger than steel. They also have more reactive surfaces and bond better than most synthetic fibers, but they may degrade with water, ultraviolet radiation and heat. However, a wide range of products can be made with nothing more than starch and paper. The work on Appropriate Paper Technology in Zimbabwe shows what can be done with a little inspiration and research and testing. APT products are very strong, and the process creates wood like grain and strength.

Straw or dung reinforced clay or earth blocks or monolithic walls are found in most areas of the world in the archeological record, and are still used today by hundreds of millions of people. Straw was often used to strengthen monolithic mud walls built without frames or forms. Mud and clay with fiber was also used to help improve the properties of mud-based blocks. As buildings became more complex, with wood frames, infill materials with good stability and some insulation value were used for wattle-and-daub and other wall systems. Reinforcing fibers might include straw, flax, other plant parts, or hair. Studies in England show that flax fiber reinforced daubs remain strong and flexible after several centuries, while straw eventually becomes brittle.

In the area of new ecocomposite materials 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. Gregory Glenn has developed starch-based microcellular foams and lightweight concrete. Straw panels made by compressing straw are again available.

Natural Materials & Building

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 and matrix materials in farming areas beset with economic and environmental problems. The introduction of straw-based building materials can reduce air pollution problems, add value to farm crops (selling straw as well as grain), absorb some of the plastic waste stream, and improve the energy efficiency of the homes and commercial buildings. The challenge of harvesting and handling fibers to optimize value is an important area for investigation and development. Keeping straw long, orienting fibers, and slitting instead of chopping can increase fiber quality. Perhaps binder reapers will re-emerge as the best choice for harvesting grains and straw.

Material choices today are typically predicated on a straightforward analysis of first cost, weight and strength. The cost is narrowly counted and ignores the environmental costs of mining, pollution, and nonrenewable resource consumption associated with processing, manufacturing, maintenance and disposal, and the health risks associated with the material. Considerable effort has been directed at improving ecological accounting in recent years, but much still remains to be done. Bio Schimdt-Bleek and others at the Wuppertal Institute in Germany have advocated a redirection of engineering and material science to more sustainable practices that count environmental costs, including the concept of Material Intensity per Service (MIPS).* The MIPS includes resource inputs and effects in developing a material footprint factor. These range from 1.2 for round wood, to 2 for glass, 2 to 7 for plastics, 7 for steel, 15 for paper, 85 for aluminum, and 500,000 for platinum. Straw and earth plasters would be below one!

Ecocomposites will play a critical role in developing sustainable manufacturing systems. The workers who manufacture them are not exposed to toxic materials. The waste byproducts from manufacturing can be composted. Maintenance is required for durability, but materials for maintaining these products are low cost and have little impact on the environment. At the end of use and maintenance, a clay/straw home will gradually melt into the soil, leaving little trace.

Ecocomposites represent an exciting new frontier that requires the talents, skills and enthusiasm of builders, engineers, hobbyists, farmers, chemists, botanists, ecologists, mycologists, agronomists, anthropologists, historians and economists. The First International Conference on Ecocomposites held in London (2001) was a revelation for most of the other participants and me. The Third International Conference on EcoMaterials was held November 14-17, 2005, at the Central University of Las Villas in Santa Clara, Cuba. *The Last Straw* and the straw and earth builders are pioneers on the ecocomposite path. Integrated, holistic, systems-oriented development will be needed to realize the full potential of these materials in the development of a sustainable Industrial Ecology. We can hasten this transition and improve the performance of ecocomposite materials by learning from past uses, successes and failures.

*An article on Material Intensity per Service by David Bainbridge will be included in *TLS*#53/Spring 2006.

Resources

www.ecocomposite.org

Wuppertal Institute, Germany. www.wupperinst.org

Appropriate Paper Technology in Zimbabwe www.csun.edu/~hfdss003/atacp/supplements/nocostdme.html

Benyus, J.M. 1997. Biomimicry. William Morrow, New York, 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. IRED, Harare, Zimbabwe 176 p.

Robson, D. and J. Hague. 1993. The properties of straw fibre. pp P#03: 1-19. In Proceedings Straw – A valuable raw material: Volume 1. Pira International, Leatherhead, Surrey, UK.

Schmidt-Bleek, B. 2000. The MIPS-Concept: Bridging Ecological, Economic, and Social Dimensions with Sustainability Indicators.

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

David A. Bainbridge, Associate Professor, Sustainable Management California College of Business and Organizational Studies, Alliant International University, 10455 Pomerado Rd., San Diego, CA 92131 <dbainbridge@alliant.edu>

David Bainbridge started life as an earth scientist, switched to ecology and planning (helping make Village Homes possible), headed the Passive Solar Institute, has spent 20 years on desert restoration, and in his spare time enjoyed helping birth straw-bale building. He currently teaches business management with a sustainable focus. If he was independently wealthy, he would spend his time working on ecocomposites and large scale desert restoration from a straw-bale castle in the high desert.

His books include: Village Homes Solar House Designs, The Water Wall Solar Home Book, Integral Passive Solar Water Heaters, Passive Solar Catalogs (I and II), The Straw Bale House *(with the Steens and David Eisenberg), and he is currently finishing* Desert Restoration: New Hope for Arid Lands *(Island Press). His next book will be on buried clay pot irrigation. www.ecocomposite.org*

The best time to plan a tree is 20 years ago. The next best time is now. - Chinese proverb