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Clearing the Air About Agrifiber Board

Rapidly renewable sorghum boards reduce air pollution

by Michael Hurst, Michael Mehlhoff, PE, and Steven H. Miller

The construction industry has flirted with agrifiber board products of various description and composition for a decade. Despite the obvious theoretical attractions, the earliest products introduced in North America found only limited acceptance. (Some products have been successful overseas.) Marketplace forces, product limitations, and timing all played a part in this slow start.

The newest evolution of this idea, however, is poised to fulfill the promise of agrifiber board. Based on sorghum straw, this environmentally responsible product offers a direct substitute for particleboard, medium-density fiberboard (MDF), and even plywood and/or oriented strandboard (OSB) in non-structural applications. In performance, environmental impact, and cost, it is comparable to or better than those wood-based products, and unlike many of them, emits neither formaldehyde nor volatile organic compounds (VOCs).

The nature of the sorghum stalk makes it a better fiber for construction than many other agrifiber materials. Moreover, it presents a unique look that makes the material an intriguing possibility as a finish. The new sorghum products arrive at a time when the design/construction industry is ready and willing to embrace high-performing green products.

The agrifiber dream

The term ‘agrifiber’ describes a class of raw materials derived from plants, mostly grain crops. After harvest, the non-edible parts of the plant—the stalks or ‘straw’—are left over and must be disposed of. Agrifiber board uses this cellulose-rich material as the raw ingredient for a new wood-substitute panel product.

In certain ways, the idea parallels the original development of composite wood products such as particleboard and MDF—materials initially made by using waste products of lumber fabrication. Chips and sawdust were formed into wood-like panels that were less expensive than solid wood, and could substitute for wood or plywood in applications where structural properties were not necessary.

Agrifiber takes the conservation aspects of this concept a step further. Agricultural waste presents a disposal problem to farmers. Ploughing it under can be expensive, and some of the fibers are so durable they take years to decompose in the ground, rendering the land non-arable. In many parts of the world, the straw is removed by burning the field. After harvest time, skies darken with soot. Traveling miles across the landscape, the resulting smoke plumes are so thick they can be seen in photos taken from outer space. It not only pollutes the air, but emits greenhouse gases (GHGs) linked to the current climate crisis.

Utilizing agricultural waste diverts it from this process, eliminating a source of GHGs and large-particle air pollution. Another green aspect of the raw material is the embedded energy to produce agrifiber panels is less than with wood panels. In making both composite wood and agrifiber boards, moisture inside cells or between them must be removed for proper penetration of binder. Agrifibers generally have larger cellulose cells than wood, so the cell wall is softer and thinner, and moisture removal requires less energy.

Rice husks, wheat straw, and a number of other agrifibers have been made into board products. Some have been made by processes similar to particleboard manufacture, mixing them with a resin binder under heat and pressure to make a lumber product. For example, one product line formerly made by a major chemical manufacturer used wheat straw and a polyurethane binder to make a board product very similar in texture and machineability to MDF. However, it was discontinued in 2005 due to a combination of high material cost and low market demand.

Other products have been made using little or no resin binder, faced with paper to improve strength and stability. Most of these are limited in application, designed chiefly as insulating panels or as elements of a frame/panel partition system. They tend to be 63.5 mm (2.5 in.) thick (or more) and are unsuitable for machining, fabrication, screwholding, or other traditional woodworking techniques. Agrifiber has also been successfully combined with wood in some conventional particleboards.

Like particleboard, the binder in some of the first-generation agrifiber products was based on urea-formaldehyde, which is a known health hazard. (See "The Formaldehyde Problem," page 5.) As green consciousness has spread, the importance of protecting indoor air quality (IAQ) has led some manufacturers of wood products to seek ways to reduce emissions from their urea-formaldehyde binders or simply create formaldehyde-free formulations. However, for the time being, urea-formaldehyde continues to be the standard binder for particleboard and MDF. Some agrifiber manufacturers have already begun using nonformaldehyde binders.

The cellulose of agrifiber cell walls is more easily penetrated by chemicals than similar structures in wood fiber, making modifications to improve material properties more effective. For example, agents such as acetyls (commonly used in engineered wood panels to improve dimensional stability, moisture resistance, and strength) are more effective when treating agrifiber stalks. Ease of cell penetration in agrifiber also makes it more likely than wood to accept new green binders such as soybean protein, modified flour pastes, or even recycled thermo-setting plastics.

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With many grain crops, the non-edible stalks of the plants left over after harvest present a disposal problem to farmers. It is commonly solved by field burning that dumps huge amounts of pollutants into the atmosphere.

Realization of an alternate

The agrifiber goal, both for environmental responsibility and market viability, is a sustainable fiberboard product that can be directly substituted for particleboard while being cost- and performance-competitive. The new sorghum-based boards exceed these goals.

Sorghum is a genus of grasses with about 30 species. The primary cultivated species, *sorghum bicolor,* grows well in hot, arid climates, making it popular with subsistence farmers. Also known as grain sorghum, this crop is used as food for both humans and cattle, forming two important links in the chain of human food production. (It is also employed for making alcohol and biofuels.)

Grain sorghum is grown in the United States, Mexico, India, and throughout Africa and South Asia. It is considered the fifth most important cereal crop in the world. Notably, sorghum straw is a rapidly renewable resource—it can grow more than 2 m (6 ft) tall in a single season. Similar wood growth can take many years.[1]

Sorghum is a rapidly renewable resource, growing to 1.8 m (6 ft) tall in a single season. When dried, the long thin stalks can be made into a composite board product, diverting them from becoming a pollution source. The height and slenderness of the stalks is indicative of the strength of sorghum fibers.

The non-edible stalks are used for thatch, fences, baskets, brushes, and paper, but the demand for these applications is low. Generally, the stalks are disposed of by burning. Annually, sorghum burning is believed to release 24 million tons of GHG carbon dioxide (CO2) and 2 million tons of nitrogen, a smog-constituent.[2]

In China, one of the world's five leading producers of sorghum and currently the source of most sorghum used in agrifiber boards, researchers determined that agricultural burning accounted for:

- more than six percent of CO2—about 210.2 million tons;
- 11 percent of VOCs; and
- eight percent of the carbon monoxide emitted in 2000.[3]

It also contributes to the country's dire air pollution problem.

The reclaiming of sorghum straw not only eliminates environmental problems caused by burning, but also has a socially responsible aspect, providing an additional source of income for farmers. Since it is often grown by subsistence farmers in agriculturally challenging climates, this 'second harvest' can have significant financial impact.

A practical product

As a raw construction material, sorghum straw has several attractive properties. Sorghum is approximately 48 percent cellulose (close to the 50 percent cellulose content of wood), giving sorghum straw its high strength-to-weight ratio. The stalks are longer than most other agrifibers or the wood chips or fibers typically used in particleboard or MDF. This gives the boards great integrity and reduces slippage between fibers. The stalks are far thicker and more substantial than wheat or rice straw, allowing for better engineering of the product. Sorghum boards are made by a careful orientation of whole stalks into a three-dimensional matrix. This contributes to the strength of the composite in a way similar to the crossed grains of plywood layers or OSB. Sorghum board can be cut and machined like wood or composite wood products.

The center of a sorghum stalk is far less dense than the hard outer ring, so the material can be compressed to different degrees. Thus, the density of the final product can be varied over a wider range than products made from wood dust, strands, or peeled veneers. Sorghum boards range in density from 352 to 993 kg/m^3 (22 to 62 pcf), conditional on how much pressure is applied in the forming process.

Sorghum board products have flexural strength of 17,926 to 24,821 kPa (2600 to 3600 psi), depending on the design and composition of the specific brand and model. By comparison, particleboard flexural strength ranges from 3000 to 23,497 kPa (435 to 3408 psi), with nine of the 12 grades recognized by the American National Standards Institute (ANSI) falling below 17,237 kPa (2500 psi).[4]

Sorghum board is less vulnerable to damage from moisture than is particleboard or MDF; it also has good screw-holding characteristics. It is also much less prone to flaking and crumbling than particleboard. Strength and density testing (and practical experience to date) suggest the material will equal or exceed its traditional counterparts' long-term durability and require little or no maintenance.

Further, since the crop is frequently grown using less fertilizers and pesticides than other grains, the material is low in chemical residues. As an added benefit, it is naturally resistant to many types of fungi and insects.

The first sorghum board products brought to the U.S. market were available in 0.3 x 2.8-m (1 x 6-ft) and 1 x 1.8-m (3 x 6-ft) panel sizes—dimensions not widely accepted by the U.S. or European construction industries, but standard in Japan (where those materials were developed). Newer products are expected to be offered in more familiar 1.2 x 2.4-m (4 x 8-ft) sheets early next year, allowing direct substitution for particleboard in existing industrial and construction designs. Sized to nominal thicknesses of 6.4 mm, 12.7 mm, 19 mm, and 28.6 mm (0.25 in., 0.5 in., 0.75 in., and 1.125 in.), the boards are suitable for a variety of non-structural applications in furniture, cabinetry, shelving, door cores, floor underlayments, and other typical applications of particleboard and MDF.

The sorghum stalk has a soft center surrounded by a strong, hard outer ring. By adjusting the pressure applied in forming the stalks into boards, the density of the finished product can be varied.

As mentioned, sorghum panels have an intriguing appearance, including grain lines and shapes, and variegated colors in the earth-tone palette. The surface of particleboard and MDF products is generally uniform and featureless, and not considered suitable as an appearance material—these products are usually only used as finish materials by the addition of veneers or coatings, often including VOC emissions from the adhesives.

The structure and color of sorghum board gives it potential for use as a finish material. Accordingly, it has been specified to make countertops, tables, chairs, cabinets, and small moveable objects. It is also suitable as a wall panel. Sorghum board has been used in flooring applications and an engineered system of tongue-and-groove interlocking flooring panels is currently under development.

The present generation of sorghum boards is designed for interior use, but exterior- and marine-grade products (with appropriate binders and sealants) are being researched. Sorghum boards have been tested to 200 freeze−thaw cycles with no deformation or other adverse effects.

Future of sorghum board

The newest sorghum products are expected to be price-competitive (both in first costs and over the long term) with current particleboard and MDF products. They will, therefore, offer the industry a choice for a greener product in many existing applications.

As the new formaldehyde regulations discussed on page 5 become increasingly stringent, the cost dynamic may shift in favor of sorghum by raising the price of composite wood products. According to the Composite Panel Association (CPA), "the development and installation of the technologies necessary to produce those [reduced formaldehyde] products and the ongoing burden of testing and compliance are very expensive."

If CPA's prediction of "additional cost to the consumer" is correct, sorghum boards could have a price advantage. At the same time, the current emphasis of the energy industry on biofuels is driving demand for many grains, suggesting desire for sorghum will increase, the supply of stalks will remain high, and their cost will remain low.

The industry has already embraced the environmental revolution, and client demand for greener products and methods continues to grow. Sorghum board is a way to put a more sustainable material into a variety of furnishings and other non-structural applications without increasing costs or altering construction methods. It also offers a visible sustainable finish material, with an attractive look that has true bragging rights and sparks conversation about sustainability.

Notes

[1]According to the U.S. Green Building Council's (USGBC's) Leadership in Energy and Environmental Design for New Construction and Major Renovation (LEED-NC) Version 2.2 Reference Guide (2nd Ed.), a rapidly renewable resource is one that is "planted and harvested in less than a 10-year cycle." By this standard, sorghum is among the most rapidly renewable resources on the planet.

[2] Based on rate estimates in "Pollution by Cereal Waste Burning in Spain," by I. Ortiz de Zárate et al in issue 73 of Atmospheric Research (Elsevier, 2005) and annual world sorghum production estimates of the UN Food & Agriculture Organization.

[3] According to a study by Cao Guoliang (Centre for Atmosphere Watch and Services at the China Meteorology Administration), published in the August 2007 Chinese Science Bulletin.

[4] For more information, see the Composite Panel Association's (CPA's) Panel and Surface 2008 Buyer's Guide.

[5] See CPA's "Customer Fact Sheet on the New California Formaldehyde Regulation," available at www.pbmdf.com.

Sorghum boards' unique visual texture can be enhanced with stains and clear finishes that bring out the natural beauty of the stalk.

The Formaldehyde Problem

Urea-formaldehyde is a resinous binder material that is inexpensive, strong, and reliable. Unfortunately, it is also a known carcinogen. Animal studies released in the early 1990s established a link between formaldehyde and cancer. The International Agency for Research on Cancer (IARC) reclassified the chemical compound from "probably carcinogenic to humans" to "carcinogenic to humans" in 2004, based on the increased risk of nasopharyngeal cancer.

The California Air Resources Board (CARB) found one of the major sources of formaldehyde exposure in the state is from "inhalation of formaldehyde emitted from composite wood products containing ureaformaldehyde resins." In 1992, formaldehyde was designated a toxic air contaminant (TAC) in California with "no safe level of exposure."* Formaldehyde has other adverse health effects including eye/lung irritation and increased sensitivity to other chemicals. Adverse effects are linked to cumulative exposure.

Products made with urea-formaldehyde adhesives and binders tend to off-gas. Consequently, items such as furniture containing particleboard, shelving, and floor underlayments present possible sources of exposure in many interior environments. According to the U.S. Environmental Protection Agency (EPA):

> In homes, the most significant sources of formaldehyde are likely to be pressed wood products made using adhesives that contain urea-formaldehyde resins. Pressed wood products made for indoor use include: particleboard (used as subflooring and shelving and in cabinetry and furniture), hardwood plywood paneling (used for decorative wall covering and used in cabinets and furniture), and medium-density fiberboard (used for drawer fronts, cabinets, and furniture tops). Medium-density fiberboard contains a higher resin-to-wood ratio than any other UF pressed wood product and is generally recognized as being the highest formaldehyde-emitting pressed wood product.**

Formaldehyde was in the news recently when unacceptably high levels of it were detected in trailers supplied by the Federal Emergency Management Agency (FEMA) to victims of Hurricane Katrina (those –emissions were largely from particleboard).

In a 2007 letter, which was obtained during a congressional hearing by the House Science Committee Investigations and Oversight Subcommittee, Christopher T. DeRosa, chief of toxicology of the Centers for Disease Control and Prevention's (CDC's) Agency for Toxic Substances and Disease Registry (ATSDR) informed FEMA there is no "safe level" of long-term exposure to formaldehyde.

Formaldehyde has been used for decades, and the Composite Panel Association (CPA) asserts it has been safe.† The association disputes the applicability of laboratory animal studies to the types of exposure humans normally receive from composite wood products. Nonetheless, government agencies are cracking down on formaldehyde emissions from those products. As of January 1, 2009, a California law cuts allowable formaldehyde emissions from raw materials and finished products over a three-year period.

By the time it takes full effect in 2012—20 years after CARB declared formaldehyde a toxic air contaminant—emissions must be reduced to one-third of the 2002 levels, down to:

- 0.09 parts per million (ppm) for particleboard;
- 0.11 ppm for MDF;
- 0.13 ppm for thin MDF; and
- 0.05 ppm for hardwood plywood.

Other states are considering similar measures. The California market's sheer size could very well make its laws the effective standard throughout the U.S. industry, regardless of the progress of legislation elsewhere. This will add momentum to the acceptance of building products containing no added urea-formaldehyde, including sorghum panels.

* For more information, see the California Environmental Protection Agency's Air Resources Board site. Visit www.arb.ca.gov/toxics/compwood/compwood.htm.

** See "The Inside Story: A Guide to Indoor Air Quality," accessible by visiting www.epa.gov/iaq/pubs/insidest.htm. The resource is co-sponsored by the U.S. Environmental Protection Agency (EPA) and the Consumer Product Safety Commission (CPSC).

† See the Composite Panel Association's (CPA's) "Customer Fact Sheet on the New California Formaldehyde Regulation." Visit www.pbmdf.com.

Additional Information

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Abstract

New agrifiber boards made from recycled sorghum stalks are available as an alternative to particleboard and other composite wood products. The boards perform comparably to—and in many cases, better than—particleboard of similar density. They have a high cellulose content (similar to that of wood) and use formaldehyde-free binders; at the same time, they offer sustainable advantages with respect to diverting materials from the wastestream and reducing emissions.