INTRODUCTION

With the continuing growth in the use of macrosynthetic fibers and macrosynthetic-microsynthetic fiber blends, a more precise understanding of the properties of concrete reinforced with these materials is required. Currently, three test methods are on the books at ASTM International that are specific to the testing of fiber reinforced concrete (FRC) post-first crack. These test methods are ASTM C1399, C1550 and C1609. These test methods can be found in ASTM International Standards Volume 04.02. There are other test methods that have international recognition: specifically the EFNARC Square Panel Tests and the British Standard Notched Beam Test (CMOD). ABC Polymer Industries is developing a data base for our macrosynthetic fibers with these test methods as well.

STANDARD TEST METHODS

ASTM FRC/FRS specifications and test methods are under the purview of Subcommittee C09.42. The specification for Fiber Reinforced Concrete and Shotcrete is C1116. The value of this specification is very limited. Basically, it addresses the chemical compatibility of the various fiber groups with cement concrete. Additionally, it covers the approach to use when specifying FRC. Four test methods fall within the control of subcommittee C09.42, three of which evaluate post-first crack properties of the FRC/FRS. These post-first crack methods basically look at the same engineering properties, but each in a different way. Please note that standard plastic and hardened concrete test methods apply to FRC/FRS as well.

1. C1609 – Flexural Toughness and First-Crack Strength of FRC. This test replaces the C1018 test method, which has been abandoned by ASTM International.

2. C1399 – Average Residual Strength of FRC. This test is unique in that a steel plate is inserted beneath the test beam up to and including first crack at which time it is removed and the test is continued.

3. C1550 – Average Residual Strength using a Round Panel Test of FRC. This is the newest of the three post-first crack test methods. The equipment required to conduct this test is super-sized based on the dimensions of the round panel. To date, the test has not gained traction in the U.S.

TEST METHOD SELECTION

In the United States, ASTM C1399 and C1609 are the test methods consistently used in evaluating FRC/FRS. Both C1399 and C1609 address the FRC properties post-first crack. First crack is the point when C78 produces the ultimate flexural strength and the C78 test is concluded. C1399 and C1609 pick up the testing of the fractured beam from this point forward. Very specialized equipment and software are required to accurately record, analyze and report the data for these two test methods. ASTM C1399 was originally developed to test microsynthetic fibers, but has become the alternate test method for macrosynthetic fibers and macro-micro blends assessment. ASTM C1609 is the most versatile as it can be used with macros, steel and blends. Today C1609 is becoming the preferred test method in the U.S. Reasons for selecting this test method over C1399 include the fact it is a continuous test and the loading is by closed loop. Closed loop is defined as loading of the test specimen based on the deflection of the specimen. The loading is not uniform based on pounds per time increment.

Caution: The test equipment and the assembly of this equipment are paramount to the success of producing valuable, reliable test data. Unfortunately, some laboratories misinterpret the equipment requirements, do not have the proper equipment to conduct the tests, or fail to understand the need for precise assembly of the required equipment. An accurate beam test assembly as prescribed by ASTM C1609 is depicted to the right.
To address this critical issue, the Fiber Reinforced Concrete Association (of which ABC Polymer Industry is a member) has contracted with TEC Services in Lawrenceville, Ga. to conduct testing intended to: first, establish the contribution of various equipment components to the test results and, second, offer solutions to improve the equipment or assembly to ASTM Subcommittee C09.42. The goal is to reduce the Standard Deviation and Coefficient of Variation issues that have plagued these test methods.

ABC Polymer has made it a priority to work with the commercial laboratory that will meet the high-performance standards required for conducting ASTM C1399 and C1609. That commercial laboratory, in our opinion, is TEC Services.

**OTHER IMPORTANT PERFORMANCES**

Additional test methods exist to evaluate properties other than post-first crack toughness:

- **C1579** – Evaluating Plastic Shrinkage Cracking of Restrained Fiber Reinforced Concrete (using a Steel Form Insert). This is a relatively new test method (the fourth within the control of subcommittee C09.42) and has been in the development stage since the early '90s when originally conceived by Dr. Paul Kraai. Some limits still remain to this test method in terms of the variability of the data generated. It is a good indicator of the FRC's ability to reduce the number and size of plastic shrinkage cracks. This test method as well as the others cited below can be found in ASTM Standards Volume 04.02.

One additional test method has yet to be adopted by ASTM Subcommittee C09.42, but is used by the industry for compliance testing and/or research:

- **Impact Test** – How the fibers affect the energy required to initiate cracking and to what degree the fibers hold the concrete together after it has cracked. A modified Proctor or Marshall test-assembly (a 10-pound hammer is dropped 18 inches onto a steel ball that imparts a point impact load to a concrete disk measuring 6” in diameter that is 2.5” high). This test method can be found in ACI Committee Report 544.2R at http://civilwares.free.fr/ACI/MCP04/5442r_89.pdf. More information can be found on the impact strength of FRC in the Technical Bulletin titled “Abrasion, Impact, and Fatigue Resistance of Synthetic Fiber Reinforced Concrete.”

**ADDITIONAL CONSIDERATIONS**

One modification that may be required when testing FRC comes when testing the air content. Selection of the equipment to measure the air content of fiber reinforced concrete/shotcrete when low dosage levels of fibers are used is not critical (0.5 to 2.0 pcy). However, when higher dosage levels of fibers (typically macrosynthetic fibers at 5.0 pcy or higher) are specified some potential exists for the fibers to bridge in the cylindrical pressure vessel and create entrapped air voids, even when the proper consolidation method is followed. **DO** externally vibrate the vessel. **DO NOT** internally rod the vessel. To determine true air content values at the higher fiber dosage level, a roll-o-meter test (ASTM Test Method C173) should be considered due to the potential of entrapped air resulting from the elevated dosage levels of fiber. This practice is recommended for synthetic fiber dosage levels at or above 5.0 pounds per cubic yard and steel fiber dosage levels at or above 65.0 pounds per cubic yard.

**CONCLUSIONS**

ABC Polymer Industries has developed a full menu of macrosynthetic fibers. Each of these products has its own distinctive physical properties and properties beneficial within the concrete. We have secured approvals from several state DOTs for these macrosynthetic fibers and continue to work with additional agencies to secure approvals for these products.

Please contact your FiberForce Representative for more information on these products and their approvals.