



Engineered polymer fibers allow concrete to bend.

Source: Dr. Victor Li

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INCHES

BEND But Don't BREAK

New materials systems, highlighted by engineered cement, show promise in providing protection against hurricane-force winds

STORY DOUG SMOCK, CONTRIBUTING EDITOR, MATERIALS AND FASTENING

New building codes and soaring insurance costs are triggering a drive to develop new materials and structures that are more resistant to hurricanes, as well as other natural calamities such as earthquakes.

One of the more exciting developments is a new "bendable" cement (<http://rbi.ims.ca/5408-549>) in which aggregate is replaced with a network of finely engineered and coated polymer fibers.

The new engineered concrete under development at the University of Michigan is 500 times more resistant to cracking and 40 percent lighter than regular concrete. The new concrete "will redistribute loads in a manner very similar to metal," says Victor C. Li, who is a professor of civil and materials science engineering at the University of Michigan.

The key to the success of the engineered structure is the synergistic working of the





Structural cores made with more ductile concrete make buildings in Japan more earthquake-resistant.

materials. "When an initial defect grows into a crack due to a large amount of load, the crack will grow in a very controlled manner," says Dr. Li. "The crack will be very much less than the dimension of a human hair or less than 100 microns. The load is carried across that crack through the bridging fibers. These fibers, in turn, carry the load back into other parts of the composite."

Specialty polymer fibers that comprise about 2 percent of the mixture's volume are critical in providing the enhanced performance. The microscale fibers in effect replace stone aggregate and act as ligaments that allow the concrete to flex. Li's research team is focused primarily on three types of polymers for use as fibers: polyvinyl alcohol (PVA), high-modulus polyethylene and high-strength polypropylene. "We are looking at the mechanical properties and dimensions of the materials," says Li. "We're focusing on the strength of the fiber, its ability to flex and the amount of deformation it can take before breaking."

Synergistic Ductility

The key to the ductility of the new concrete composite is a coating on the plastic fibers that allows movement under stress.

"How the fiber works (<http://rbi.ims.ca/5408-550>) inside the composite needs to be just right. It means that fibers don't come out too easily. Otherwise you don't have a composite, per se," says Dr. Li. "On the other hand you don't want them bonded too strong. If that was the case you wouldn't allow the fiber to slide; you would break the fiber. In either case it would return to a brittle material as opposed to the ductile behavior we are looking for." The engineering was done in collaboration with a producer of the fiber. Li said the name of the partner is confidential.

A bendable concrete composite developed at the University of Michigan is among new materials systems that show promise in protecting buildings from hurricane-force winds.

The fibers are mixed with sand and concrete using conventional equipment, making them isotropic or exhibiting equal strength in all directions as is the case with metal. The fibers can be aligned if that fits a design engineer's requirements.

The composite material can be cast, sprayed like a foam or even extruded like a pipe.

Another flexible concrete has been under development in France and is commercialized. Called Ductal (<http://rbi.ims.ca/5408-551>), the material was developed by researchers at Lafarge and its partners, Bouygues and Rhodia. Four patents were filed between 1994 and 2001 and prototypes were introduced to

North America in 1998. Its goal is to reduce materials required, speed construction and reduce labor and maintenance.

One of the major new applications is the Thiais Bus Center, near Paris, in which the building is entirely covered in a Ductal concrete skin. Use of Ductal in the building is primarily a design statement. It looks as though it is rising out of the road or growing out of and fusing with the landscape.

Ductal has approximately twice the strength of ECC, while ECC has approximately 20 times the tensile ductility of Ductal. Relatively speaking, Ductal is stronger than ECC but more brittle. Because of the high ductility of ECC, it has a much higher energy-absorption capability for impact resistance.

As a result, the emphasis on the University of Michigan material is protection against natural calamities. Structural engineers are using the Engineered Cement Composites as cores of buildings in Japan as protection against earthquakes. Li says the ECC also saves costs because less material is used in the design.

Michigan Bridge Repair

The material was used earlier this year to retrofit a section of the Grove Street Bridge deck over I-94 in Michigan. An ECC slab replaces an expansion joint to form a continuous deck. "The ECC material has promise for solving some of the deck durability issues we face, such as premature cracking," says Steve Kahl,



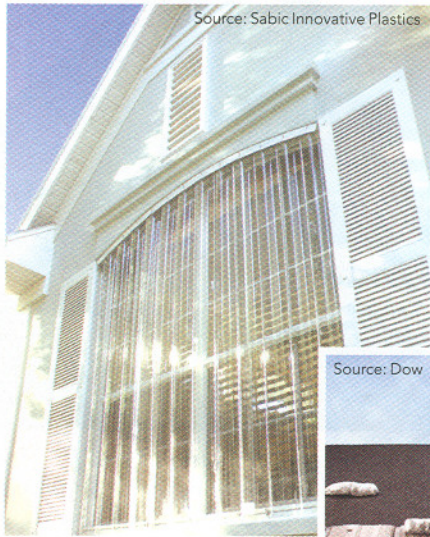
Lookout Shutters installs polycarbonate guards over windows and doors for storm protection.

supervisor, experimental studies group, with the Michigan Dept. of Transportation's construction and technology division. "We're hoping the ECC will work well and possibly lower the cost when experience is gained on large scale production."

Dr. Li says an Australian company is also fabricating a prototype pipe made from ECC to replace steel-reinforced concrete pipe. "For a liter length, it costs less than steel-reinforced pipe and it's stronger," says Dr. Li.

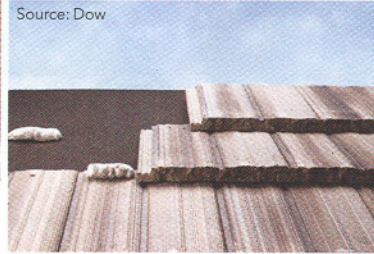
The University of Alabama is exploring new materials combinations that could provide protection in hurricane-force winds (<http://rbi.ims.ca/5408-552>). "Improved building materials have the potential to reduce life and property losses, which will continue to increase if steps are not taken to make coastal communities less vulnerable," says Nasim Uddin, a wind damage mitigation expert at the University of Alabama at Birmingham.

Uddin is the principal investigator on a National Science Foundation project to create fiber-reinforced polymer composites that form a structural insulated panel (SIP). The new panels would replace plywood or similar face-sheet materials that use



Source: Sabc Innovative Plastics

Special UV coatings on polycarbonate approach the hardness of glass.



Source: Dow

Super-strong adhesives are being used to keep tiles from blowing off in hurricanes.

molded expanded polystyrene as the core material, which have poor resistance against wind-borne debris. They are also heavy and foster mold growth.

The panels survived a test without harm in which the equivalent of a 15-ft piece of wood traveling at 130 mph hit the less-than-6-inch-thick SIP. "Now, imagine that's a tree limb being slung at your house during a tornado," Uddin says. "It's essentially a missile. These panels have better penetration resistance against wind-borne missiles during weather events like hurricanes and tornadoes and these tests prove it."

Uddin envisions use of natural fiber-reinforced composites of jute, sisal and kenaf in the reinforced panels.

Ready Right Now

Meanwhile, major plastics' producers have several solutions on the market that could ease wind and water damage right now.

One of the major efforts is the replacement of windows with polycarbonate glazing systems which combine excellent impact resistance with good optical properties. One downside traditionally of polycarbonate, however, has been its tendency to show scratches.

The Home Depot and Sabc Innovative Plastics (formerly GE Plastics) are jointly marketing a hurricane protection system in southern Florida (<http://rbi.ims.ca/5408-553>). The installed system, which includes track mounting, is said to be more than four times stronger than half-inch plywood sheets often used to protect windows from wind-borne projectiles. "Plywood can split and crack and open up little holes," says Ralph Buoniconti, regulatory engineer at Sabc Innovative Plastics. "And ours doesn't." The UV-coated, corrugated sheets are more than 250 times more impact resistance than glass. The system is compliant with codes developed for the High Velocity Hurricane Zone by the Miami-Dade County Building Code Compliance Office (NOA 07-0326.06).

The retail price at Home Depot is \$9.40 per linear ft. Installed cost through contractors, such as Lookout Shutters, ranges from \$14 a sq ft up to \$22 per sq ft. Demand for panels was slow in the most recent hurricane season. "I think it's partly related to the current housing market and uneasiness about making investments," says Tammy Rucker, global product manager at Sabc Innovative Plastics. "People are watching their pocketbooks and waiting for a

hurricane to come closer to them."

Rucker says the Sabc unit is also exploring other PC-based hurricane-proof products. "We're looking at creating additional solutions, such as a multi-wall sheet that would be used to protect openings in homes such as windows or skylights," she says. The new sheets are extruded with fluting, providing strength along the same principle as a steel I-beam. "The trick is not to think of it as a laminate or two separate sheets," says Buoniconti. "It's one piece of material that has hollow flutes."

Bayer MaterialScience, through its Sheffield Plastics group, also views the hurricane market as an important target.

"We are working with our partners to develop new designs that we feel are more effective than current solutions in hurricane disasters," says Doug Mahler, industry manager at Sheffield Plastics, which is located in Sheffield, MA. One of those current systems (not a Bayer product) uses a polyvinyl butyral interlayer between two sheets of glass, a construction similar to those used in auto windshields.

Those systems are heavy and can even require a crane for lifting and placement. Sheffield is studying solutions in which polycarbonate is used to protect the glass, either as an active (installed when storm approaches) or a passive (more permanent) approach. A potential problem with polycarbonate in a passive system is its well-known problems with scratching and weatherability. PC is not a naturally clear material and when it weathers it exhibits a yellowish hue. Mahler says new UV coatings used today have hardness approaching glass. Sheffield's system would add 20 to 25 percent to the cost of a standard window, according to Mahler.

Earlier this year, DuPont Glass Laminating Solutions launched Dry Glaze SentryGlas Plus, which features a new interlayer that is 100 times stiffer and five times tougher than PVB. The new product seems to solve labor issues related to PVB-type glazing. A glazer in south Florida, who installed 7,000 sq ft of glazing in an office building, realized lower install costs than PVB wet-glazed systems and a much faster installation, according to a DuPont



Source: Dow

Sprayed on urethane systems are protecting buildings for leaks.

press release. In St. Petersburg, FL, a new curtainwall system consisting of Dry Glaze SentryGlas Plus also saved labor costs.

Other products include a stronger tile bond adhesive for roofing materials and a polyurethane spray foam system that makes roofs water tight. Both are from Dow Chemical.

USEFUL LINKS

//Check out the links below for more info//

- To hear Victor Li discuss engineered cement composites, go to <http://rbi.ims.ca/5408-554>.
- For a video showing a four-point bending test with ECC, go to <http://rbi.ims.ca/5408-555>. The speed of the movie shown for ECC is 50 times that of its actual speed.