Born of a Need

Emerging as true crack-control reinforcement, "structural" fibers have gained a stronger foothold in concrete

By Ted Worthington

Synthetic fibers have been around for 25 years, and are acknowledged as being effective at controlling plastic shrinkage cracking in concrete and can be beneficial to help concrete resist abrasion and impact. A new generation of fibers, though, has now been developed that serves to control crack widths from thermal forces and shrinkage cracking, replacing *secondary* or *temperature* reinforcement.

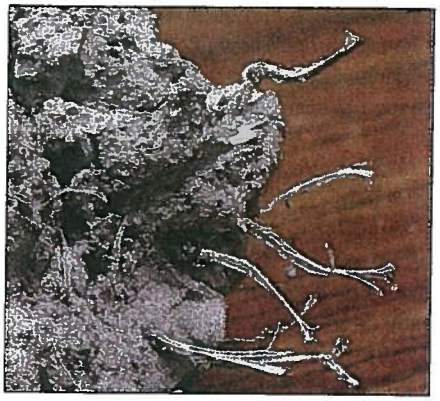
The newer fibers, called *macrofibers* or *structural* fibers, have demonstrated their ability to control crack widths, particularly in slabs on ground. However, many concrete contractors are unfamiliar with how the old fibers (now referred as to *microfibers*) differ from the new macrofibers, and are unfamiliar with the capabilities and benefits available with these new fibers.

In general, the differences between the fiber types are few, but very meaningful. Dan Biddle, of Forta Corp., points to the 4 C's of structural or macrofibers—Chemistry, Content, Configuration and Correct length—to get at the differences.

Chemistry simply refers to what the fiber is made of. Microfibers originally were made from all sorts of things, including polyester, nylon, and steel. Their purpose was to build up early tensile strength to resist shrinkage stresses that increase as the concrete sets. They didn't necessarily have to last forever; their job was finished once the concrete hardened.

However, macrofibers have to last as long as the concrete, so polypropylene (also referred to as *polyolefin*) tends to be most popular choice. It doesn't absorb water and is resistant or inert to alkali.

Content refers to the amount of fibers placed in a mix. The dosage of the first-generation synthetic fibers is 0.5 to 1.5 pounds per cubic yard to be effective in reducing plastic shrinkage cracks. Structural fiber dosages up to 20 pounds per cubic yard, though, are not uncommon. So, the suggested dosage, as found on a technical data sheet, is a dead giveaway whether a fiber is intended to control plastic shrinkage cracking or can provide something more.



Synthetic "structural" fibers in concrete.

Macrofibers can function as secondary reinforcement, but they actually help with everything beyond plastic shrinkage cracking, says Mike Mahoney, materials engineer for Euclid Chemical. This includes drying shrinkage and thermal cracking—and they may also be effective for increasing the flexural strength of the concrete. The term "structural" fibers, however, isn't universally accepted. For example, the American Concrete Institute does not recognize any tensile contribution from synthetic fibers in the design of concrete structures.

Yet, unlike wire mesh or rebar, macrofibers are added directly into the mix and thus do not need to be placed into position. They don't affect the mix design because they don't absorb water. However, macrofibers can affect the slump of the mix, which might require the use of superplasticizers. As always, it is best to consult the manufacturer

Glossary of selected fiber terms

Aspect ratio: the ratio of the length of the fiber to its equivalent diameter.

Fibrillated: a fiber that breaks down into a smaller network of fibers. It also anchors better in the concrete than monofilament fibers.

Macrofibers: This term is frequently used to describe synthetic "structural" fibers. Usually longer than first-generation fibers (now sometimes called microfibers), they range from 1 to more than 2 inches in length. Macrofibers can serve as secondary reinforcement in slabs or precast concrete in the place of WWF or rebar. The term structural fibers has not gained universal acceptance, since these fibers do not replace primary reinforcing steel.

Microfibers: These fibers were introduced to act as secondary reinforcement, although that is debated. They are usually acknowledged as helping to control plastic shrinkage cracking.

Monofilament: a single strand of synthetic material.

Plastic shrinkage cracks: This is the cracking that can occur as the concrete sets. These cracks are the arena of the shorter, first-generation microfibers.

Polyolefin: any of a group of polymerized thermoplastic resins; the term is often used interchangeably with *polypropylene*.

Polypropylene: polymerized propylene; a very light, highly resistant, thermoplastic resin used for making everything from clothing to coatings, plastic pipe to packaging material. It is the most common material for making macrofibers because of its alkali resistance.

Poly vinyl alcohol: a polymerized vinyl compound sometimes used in making macrofibers.

Synthetic structural fibers: also known as *macrofibers* (see above).

Pouring a bridge deck overlay with synthetic macrofibers.

for mixing, placing, and finishing procedures.

Configuration refers to the shape of the fiber. The two main shapes are monofilament or fibrillated. Monofilament fibers are single discrete fibers, though some have bulbous ends that act as an anchor in the concrete. Fibrillated fibers, which disintegrate into a smaller network of fibers, tend to provide a better anchor than standard monofilaments. Some manufacturers have developed combinations of monofilaments and fibrillated fibers; others blend macrofibers and microfibers together.

Last but not least, *correct length* is important. First-generation fibers (microfibers) are typically ¾ inch in length, but macrofibers tend to be longer, usually 2 inches, sometimes longer. That's where the term *macrofiber* comes from.

The price of steel in China

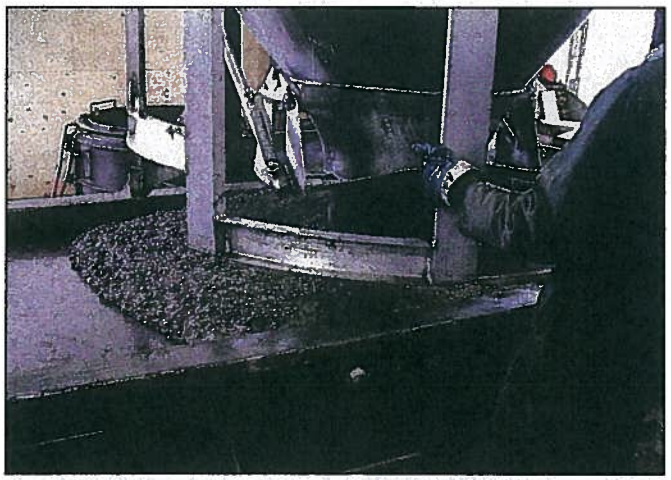
What is so important about macrofibers? Manufacturers have been testing fibers for structural uses for years, but the demand for macrofibers took off only recently as steel prices began to rise. In the last two years, the price of steel more than doubled, partly as a result of the building boom in China, and contractors began looking for an economical alternative.

While the cost of the fibers is about the same as steel, macrofibers save money in other ways. Placing steel reinforcement requires time and labor. Macrofibers are simply added to the mix—they are self placing.

In slabs on grade, concrete contractors using macrofibers can consider increasing the joint spacings, cutting costs on joint filling and maintenance. Precast producers are finding benefits in macrofibers; this is what they have been wanting all along, says Biddle.

While synthetic fibers have been used in concrete for 25 years, Biddle says the advances due to macrofibers have not yet been fully realized. He also notes that some researchers have begun testing the ability of macrofibers to decrease slab curling.

Contractors eventually will come to know the benefits of these products, but in the meantime the accompanying table and glossary can help cut through all the clutter. If you are interested in any of the products listed, circle the corresponding reader service number and mail the card in.



Pouring a precast structure with only macro-synthetic fibers as the reinforcement.

Comparison of fibers

Product	Company	Material	Form	Length (inches)	Dosage	Website	Circle Number
Forta Ferro	Forta Corp.	Polypropylene	Monofilament/fibrillated	2.25	3–20 lbs/yd^3	www.fortacorp.com	1
Bone Shaped Fiber	Silacon Valley	Polyolefin	Monofilament	1.5	5–15 lbs/yd^3	www.silacon.com	2
Novomesh 950	SI Concrete Systems	Polypropylene	Monofilament/fibrillated	2	5 lbs/yd^3	www.fibermesh.com	3
NyconXL	Nycon	Polyolefin	Collated Fibrillated	1.5	3–7 lbs/yd^3	www.nycon.com	4
Strux 85/50	Grace Construction Products	Polypropylene/polyethylene	Monofilament	2	5–15 lbs/yd^3	www.graceconstruction.com	5
Strux 90/40	Grace Construction Products	Polypropylene/polyethylene	Monofilament	1.5	3–11.8 lbs/yd^3	www.graceconstruction.com	6
PVA fibers	Kuraray	Polyvinyl alcohol	n/a	n/a	10 lbs/yd^3	www.kuraray-am.com	7
Durafiber CF	Durafiber	Polypropylene	Fibrillated	0.5-2	3–7 lbs/yd^3	www.durafiber.com	8
Tuf-Strand SF	Euclid Chemical	Polypropylene/polyethylene	Monofilament/fibrillated	2	3–20 lbs/yd^3	www.euclidchemical.com	9

n/a = not available