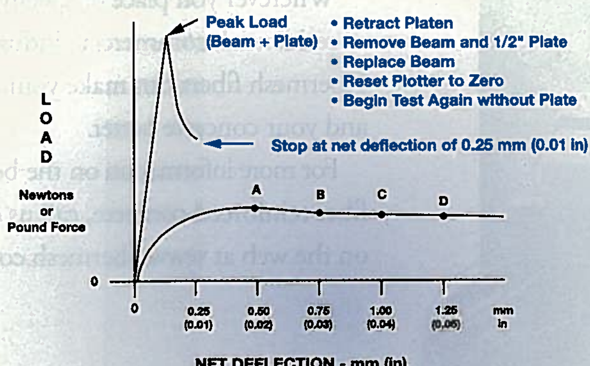
Cracking new markets

ASTM test method, high dosage practice further synthetic fiber practice

Higher doses of synthetic fibers in value-added, specialized applications are driving new markets for concrete producers and practitioners. New applications in blast-resistant design and reinforcement for concrete are undergoing research in corporate and university laboratories, while proven high-dosage targets like bridge decks and ultrathin whitetopping (concrete overlays) are moving forward (note UTW companion report, page 34).

And for now, the industry appears to have weathered a period in which a lack of standard specification — and naivete on the part of contractors and customers — led to inconsistent fiber application and disappointing as-built results. Indeed, the new ASTM C 1399-98 — Test Method for Obtaining Average Residual Strength of Fiber-Reinforced Concrete, approved this past June by Subcommittee C-9.42 on Fiber-Reinforced Concrete, will go far in measuring the relationship between dosage, configuration and performance of concrete containing fibers. At the same time, the problematic issue of standard, recipe-style national specifications for fiber-reinforced concrete with which the industry has struggled for years may turn moot as performance specifications become the norm. This would make the actual dosage unimportant as long as the final product performs as warranted.

"It should be a performance specification," contends Dennis Hogan, director of marketing for Construction and Civil Engineering Group of Synthetic Industries, Inc. (SI), parent of Fibermesh. "Fiber reinforcement should be used based on the history of performance and test data. Performance specs are getting more popular because they lend themselves to innovation. One size doesn't fit all."



With ASTM C1399—Test Method for Residual Strength of Fiber-Reinforced Concrete, cast or sawn fiber-reinforced concrete beams are conditionally cracked using the third point loading arrangement specified in ASTM Test Method C78. A steel plate supports the beam until it is cracked, and then is removed. The beam is then reloaded to obtain a residual load-deflection curve. Loads are measured at specified net deflection points on the residual curve (points A, B, C, D above). These loads are then averaged and factored for beam geometry to obtain the residual strength for the specimen. Illustration: Fibermesh

Measuring performance

The ASTM test method originated at SI's Construction and Civil Engineering Group's Fibermesh Division. "We had to have some way to measure the performance of fibers in concrete," notes Leonard Bell, P.E., director of engineering services.

ASTM C 1399 measures the level of load sustained by fibers on a concrete beam after the beam is cracked in a controlled manner, he adds. This load-carrying capacity determines a "residual strength" for a fiber-reinforced concrete beam. Residual strength is determined from load readings at specific net deflections after the specimen has been cracked. The average strength is intended to characterize that portion of the stress-strain curve that is consistently and significantly affected by addition of fibers (note deflection graph, test method description, left).

"We could have pulled on the fibers by themselves, but we wanted to see their effect within the concrete media. The idea expanded into a user test, as a standard method was not available," Bell explains. "Full-scale testing of fibrous concrete indicates performance with which a designer or engineer could be comfortable. This information could be used to duplicate fibrous-concrete performance anywhere in the world.

"The test is comparative rather than definitive. Measurements only tell how much stronger one fiber system will be to another in concrete, or between one pound of synthetic fiber and five pounds. It indicates what the crack-holding power of a fiber is in the concrete test specimen."

Stakes rise

The stakes are enormous for the synthetic fiber industry, along with the producers and contractors who promote fibrous cast-in-place and precast, market observers find. U.S. demand for concrete admixtures, including fibers, will expand 8.2 percent per year, including price increases, to reach more than $1 billion in the year 2002.

While chemical admixtures will become a half-billion dollar market by 2002, fibers will be the fastest growing segment of the admixture market, according to a 1998 report from Cleveland-based Freedonia Group Inc. Market growth will be fueled by concrete-intensive construction, more widespread admixture use, increasing dosage rates, and expanded use of value-added proprietary products, especially reinforcing fibers, Freedonia researchers report.

"The use of fibers is escalating at a growth rate of least 10 percent per year," adds Hogan. In this context, Fibermesh and other major synthetic fiber producers are jockeying for market position. Earlier this year, SI expanded its scope by purchasing Novocon International Inc., a manufacturer of steel fibers for concrete.

The industry has seen marketing of synthetic fibers become even more intense and competitive. Commodity pricing has flourished as "me-too" suppliers have gotten in the act. "There always will be people in a low-spec market, in particular, who will buy some staple fiber offered through an 800 number," Hogan notes.

1+ percent solution

Use of higher addition rates than the standard one pound per cubic yard of concrete in engineered applications constitutes a growth area for manufacturers seeking to separate themselves from the commodity market. Current research is aimed at determining optimum dosage for these applications.

"The use of discontinuous fibers as a premix for concrete has seen tremendous development in North America and Europe," notes University of Michigan's Dr. Antoine Naaman. "But what we don't have is translation of this technology or these ideas into practical applications."

Standard usage of synthetic fibers at rates of 0.1 percent by volume won't do much more than effectively control plastic shrinkage cracks, Naaman adds. "But when you look at relatively higher content (1 to 2 percent or higher), and optimization for a desired property, then fibers can improve strength and toughness of concrete enormously."

And while the customer or user might view mixes with such dosages as too expensive, he concedes, better-performing concrete will be the result. Fibers have been used in the amount of 10 percent in special military applications, Naaman adds.

Yet prospective high-dosage applications are not confined to low-volume markets. The advent of ultrathin whitetopping—placement of a cement-rich, concrete pavement over asphalt—represents a growing performance market that typically uses 3.0 lbs. of fiber per cubic yard of mix.

Fiber added at this rate equates to a minimum 100 psi of residual strength, an engineering factor fibrous-concrete proponents cite in promoting whitetopping methods.

Concrete pipe is another area getting close attention from the industry, Fibermesh's Hogan notes. "An unbelievable opportunity is emerging. We're doing extensive trials with very favorable results in fibrous concrete pipe," he says.

"Our marketing emphasis is going to be on performance fibers," says Dan Biddle, national sales manager for Forta Corp. "There are lots of researchers who are suggesting that 0.1 percent by volume — or 1.5 lbs. per cubic yard — is the absolute minimum dosage that should be considered" for enhanced applications.

Blast-resistant concrete eyed in the wake of the April 1995 Oklahoma City federal building bombing offers a market for performance fibrous concretes, while developments in synthetic fiber applications will spawn a "second revolution," he adds. Forta will reportedly unveil new fiber technologies next year.

Synthetic fibers work

Secondary reinforcement of concrete, as manufacturers point out, is an ancient technique. "The practice of adding fibers to concrete, mortar and other cement composites to inhibit cracking began thousands of years ago," says Bob Cruso, vice president of technology, Nycon, Inc.

It has been proved through laboratory testing that the addition of synthetic, steel and glass fibers improves the strength and durability of concrete. Synthetic fibers provide "secondary" (nonstructural) reinforcement, resisting cracks and even moisture. These synthetic fibers are used for crack control of concrete flatwork, including driveways, patios, slabs-on-grade, decks, sidewalks and curbs. They are also used in precast applications, such as vaults and septic tanks, where they make handling of units less problematic after release from forms.

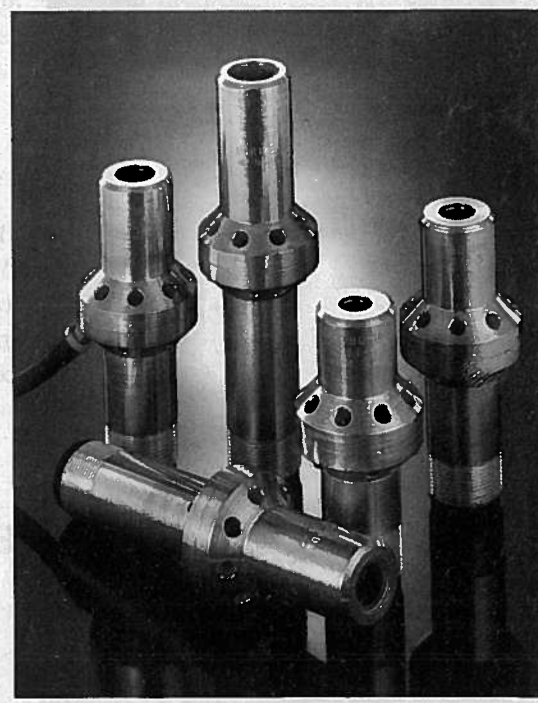
Nycon reports that testing conducted by San Jose University Professor of Engineering Paul Kraai shows a 71.5 percent plastic-shrinkage crack reduction in a fiber-reinforced sample over plain concrete, compared to a 6.5 percent crack reduction in a welded wire fabric sample.

Cruso adds that Nycon's nylon fibers produced "an 83 percent reduction in plastic-shrinkage cracking when the fibers were applied at the rate of one pound per cubic yard of concrete."

Likewise, Fiber-Ad Corp. of Charlotte, produces fibers meeting specs calling for minimum requirements of one pound of monofilament polypropylene fiber per cubic yard of concrete. But the issue of dosage has proved perplexing to the industry. In recent years, synthetic fibers' reputation has taken a hit as less-than-optimal doses have been applied in residential and commercial applications.

"We saw fibers shrink in length, diameter, shape, and change in chemistry," says Forta's Biddle. "We've seen dosages go from 1.5 lbs. per cubic yard down to a half-pound per cubic yard.

Continued with companion whitetopping report on page 34



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No small surprise that we began to hear comments that fibers don't work like they used to. We became concerned and are thrilled to hear researchers suggest that fiber dosage and length need to be reconsidered."

In its newsletter, the Carolinas Ready Mixed Concrete Association decried that trend, stating those who underplay dosage and use inappropriate fiber configurations to save money were threatening the goose that lays the golden egg, so to speak. "One trade practice has been to call 1.5 lbs. of fiber [per cubic yard] a 'commercial' dosage, and 0.75 lb. a 'residential' dosage," the association notes, adding that a concrete mix certainly can't know the difference between applications as it leaves the plant. — *Tom Kuennen*

Whitetopping gets respect

Ultrathin whitetopping (UTW) is a critical market for synthetic fibers, and not just because the new Transportation Equity Act for the 21st Century (TEA-21) brings an average 44 percent increase in federal funding for surface transportation each year through 2003.

Producers also see considerably higher dosage rates indicated for UTW, well in excess of the 0.1 percent used for residential applications — in fact, closer to 3 to 4 percent by weight. "In 1998, we have became more active in fibrous concrete for the transportation sector," says Peter Martinez, president and CEO, Kapejo, Inc. "Ultrathin whitetopping brings fiber-reinforced concrete into the DOT market. This traditionally goes at a rate double the normal dosage rate of the particular fiber used."

Durafiber, Inc. has been particularly active in promoting UTW applications, working with the Tennessee DOT and research efforts. "The Tennessee DOT has been very progressive in partnering with the concrete industry," says Jim Speakman, national sales and marketing director. "A lot of states are changing their ways and partnering with new applications and techniques that provide longer life."

Nationwide, UTW has moved ahead on several fronts this year. In May, a test began at Turner-Fairbank Highway Research Center's Accelerated Loading Facility (ALF) to compare performance of UTW with and without polypropylene fibers. Turner-Fairbank is the McLean, Va.-based research unit of the Federal Highway Administration (FHWA).

"This is the first time that concrete has been tested under the ALF," notes Charlie Churilla of FHWA's Office of Research. "We believe that thin concrete overlays offer a cost-effective solution for high loadings, especially in slow-speed trafficked areas such as intersections. The ALF is especially suited to this type of testing."

ALF applies an average of 50,000 loads per week, testing 24 hours a day. Initial tests are being done on eight, 14.5-m lanes. The UTW overlays are 6.4 cm (2.5 inches) and 8.9 cm (3.5 inches), with and without polypropylene fibers, and have 1-m, 1.2-m, and 2-m (3.3-, 3.9- and 6.5-foot) joint spacings.

Just before the ALF project, a definitive, peer-reviewed paper on UTW was presented at the 1998 meeting of the Transportation Research Board in Washington, D.C. *Ultra-thin Whitetopping: The State-of-the-Practice for Thin Concrete Overlays of Asphalt* was presented by American Concrete Pavement Association engineers James Mack, director of engineering and rehabilitation; Lon Hawbaker, director of market development/local roads; and Larry Cole, vice president, engineering and research. Since a 1991 Louisville UTW investigation, there have been over 100 projects built throughout North America, the vast majority at intersections, they write. Among a variety of admixtures, including water reducers and/or plasticizers for a low water cement ratio, are synthetic fibers. "The fibers are added to increase the post-crack integrity of the panels," the authors contend. (Note chart for mix designs used for recent UTW projects.)

Tennessee Department of Transportation's work with ultrathin whitetopping has included a project along Main Street in South Pittsburgh. Placed over a weekend, the job called for a new fiber-reinforced topping slab 4 in. thick. Sequatchie Concrete Services provided material.

In the 1998 TRB paper, Mack, Hawbaker and Cole of the American Concrete Pavement Association detail concrete mix designs for ultrathin whitetoppings with and without synthetic fibers.

- Iowa State Route 21, 1994: normal mix for opening to traffic in five to seven days
- Leawood, Kan., 1995: opening to traffic in one to two days
- Tennessee & DeKalb County, Ga., 1996: fast track mix for opening to traffic in 24 hours or less

Material Proportions (One cubic meter)	Iowa S.R. 21	Leawood	Tennessee/DeKalb
Cement (kg)	340	362	474
Fly Ash (kg)			
Coarse Aggregate (kg)	986	1005	1008
Fine Aggregate (kg)	809	783	730
Water (kg)	145	133	166
Air Content (%)	6	6.5	
Water/Cement Ratio	0.43	0.37	0.35
Synthetic Fibers (kg)	0* or 1.36	0* or 1.36	1.36
Compressive Strength 24 hrs. (D=design), (A=actual)		20.69 (D)	20.69 (D) 34.48 (A)

* Sections without fibers used as control sections