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Siegel & Strain's Oak Lodge is built with highly insulating straw bales (this page and opposite). The bales are held in place with rebar and heavy wire mesh.

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Rapidly Renewable Materials' Complex Calculus

EVALUATING THE ENVIRONMENTAL IMPACT OF ALTERNATIVE BUILDING PRODUCTS IS MORE INVOLVED THAN A STRAIGHTFORWARD EXAMINATION OF THE LENGTH OF PLANTING AND HARVEST CYCLES

By B.J. Novitski

To make construction practices more sustainable, many architects have begun specifying "rapidly renewable materials." Unlike products made from petroleum, which is nonrenewable, or old-growth timber, which takes centuries to renew, these raw materials have very short harvest cycles. The LEED system of building certification from the U.S. Green Building Council (USGBC) offers points for rapidly renewable materials that regenerate in 10 years or less, such as bamboo, cork, wool, and straw. To qualify for the credit in a new construction project, the value of these materials must represent at least 2.5 percent of the cost of the products used in the building.

The council is continually considering adjustments to these and other credits that are part of the rating system. "People who have been doing LEED for six or seven years probably think some credit achievement percentages are a bit on the easy side," says Brendan Owens, USGBC vice president of technical development. "But we try to maintain a balance between technical rigor and market accessibility to encourage participation."

But probe beyond the concept of quick regeneration and you'll find caveats that make some rapidly renewable materials more green than others. The circumstances of production may cast a shadow on the sustainability of an agricultural product: Are fossil fuels, irrigation, or harmful chemicals used in its cultivation or manufacturing? Is the crop diverting acreage from food production? Are natural forests being destroyed to produce raw materials for construction? Does transportation consume inordinate amounts of fossil fuel?

Bamboo is a case in point. This fast-growing grass is hard enough to be used as a replacement for wood in applications such as flooring and furniture. However, most bamboo is grown and processed in China, and there are concerns about forestry practices, the toxicity of binders, and worker safety. A few bamboo plantations have earned certification from the Forest Stewardship Council (FSC), which accredits forests managed "to meet the social, economic, ecological, cultural, and spiritual needs of present and future generations." However, certified bamboo products are still not widely available in the U.S. And even though bamboo plantations sequester as much carbon as native forests, they do not support the same wildlife. What is more, while ocean shipping consumes less fuel per mile than overland trucking, the fuel used in shipping is more polluting. Clearly, the environmental balance is more difficult to calculate than by simply examining the length of a harvest cycle.

Given such complex questions, it's worthwhile to reconsider whether materials now deemed rapidly renewable are as green as those derived from well-managed forests of fast-growing trees, say some sources. Well-managed forests can be relatively healthy ecosystems, while agricultural fields are essentially clear-cut every year, exposing soils to erosion, and they are often treated with chemicals and irrigated, says Alex Wilson, who heads BuildingGreen, publishers of *Environmental Building News* and the *GreenSpec Directory*, and is consulting editor of *GreenSource*, which like ARCHITECTURAL RECORD, is published by McGraw-Hill. Until now, the USGBC has awarded LEED points for wood only if it comes from FSC-certified forests. Recognizing that LEED would make faster inroads in U.S. construction with timber industry support, Wilson advocates a two-tiered system that gives partial credit when wood from well-managed forests that do not meet FSC criteria is used. He also recommends considering many life-cycle attributes when comparing wood and more rapidly renewable materials.

The USGBC is evaluating modifications to the LEED credits that pertain to rapidly renewable materials and wood certification. Owens points out that the term "renewable" should be considered in context. "If you're using wood for structural framing in a house that will exist for 100 years, 'rapidly renewable' might be 50 years, because the resource regenerates in less time than one cycle of its use."

Green giant

Regardless of how wood will compare in the USGBC's analysis, there is much to appreciate about materials that regenerate more rapidly. In only five to six years, bamboo grows to a height of 40 feet and a diameter of 6 inches, and can be harvested without killing the root system, which then regenerates it. The hollow stalks are cut into strips which are dried, planed, and glued together to form durable flooring, plywood, and veneers. Some bamboo importers, such as EcoTimber and Smith & Fong,

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PHOTOGRAPHY: © J.D. PETERSON (OPPOSITE); COURTESY SIEGEL & STRAIN (TOP RIGHT)

CONTINUING EDUCATION

Use the following learning objectives to focus your study while reading this month's ARCHITECTURAL RECORD/ *AIA Continuing Education article. To earn one AIA learning unit, including one hour of health, safety, and welfare credit, turn to page 156 and follow the instructions. Other opportunities to receive Continuing Education credits in this issue can be found on page 159.*

LEARNING OBJECTIVES

After reading this article, you should be able to:

1. *Examine the sustainability claims of rapidly renewable building products.*
2. *Discuss the circumstances in production that influence the greenness of rapidly renewable materials.*
3. *Explain how some materials are easily regenerated.*

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Bamboo, cultivated primarily on Chinese plantations (top left), is a grass that grows to a height of 40 feet and a diameter of 6 inches in as little as five or six years. Though it is a grass, it is a popular substitute for hardwood in applications such as flooring (far left) and furniture. The bark of cork oaks can be stripped every 10 years without damaging the tree (top right). After stripping, the large slabs of bark are boiled, and bottle stoppers are punched from them. The leftover bark is ground up and pressed into sheets to make floor tiles (above).

now offer products without urea-formaldehyde and are encouraging Chinese foresters to move away from use of pesticides, herbicides, and chemical fertilizers.

Cork is the bark of cork oaks grown in the Mediterranean region. Unlike nearly every other tree species, it is not harmed by removal of its bark. A mature tree is stripped about once every 10 years and lives for an average of 16 strippings. The cork oak forests thrive without chemical herbicides, fertilizers, or irrigation and provide habitat for wildlife such as the threatened Bonelli's Eagle and Iberian lynx. After stripping, the large slabs of bark are boiled, and bottle stoppers are punched from them. The leftover material is then ground up, pressed into sheets, and cut into tiles for flooring. This dual-purpose production is critical to the cork industry. According to Wilson, the stopper industry might not be economically viable without the supplementary income from flooring products. And yet, if winemakers continue to seek alternatives to cork stoppers, the revenue from flooring might not be sufficient by itself to maintain the cork industry. "If the industry collapses," Wilson predicts, "whatever the land is converted to—say, housing or farmland—might be less environmentally sustainable than growing cork oak trees."

Wool for carpet and furnishings is a popular alternative to synthetic fabrics; it is prized for its beauty, natural origins, and biodegradability. Depending on the breed, a sheep can be shorn one to four times every two years, posing no harm to the animal. After shearing, the wool is spun into yarn and woven into carpets or other textiles. Much of the wool in the United States is imported from New Zealand, where farmers raise sheep without harmful pesticides, on land ill-suited for other agricultural purposes, so there is no competition with food production. But wool is often treated with chemicals to ward off moth and microbial attack. Some organic wool is grown domestically, removing the environmental burdens of ocean shipping.

Another natural fiber, cotton, is now being used for building insulation. For example, Bonded Logic, in Arizona, produces R-30 batts from postindustrial recycled denim, the scraps from manufacturing blue jeans, diverting about 200 tons of material per month from landfills. The fibers are treated with nontoxic borate for fire-, pest-, and mold-resistance. Then they are blended with binder fibers, heated, formed into solid batts, and cut to size. Any waste from this trimming is returned to the raw material supply. Although cotton is often grown with chemicals and heavy irrigation, it can

PHOTOGRAPHY: COURTESY ECOTIMBER (LEFT TWO); GLOBUS CORK (BOTTOM RIGHT); © APCOR (TOP RIGHT)

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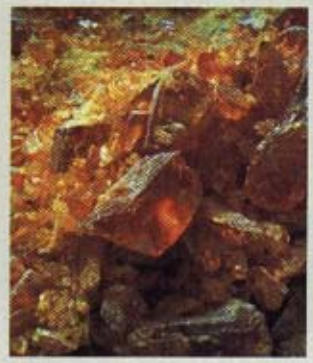

Natural linoleum is formed from a variety of rapidly renewable materials, including linseed oil, wood flour, and pine rosin (above left). During production, the ingredients are heated, mixed, and rolled flat (left). The sheets are cooled, backed with jute, then dried and trimmed. Pigments that do not contain heavy metals are used to achieve a wide variety of colors and unusual flooring installations (above right).

Wheatboard (far left) and sunflower board (left) mix agricultural "waste" with urethane-based binders to create an alternative to wood particle board.

Cotton insulation (right) is produced with denim scraps from blue-jean manufacturing, diverting tons of material from landfills.

PHOTOGRAPHY: COURTESY FORBO (TOP THREE); BALTIX SUSTAINABLE FURNITURE (BOTTOM LEFT TWO); BONDED LOGIC (BOTTOM RIGHT)

be argued that the environmental "burden" of the agricultural process falls to the first use, not to the postindustrial recovered material.

Linoleum has a long history of popularity and, unlike vinyl flooring, is not made from petroleum. For example, Forbo's Marmoleum contains pine rosin, tapped from trees without affecting their growth, and linseed oil, to provide strength and flexibility. Linoleum also includes finely ground limestone and pigments made without heavy metals. Hardwood flour, from timber grown in controlled forests, binds the pigments and ensures a smooth surface. During production, the ingredients are heated, rolled flat, backed with jute, and trimmed. Forbo, based in Switzerland, has a reclamation program that composts used linoleum to make a soil amendment.

Waste not

Arguably more green than fast-growing materials are "products" that are actually agricultural waste. For example, the leftover straw from food harvesting has until recently been considered a nuisance. Farmers have had few options but to landfill it or to burn it, releasing greenhouse gases and other pollutants. And plowing straw back into fields actually increases the need for nitrogen fertilizers. But now some of these materials are finding their way into building construction. Many qualify for LEED points for recycled content in addition to the credit for rapidly renewable materials.

Environ Biocomposites, in Minnesota, manufactures boards by combining wheat straw and sunflower hulls with urethane-based resin instead of the urea-formaldehyde binders traditionally used in wood particle board. The boards come in ½-, ¾-, and 1-inch thicknesses and are appropriate for the same interior applications as wood particle board.

Agriboard Industries, in Kansas, produces a composite structural panel from highly compressed wheat and rice straw sandwiched between oriented strand board (OSB) made from young-growth, rapidly growing hardwoods. The panels provide both structure and insulation in wood floors, walls, and roofs. Engineered at the factory with precut openings for doors, windows, electrical conduit, and ducts, they vastly reduce job-site waste. The manufacturing process combines heat and pressure, drawing lignin from the cell walls of the straw, and creating a natural binder that obviates the need for urea-formaldehyde or other additives. The result is a highly insulative panel that is resistant to insects, fire, and F-5 tornadoes; does not off-gas; and can eliminate more than 80 percent of the dimensional

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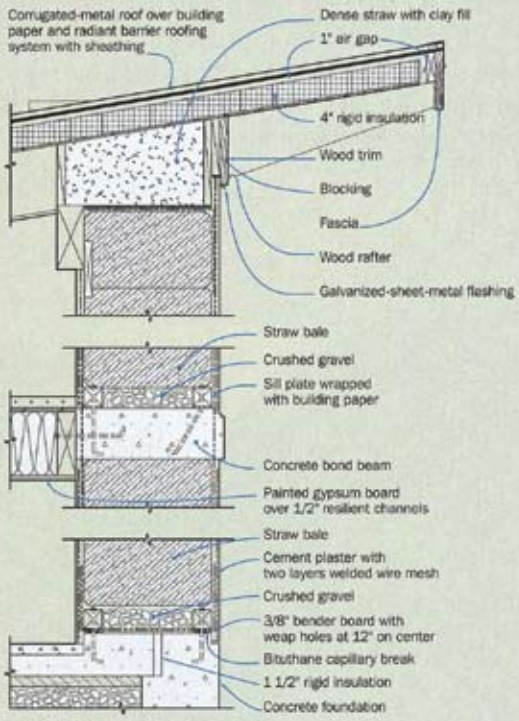

STRAWBALL WALL SECTION DETAIL

Oak Lodge (top left), a Jesuit retreat in California's Sierra Foothills designed by Siegel & Strain Architects, has walls of highly insulating straw bales covered by stucco. Details for incorporating the straw bale into standard construction (left) are evolving. Agriboard Industries subjects wheat and rice straw to intense pressure and heat as part of a manufacturing process (right) for panels (above) that provide structural strength and insulation.

lumber used in traditional construction, according to the manufacturer.

Baled straw can also be used in construction without any processing at all. One recent example is Oak Lodge, a Jesuit retreat in the Sierra Foothills, designed by Emeryville, California–based Siegel & Strain Architects. The designers chose straw-bale construction partly for its high insulating capacity, making evaporative cooling viable during very hot, dry summers. Eliminating mechanical refrigeration reduces the building's energy consumption and carbon emissions. Moreover, according to principal Henry Siegel, FAIA, the stucco on the interior and exterior provide substantial thermal mass and shear resistance to earthquakes. The bales are so tightly bound that they are effectively fire-resistant. At Oak Lodge, the straw bale is infill in a two-story, post-and-beam structure, held in place by rebar and heavy wire mesh. The bales come directly from nearby rice fields where, until recently, they would have been burned as waste.

As such materials become more common, standard details are emerging. Oak Lodge is Siegel & Strain's third straw-bale project, and Siegel explains that the firm's approach is evolving: "We used to place rebar down through the middle of the bales; now we put the rebar vertically on both sides and tie through the lathe to hold it together." He credits the Ecological Building Network and the California Straw Building Association for promoting the sharing of successful detailing techniques.

Sorting it all out

With all these options, it's a daunting task to compare environmental impact of the various rapidly renewable materials with each other, let alone with competing conventional products. Owens explains that questions about where a material comes from, how it's used, how long it will last, and whether it has recycled content are "single-issue proxies for life-cycle-assessment-based thinking." Life-cycle assessment, or LCA, is a methodology that quantifies the environmental impact of a material by examining how it is grown, harvested, transported, maintained, and eventually disposed of, computing costs in energy and water use, air degradation, and other factors. The USGBC Materials and Resources Technical Advisory Group is grappling with the best way to incorporate what Owens calls "multi-attribute life-cycle screening" into LEED.

However, life-cycle assessment has its shortcomings, according to some sources. Although the methodology can provide a more standardized way of comparing diverse material options, different analyses

PHOTOGRAPHY: © J.D. PETERSON (TOP LEFT); COURTESY AGRIBOARD INDUSTRIES (RIGHT TWO)

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might use different data sets, leading researchers to completely different conclusions, says New York City–based Cynthia Tyler, senior research scientist at Material ConneXion, an information source for innovative materials. In addition, an LCA typically considers no options besides disposal at the end of a material's useful life. This "cradle-to-grave" analysis will essentially tell you only which option is less detrimental, she says.

Material ConneXion has recently teamed up with McDonough Braungart Design Chemistry and the Environmental Encouragement Protection Agency, organizations established by architect William McDonough and chemist Michael Braungart, respectively, to offer their Cradle to Cradle (C2C) material assessment, product development, and certification to manufacturers. McDonough and Braungart argue that when a product is made of appropriate materials and is designed so that its constituent parts can be recovered at the end of its useful life, any waste is "food." The waste becomes raw material for the manufacture of more products, either by composting if biobased or by recycling if synthetic. The approach effectively closes the loop, eliminating the concept of waste.

Diverse standards make it hard for architects to know how to do the right thing. The field is further confused by "greenwashing," or exaggerated claims made by some manufacturers. Tyler recommends that architects seek guidance from third-party certification organizations, such as FSC for sustainably harvested wood, the U.S. Department of Agriculture for organic materials, GreenGuard for building products and furniture with low volatile organic compound emissions, or GreenSeal for building products evaluated by LCA. However, "each program has different criteria and certifies only certain products," she cautions.

Another rating system that seeks to broaden the scope of green certification is The Pharos Project, which encourages participation from design professionals. The project's goal is to cut through the confusing array of green standards and identify products that are good for the world, rather than "issue prohibitions on what is less bad," according to its Web site.

One stumbling block to widespread adoption of sustainable materials is their up-front expense. "Most building products on the market made from rapidly renewable materials today are more expensive than their synthetic counterparts," says Wilson, pointing to linoleum, which comes at a premium over vinyl flooring. However, a complete accounting of costs associated with a product would also include its societal costs, balancing out the pricing of rapidly renewable and synthetic materials, he says.

The laws of supply and demand may also bring the prices of rapidly renewable materials down as manufacturers respond to growing market interest in green products. And if the industry reaches a consensus on comprehensive and consistent evaluation methods, architects will have more choices when specifying sustainable materials and will be able to produce better buildings with smaller environmental footprints. ■