Fibers for tomorrow

Fiber reinforcement holds great promise for increasing the speed and simplicity of construction

By S.C. McCraven

From humble beginnings more than 30 years ago as scrap byproducts of the carpet and steel wool industries, fibers today offer many advantages for reinforcing concrete. Today's market offers great variety, from short, hair-thin strands (micro- or monofilament) to macrofibers up to about 2 inches long. Fibers are made of glass, carbon, steel, nylon, polypropylene, and other materials. They can be fibrillated (frayed) or smooth, crimped or flat, colored or transparent. Many European contractors are replacing conventional reinforcing with fibers in concrete flatwork and foundations, while American contractors use fibers mostly to minimize plastic-shrinkage cracking in pavements and slabs on ground. The American approach may change with newly patented "structural fibers" and a soon-to-be-released ASTM fiber-testing standard.

Types of fibers

Steel Steel-fiber-reinforced concrete (SFRC) has significantly higher flexural strength and toughness. Up to 40% of slabs on ground are constructed with SFRC in some European countries," says Jeff Novak of Bekaert Corporation, the world market leader in steel-fiber technology. "Most of the SFRC applications today and in the future will be in flatwork," according to René Pepin of TrefilARBED, "and we have constructed pile-supported floors without conventional reinforcing."

Synthetic Synthetic fibers include polypropylene, polyolefin, polyethylene, and nylon. "There are three configurations of synthetic fibers," according to Dan Biddle of FORTA Corp., the first company to enter the synthetic fiber market in 1978. "There's the standard angel hair (monofilament) shape, net-shaped (fibrillated) products, and the new structural fibers."

Are fibers structural?

Can steel and synthetic fibers replace traditional reinforcing bars and wire fabric? For the past 15 years in France, steel fibers have been used as the only principal reinforcing

Bartley Contracting gets to work early in the morning pumping a slab that includes a new synthetic structural fiber.

W.R.GRACE & CO. CONCRETE PRODUCTS DIVISION in applications such as suspended industrial slabs supported on piles, foundations under office towers and commercial buildings, and bridge decks. Dosage rates range from 40 to 60 lbs/cy of steel fiber in pumped delivery (adding as much as $60/cy to the cost). But in the United States, the ACI 318 Building Code does not even mention fibers, which greatly inhibits their specification by American engineers.

The newest "structural" fibers, though, are not steel but synthetics with fibrillated ends to increase bond with the concrete. "Synthetic structural fibers are engineered for tight crack control, not simply plastic shrinkage control," says Jewan Bae, Grace Construction Products. "This performance characteristic increases the flexural toughness and impact and fatigue resistance of concrete. These high modulus structural fibers are designed to replace welded wire fabric, light rebar, and steel fiber in flooring applications."

"I do not think the term "structural" should be used in reference to fibers used in FRC," says Pete Tatnall, chairman of ACI's FRC committee and technical director at SI Concrete Systems "This term implies we can replace all conventional steel reinforcing in all concrete components. This is not true." E. Stefan Bernard, University of Western Sydney, Australia, agrees "It must be acknowledged that fibers are not capable of replacing conventional forms of reinforcement in all applications." He explains that the limits on fiber dosage levels and anchorage capacity mean that steel reinforcing bars will continue to be used in reinforced concrete construction.

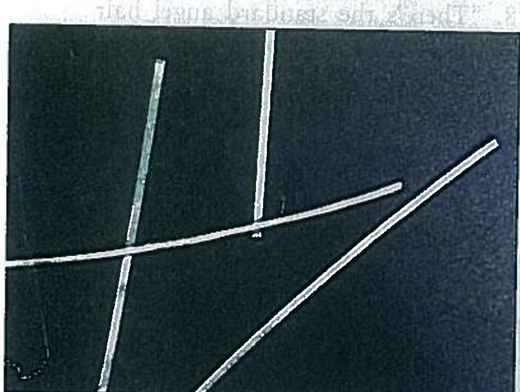
Currently several fiber manufacturers are marketing synthetic fibers and dubbing them "structural."

"It's a misnomer to say these fibers are structural," says Nycon president Bob Cruso. "What these so-called structural fibers do is enhance the structural integrity by holding together cracks." This happens by distributing shrinkage forces throughout the matrix of the concrete, resulting in much narrower cracks. "Welded wire mesh is reactive, only working after the crack has formed," says Cruso. "Fibers are proactive."

"These new structural fibers [illegible] pass the benefits of both steel and synthetic fibers in properly designed, contractor-friendly mix designs," claims Bill Phelan of Euclid Chemical. "Structural fiber technology is truly a breakthrough in the concrete industry. One very promising application is to get the top steel out of bridge decks." But until reliable product testing and proven applications of fiber technology are available and supported in building codes, we aren't likely to see widespread use of fibers in structural designs as replacement for conventional reinforcing.

Other fiber innovations

Jointless industrial floors One particularly interesting use of steel fibers is the construction of so-called "jointless" industrial floors. By adding large doses of high-performing steel fibers and some rebar at corners and penetrations, Bekaert and others have successfully increased the control joint spacing to over 100x100 feet. "This gives the owner a floor with lower cost for joint maintenance, forklift repair, and higher forklift driving speeds," claims Novak.



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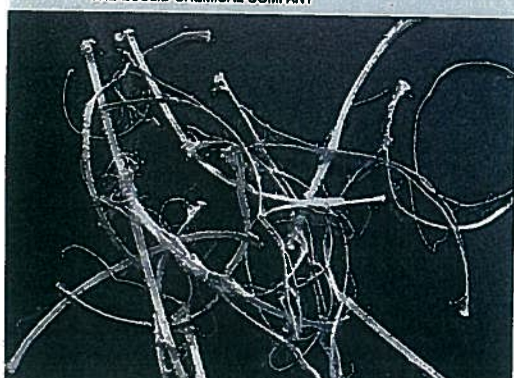

Synthetic structural fiber before mixing is shown (top), and self-fibrillating of the fiber after mixing (bottom).

JEAN-FRANCOIS DUFOUR, KING PACKAGED MATERIALS, CO.

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Top right: Steel-fiber-reinforced shotcrete continues to exhibit load-carrying capacity at large deformations. Bottom right: This hybrid fiber-reinforced cementitious mortar (carbon-and-glass fibers) is being used to repair a bridge girder in British Columbia. Hybrid fiber reinforcement was used to increase strain capacity and improve bond with substrate.

Fire resistance The addition of polypropylene monofilament fibers can reduce explosive spalling of high-strength concrete. High-strength concrete used in many high-rise projects is known for its low permeability and high durability. But low permeability can create a problem during a fire. Rising temperatures build up in concrete, causing water within the matrix to vaporize with increasing pressure, resulting in explosive spalling. Synthetic fibers vaporize at temperatures around 350° F, thereby occupying about 90% less space in the concrete matrix. These voids provide an escape path for high-pressure vapor. Dosage rates of fibers to reduce fire-spalling damage range from 1.5 to 3.5 lbs/cy. Tunnel linings are another application where this technology is important.

Blast and impact resistance According to Tatnall, "Laboratory studies and field applications have demonstrated that advanced composites can reduce structural damage due to extreme loadings, such as those associated with recent terrorist attacks." Improved FRC ductility and toughness mean that the concrete has an increased ability to dissipate energy—a desirable quality in blast-resistant concrete design.

Engineered blends Blends of fibers and traditional rebar result in flexible designs and labor-saving construction. Fiber manufacturers have become increasingly sophisticated in their ability to optimize dosage rates and to blend fiber sizes and types to achieve specific FRC properties. For example, residential contractors may prefer ultrafine monofilament fiber blends, says SI's Greg Moody, which have better finishability while controlling plastic shrinkage cracks, over the coarser fibrillated fibers, which are more often specified for industrial or commercial applications where toughness is key. Hybrid mixes (such as carbon and glass fibers or steel and polypropylene blends) are becoming more common, especially in repair and restoration work.

Insulated concrete forms One of the obstacles to increased use of ICFs in the congestion created by reinforcing bars. Using fibers to replace conventional reinforcement may make ICF construction more popular.

The success of new FRC technologies will depend on industry acceptance as well as standardized testing and codes. The real tests will be proven design flexibility, cost savings, and construction experience on successful FRC projects. ■

Steel and synthetic fiber manufacturers

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