Engineering Editorial

Steel and Synthetic Fiber Blends

BACKGROUND

Industry trends in fiber-reinforced concrete (FRC) encompass the combination (or blending) of steel and synthetic fibers. This combination leverages the ability of synthetic fibers to reduce plastic settlement shrinkage and plastic shrinkage cracking, as well as to modify the micro-macro shrinkage cracking of hardened concrete. At the same time, it maximizes the ability of steel fibers to improve concrete's tensile, shear, fatigue, and impact strength.

Nycon's steel-synthetic fiber blend is called NyconB, and it is a combination of NyconRC, a synthetic, and NyconSF Type I, a cold-drawn steel fiber. NyconRC, with 34 million ¾" fibers per one-pound dosage, provides the best fiber spacing and bond to matrix, and consequently superior interception of cracks at their origin. (Nycon also offers NyconSF Type II, a slit-sheet steel fiber; both types of steel fibers meet all standard specifications, including ASTM A820 and C1116).

NyconB is available in a number of combinations of steel fiber blended with one pound of NyconRC. Steel fibers improve specific engineering properties of concrete, such as increasing tensile and shear strength, as well as fatigue and impact strength. Additionally, at dosage levels of 40 pounds per cubic yard and higher, they improve flexural strength, a key factor in designing slabs-on-ground.

Some FRC marketing approaches suggest a lower dosage rate of steel fiber that can be used, even as low as 15 pounds per cubic yard of concrete. Nycon considers this dosage level—and, in fact, any dosage below 25 pounds per cubic yard—to be outside the meaningful contribution range of steel fiber. Below 25 pounds, the cost far outweighs the technical contribution, since only one pound of steel fiber is added per cubic foot. To meet value engineering requirements, two to three pounds of synthetic fiber would be a better alternative.

RATIONALE

With NyconB, the engineering design properties of steel fibers and the attributes of synthetic fibers are combined to mutually enhance the durability and performance of concrete: The synthetic NyconRC fibers reduce plastic and hardened concrete shrinkage; in turn, this shrinkage reduction enhances the bond between the steel fibers and mortar, providing optimum utilization of the steel fibers.

TESTING PROGRAM

Nycon engaged the services of Dr. Ramakrishnan of the South Dakota School of Mines and Technology to research the potential benefits of NyconB as a secondary reinforcement. The program also included a companion study of the engineering properties of NyconSF Type I and NyconSF Type II steel fibers.

Test points included NyconSF Type I steel dosage levels of 25, 42, 50, and 66 pounds each combined with one pound of NyconRC synthetic fibers per cubic yard of concrete. Tests included were compressive strength, flexural strength, splitting-tensile strength, ASTM C1018 Toughness Index and Residual Strength, and JSCE SF4 Japanese Toughness and Equivalent Flexural Strength.

TEST RESULTS

As indicated earlier, NyconB testing was done with both NyconSF Type I and Type II steel fibers—each at 1" and 2" lengths and at 25, 42, 50, 66, and 85 pounds per cubic yard of concrete.

A highlight of the test data was the Japanese Toughness and Equivalent Flexural Strength factor. (An important the note: Fibers contribute to pre-first crack properties of concrete, but of equal if not more importance, they benefit concrete's post-first crack properties. This is where ASTM C1018 and C1399 and the JSCE SF-4 tests provide an excellent picture of the fiber contribution to the concrete composite, the focus being on the fibers' ability to carry load after first-crack. In effect, the fibers transform the failure of the concrete from brittle to ductile. In essence, the fibers can potentially preclude catastrophic failure of the concrete.)

Except for the mix with 2" long NyconSF Type I fiber blend, testing data demonstrated that, NyconB-reinforced concrete samples had higher Japanese Toughness and Equivalent Flexural Strength numbers than the 100% steel fiber mixtures. The higher numbers demonstrate that synthetic fibers do aid in anchoring the steel fibers to the mortar to allow them to serve as a bridge across cracks and provide load-carrying capability.

DISCUSSION

When post-first-crack performance is a consideration in designing a concrete element, NyconB is an excellent reinforcement candidate. It creates a three-dimensional reinforcing network that acts like a hinge at the point of cracking, with the added quality of reducing the potential of catastrophic failure. Lastly, the fibers' ability to hold the concrete together after it cracks can be projected onto the realm of non-standard loading, as in seismic and blast/impact loading of concrete composites.

An excellent visual test of the benefit of NyconB to concrete post-first-crack is to place two standard 6" x 12" concrete cylinders, one plain and one fiber-reinforced in a compression machine. Then, test both cylinders per standard practice up to ultimate load and continue to load to fracture. The pieces of the fractured plain cylinder will fall away leaving nothing of the original specimen. The load on the fiber-reinforced cylinder, on the other hand, can be increased beyond the plain concrete's point of fracture. When the fibered sample does fracture, the pieces continue to work together to support the load. In some cases, the cylinder height can decrease from 12" to 10" with the fractured pieces still supporting load.

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