COMPOSITES FROM RECYCLED MATERIALS

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ABSTRACT

A reduction is urgently needed in the quantities of industrial and municipal solid waste materials that are currently being landfilled. Major components of municipal solid waste include waste wood, paper, plastics, fly ash, gypsum, and other biomass fibers—materials that offer great opportunities as recycled ingredients in wood composites. This paper discusses possibilities for manufacturing selected composites from these materials. Methods for producing the composites and the resultant product properties and attributes are described.

INTRODUCTION

The word “waste” projects a vision of a material with no value or useful purpose. However, technology is evolving that holds promise for using waste or recycled wood and, in some cases, even plastics to make an array of high-performance composites that are in themselves potentially recyclable.

In the United States in 1988, for example, paper and paperboard, wood, and plastics in the MSW stream accounted for approximately 71.8, 6.5, and 14.4 x 10^6 tons, respectively. In addition to the paper fiber in the MSW stream, vast quantities of low-grade wood, wood residues, and industry-generated wood waste in the form of pallets, sawdust, planer shavings, and chips are now being burned or otherwise disposed of. Other biobased materials in the waste stream include timber thinning, leaves, bark, yard waste, lake weeds, and agricultural residues, such as straw, rice hulls, bagasse, and corn stalks. These materials also represent a vast resource that can be used to make biobased composites.

COMPOSITES FROM WASTEPAPER, WOOD FIBER, PLASTICS, AND INORGANIC MATERIALS

Wastepaper, wood, plastics, fly ash, gypsum, and other biomass fibers can be reclaimed from industrial and MSW streams and used for several kinds of composite products: wood fiber-plastic composites, dry-formed wood fiber-based composites, inorganic bonded wood composites, and composites that combine wood fibers with other lignocellulosic fibers, metals, and glass.

Thermoformable Wood-Plastic Fiber Composites

Thermoformable composites are classified into two general types on the basis of the manufacturing process. Both processes—melt blending and nonwoven mat formation—allow and require differences in composition and in the lignocellulosic component.

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A typical composition for a melt-blended composite is 40 to 60 weight percent wood flour or cellulose pulp fiber with a powdered or pelletized thermoplastic such as polypropylene or polyethylene. In the melt-blending process, the wood-based fiber or flour is blended with the melted thermoplastic matrix by shearing or kneading. Currently, the primary commercial process employs twin screw extruders for melting and mixing; the mixture is extruded as sheets that are subsequently shaped by thermoforming into the final product. Limits on the melt viscosity of the mixture restrict the amount of fiber or flour (to about 50 weight percent) as well as the length of the fibers that can be used. Fiber length is also limited by fiber breakage as a result of the high shear forces during melt mixing.

In contrast, nonwoven mat technology involves room temperature air mixing of lignocellulosic fibers (or even fiber bundles) with thermoplastic fibers. The resultant mixture passes through a needling step that produces a low-density mat in which the fibers are mechanically entangled. The mat is then shaped and densified by a thermoforming step. With this technology, the amount of lignocellulosic fiber can be greater than 90 weight percent. In addition, the lignocellulosic fiber can be precoated with a thermosetting resin; for example, phenol-formaldehyde. After thermoforming, the product possesses good temperature resistance. Because longer fibers are required, this product can achieve better mechanical properties than that obtained with the melt-blending process. However, high wood fiber contents lead to increased moisture sensitivity.

It is virtually certain that virgin ingredients can be replaced by some recycled ingredients in melt blending and nonwoven mat formation for many applications. For example, the thermoplastic polymer might be totally or partially replaced by high-density polyethylene (HDPE) from milk bottles, polyethylene terephthalate (PET) from beverage bottles, or even nonsegregated plastic mixtures from MSW. Large quantities of a variety of industrial waste plastics are also available and should be considered. The virgin lignocellulosic component might be replaced by fibers from wastepaper or waste wood. These substitutions offer potential benefits in reducing both MSW and the cost of the composite processes. In some cases, the properties of the composite will probably be improved; for example, by substituting wastepaper fibers for wood flour in the melt-blending process.

Currently, the primary application of thermoformed composites, both melt blended and air laid, is for interior door panels and trunk liners in automobiles. Additional large-volume, low-to-moderate cost applications are expected in areas such as packaging (trays, cartons), interior building panels, and door skins.

**Wood-Plastic Fiber Mat Composites**

As noted previously, wood and plastic fibers can be formed into a web using nonwoven web technology. The plastic material can also be replaced with a long wood fiber like jute or kenaf.

One interesting application for low-density air-formed fiber mats is for mulch around newly planted seedlings. The mats provide the benefits of natural mulch; in addition, controlled-release fertilizers, repellents, insecticides, and herbicides can be added to the mats as needed. Research
results on the combination of mulch and pesticides in agronomic crops have been promising. The addition of such chemicals could be based on silvicultural prescriptions to ensure seedling survival and early development on planting sites where severe nutritional deficiencies, animal damage, insect attack, and weed problems are anticipated.

Dry-Formed Wood-Fiber-Based Composites

Wood fiber-based composites are made from reconstituted wood: the wood is first reduced to fibers or fiber bundles and then put back together by special manufacturing processes into panels of relatively large size and moderate thickness. Binding agents and other materials may be added during manufacture to increase strength or resistance to fire, moisture, or decay. In final form, the panel materials retain some properties of the original wood, but because of the manufacturing methods, the materials also gain some different properties. Because these products are manufactured, they can be and are tailored to satisfy a particular end-use or group of end-uses.

There is a great opportunity to produce fiber-based composites of varying densities from recycled wood fibers. One family of products, called Homasote, was first produced in 1916 and is made from old newspapers and other groundwood paper. Other fiberboard-type products now on the market also use all or partly recycled wood fiber as the raw material base stock. Uses for these types of products include insulating acoustical board; carpet board; wall, ceiling, and floor acoustical insulation panels; nail baseboard; and floor and roof insulation boards. We anticipate that many other uses for wood fiber-based products will be developed as collection, separation, and clean-up processes are further refined and developed.

Inorganic Bonded Wood Composites

Wood particles or fibers held together with an inorganic matrix, such as Portland cement or gypsum, form a composite that can be used in a variety of structural and industrial applications. These composites have a unique advantage over some conventional building materials because they combine the characteristics of both the wood fiber and mineral matrix. Some of these composites are water resistant and can withstand the rigors of outdoor applications, and almost all are either fireproof or highly fire-resistant and are very resistant to attack by decay fungi.

These types of composites, which provide another major future recycling opportunity to utilize waste wood and other postconsumer wastes, are made by blending proportionate amounts of the wastes with inorganic materials. The most apparent and widely used example is cement. Portland cement, when combined with water, immediately begins to react in a process called hydration to eventually solidify into a solid stonelike mass.

Besides wood waste, other postconsumer wastes such as glass and plastic can also be used as concrete aggregate. Depending on the type or types of aggregate used and the proportionate blend of materials in the resulting concrete, the end properties may differ somewhat but the product would generally be classified as low- to medium-strength concrete, for which there are many potential applications.
Other inorganic waste materials that can be added to the concrete mix or used independently to produce a different kind of composite material are fly ash and flue gas gypsum.

**Wood-Biomass Fiber Composites**

Wood is only one biobased resource in the waste stream. Other biobased resources include yard waste, water plants, and agricultural residues. Yard waste is a major co-mingled source of biobased fiber that is now considered only for composting. This is a vast resource that could be combined with the wood-based resource to produce composites of many different types. Many lakes and waterways suffer from an overproduction of water plants. These unwanted plants create another large waste stream that could also be considered as a valuable source of industrial fiber if they could be collected and processed economically and combined with the wood-based resource to produce composites. Because most recycling plans call for the composting or burning of this portion of the waste stream, very little thought has been given to using yard waste and water plants for composites.

Agricultural residues, such as straw, rice hulls, bagasse, and corn stalks, also represent a vast resource that can be used to make composites of many different types. In some parts of the world, these products are already being used to produce composites for various applications—from furniture to structural wall panels.

**CONCLUDING REMARKS**

Recycling is a critical element in the long-term management of renewable resources. A successful approach to recycling requires full cooperation between the government and the private sector. Government cannot logically mandate the increased use of recyclable materials without the involvement of industry—the industrial sector has the technical knowledge and equipment to separate and process solid waste and to make useful, economically viable products from waste materials. Industry provides the market for recycled resources, and it must be a full partner in all aspects of the process.

I believe that using recovered wood and fiber for wood-based composites presents tremendous opportunities for growth, for progress, and for further industry competitiveness in a world that is rapidly consuming any nonrenewable resources at an ever increasing rate.


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