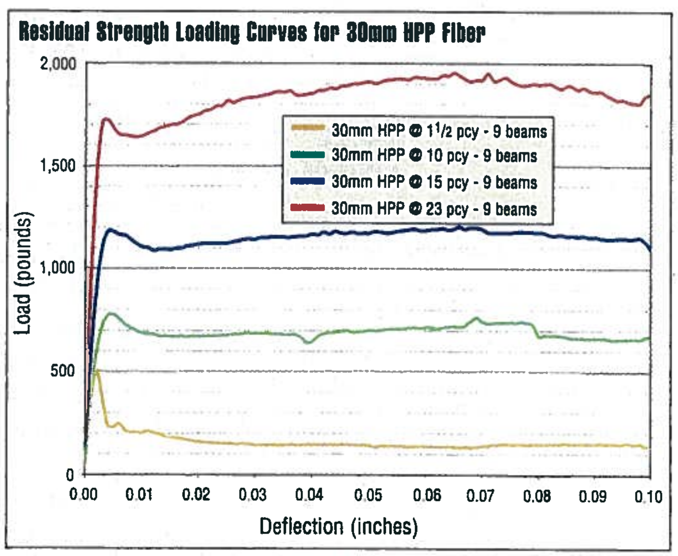
By Rick Yelton

Comparing Fiber Performance

ASTM C 1399 gives producers an easy way to measure the toughness of fiber reinforcement in concrete.

Producers have long been touting the benefits of fiber-reinforced concrete, helping concrete contractors understand how fibers improve the quality and durability of flatwork. Now, recent research and marketing initiatives are enabling producers to communicate to design engineers and code enforcement officials the benefits of fibers in load-bearing concrete applications such as poured foundation walls.

A key reason for this renewed interest in fiber-reinforced concrete is the growing interest in predicting "survivability"—how a structure withstands the effects of an unplanned destructive force. Greater survivability provides a safeguard for rescue workers and survivors of the initial cause of the building damage. Perhaps the most graphic example of survivability is the way the World Trade Center towers, in the attack of Sept. 11, 2001, remained



As the quantity of fibers are added to the mix, the residual strength of the concrete increases.

standing after the jet's impact long enough to evacuate the lower floors.

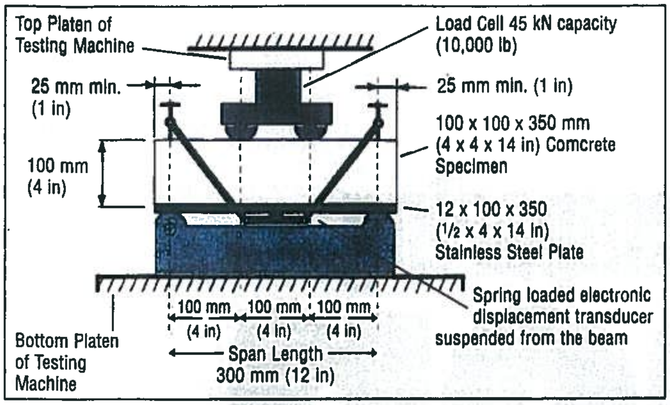
Measuring toughness

To make structures safer, many code officials are considering the call for additional provisions that require manufacturers or producers of construction materials to provide a measure of toughness. As engineers consider design improvements to meet these proposed provisions, they will rely on approved testing methods to measure and quantify such concepts. For years, the engineering community has primarily judged in-place concrete on its compressive strength. But as building code research focuses once again on seismic design and residual strength, the engineering community is recognizing the need for quantitative measurement of additional concrete properties, including toughness.

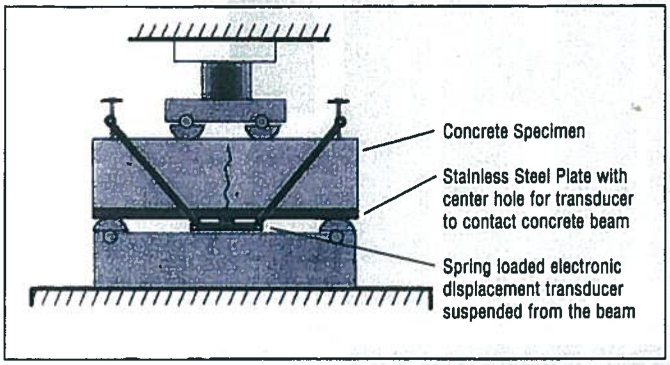
These trends point to more widespread specification of construction materials such as fiber-reinforced concrete, and producers must be prepared to provide evidence of how their materials can provide the required safety measure. ASTM C 1399, "Test Method for Obtaining Average Residual Strength of Fiber-Reinforced Concrete," can help producers meet that challenge. This recently approved method is a less expensive and less lengthy test method as compared to other tests of measuring concrete's residual strength.

In addition to providing a quantitative measure for evaluating the performance of fiber-reinforced concrete, the test also gives those involved in mix design a method of comparative analysis among beams containing fibers of different types, materials, dimensions, and shapes. Producers can use the test results to optimize the proportions of fiber-reinforced concrete mixtures, to determine compliance with construction specifications, and to help evaluate fiber-reinforced concrete that has been in service.

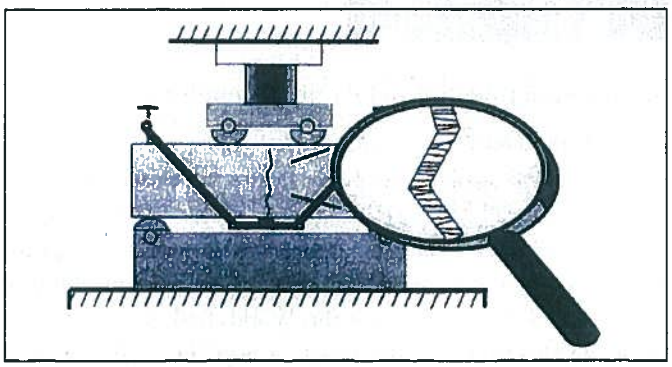
The test measures the fiber's ability to hold cracked concrete together. Known as average residual strength, this measure of toughness is determined by calculating the average of a test beam's load-sustaining capability at net deflections taken at four



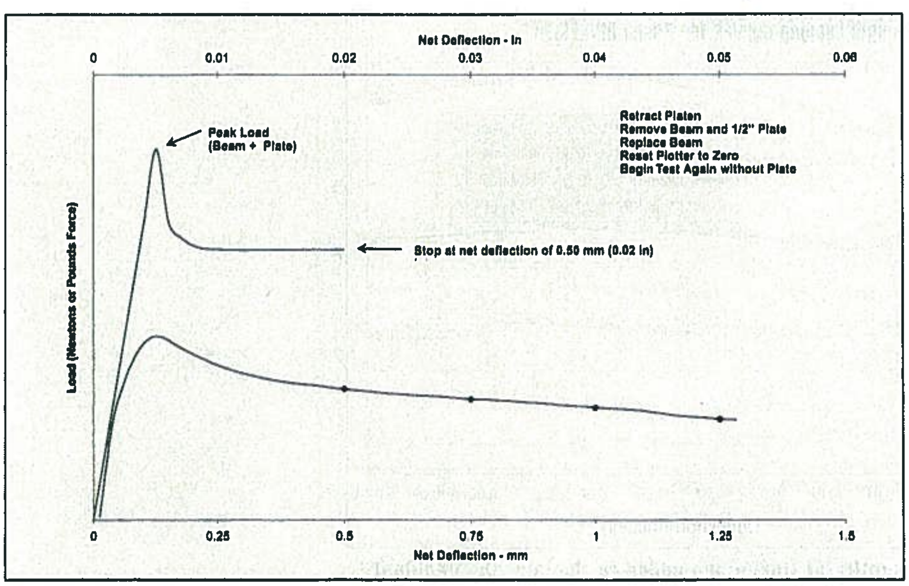
The test begins by calculating the average of a beam's capability taken at four different points.



After the beam is cracked, the residual strength is determined by the load-carrying capacity.



As downward pressure is applied, the crack opens. The spring-loaded transducer measures the deflection of the opening.



The curve of a typical result using ASTM C-1399 to calculate residual strength of fiber reinforced concrete.

Key Terms

Residual strength
The flexural stress on the cracked beam section obtained by calculation using loads obtained from the reloading curve at specified deflection values.

Average residual strength
The average stress-carrying ability of the cracked beam that is obtained by calculation using the residual strength at four specified deflections.

Deflection (sometimes termed net deflection)
Mid-span deflection of the test beam obtained in a manner that excludes deflection caused by the following: (1) the flexural test apparatus, (2) crushing and seating of the beam at support contact points, and (3) torsion of the beam.

points after reloading the cracked concrete specimen. The level of load-sustaining performance for a concrete of a specific compressive strength is primarily a function of the type, design, length, and addition rate of the fibers employed.

How the test is done

ASTM C 1399 measures the level of load sustained by fibers after a concrete beam is cracked in a controlled manner. This load-carrying capacity determines a residual strength for a fiber-reinforced concrete beam.

Cast or sawn beams of fiber-reinforced concrete are conditionally cracked using the third-point loading arrangement specified in ASTM Test Method C 78. Initially, a steel plate is used to support the span of the concrete beam so that the beam can be cracked at a controlled deflection rate on an open-loop loading system. After controlled cracking the steel plate is removed and the cracked beam is reloaded to obtain a residual load-deflection curve. Loads are measured at specified net deflection points A, B, C, and D (0.50, 0.75, 1.00 and 1.25 mm, respectively) on the residual curve. These load values are then averaged and factored for beam geometry to obtain the Residual Strength of the specimen.

The residual strength is calculated by averaging the load values of A, B, C and D and the number by a beam geometry factor k. the k factor is determined by the equation k = L/bd2, where L is span length, b is beam length, and d is beam depth.

The final formula for average residential strength is ARS = ((A + B + C + D) /4) (k (0.50, 0.75, 1.00 and 1.25 mm (0.020, 0.030, 0.040 and 0.050 in) on the residual curve.

The high the number, the more resistant to post-cracking movement the concrete is. The Average Residual Strength (ARS) is reported in psi or MPa.

How fibers add toughness

The test for residual strength is designed to measure how fibers increase a hardened concrete's toughness. While steel reinforcement, like rebar or mesh, performs this function on a large design scale, fibers can provide additional toughness on a more localized scale.

The fibers can often provide closing pressures across matrix cracks, holding small cracks together and reducing some large

Fiber Resources

Company	Location	Phone	WOC Booth
Advanced Building Technologies, LLC/Rhino ICF	Phoenix, AZ	877-530-3519	9239
AFM R-Control	Excelsior, MN	800-255-0176	
Amazon Forms LLC	San Antonio, TX	866-651-3322	
American ConForm Industries	Santa Ana, CA	800-266-3676	
American Polysteel	Albuquerque, NM	800-977-3676	
AMVIC Inc.	Toronto, ON	877-470-9991	
Arxx Building Products	Cobourg, ON	800-293-3210	
ECO-BLOCK LLC	Pompano Beach, FL	954-766-2900	
Formtech International Corp.	Markham, ON	416-410-6155	1337
ICE Block (manufactured by Tasler, Inc.)	Webster City, IA	800-482-7537	
Insul-Deck	Florence, KY	859-525-6720	
IntegraSpec	Kingston, ON	613-634-1319	
LOGIX (AMC Insulation Corp.)	Winnipeg, MN	877-442-4465	
LOGIX (Beaver Plastics Ltd.)	Edmonton, AB	888-453-5961	
LOGIX (Perma "R" Products Inc.)	Johnson City, TN	800-251-7532	
LOGIX (PSC Moulding Corp.)	Ajax, ON	888-706-7709	
LOGIX (Form Systems)	Wichita, KS	888-838-5038	
Owens Corning	Wadsworth, IL	847-623-6646	7001
QUAD-LOCK Building Systems	Surrey, BC	888-711-5625	2573
Reddi-Form Inc.	Oakland, NJ	800-334-4303	
Reward Wall Systems	Omaha, NE	800-468-6344	
SAFE Block	Westerville, OH	800-865-3805	
Standard 895 Direct	Owatonna, MN	800-424-9255	
Wisconsin Thermo-Form Inc.	Sturgeon Bay, WI	800-360-4634	

movements. Fibers also can inhibit the way cracks group together. These functions may allow the concrete matrix to hold together and aid the steel reinforcement by improving the capability of the material to carry stresses beyond matrix cracking.

The fibers' response to cracking allows for the concrete matrix to absorb more post-crack energy than plain concrete. This response is often called toughness. It has benefits under both statically and dynamically applied loads. An example of a static load would be the weight of a floor beam, or gravity.

Even absent a catastrophic event, fiber reinforcement can improve long-term durability by restricting the size of cracks in service. There is a current push to use synthetic fiber reinforced insulated concrete formed wall systems. Research sponsored by a consortium of members of the Strategic Development Council, has yielded a report that explores the design of ICF wall systems for the structural walls for habitable housing units.

The report, completed by Dr. Ron Zollo, professor at the Univ. of Miami (Fla.), showed that ICF systems that use fiber-reinforced concrete satisfy conventional reinforced concrete design standards as contained in ACI 318 Chapters 9 through11. The use of fiber reinforced concrete would eliminate the need for vertical steel reinforcement in many building applications. Consortium members plan to submit their report to residential code bodies for acceptance and approval.

Sources

1) *Banthia, N. and Dubey, A., "Measurement of Flexural Toughness of Fiber Reinforced Concrete Using a Novel Technique, Part I: Assessment and Calibration," In Press, Materials Journal, American Concrete Institute.*

2) *ASTM C 1399: "Test Method for Obtaining Average Residual-Strength of Fiber-Reinforced Concrete," Annual Book of ASTM Standards, Vol. 04.02, 1999.*

Want to learn how ASTM C 1399 really is affected by mix design? Participate in T*HE* C*ONCRETE* P*RODUCER sponsored research on ICF Mix Design. Learn about this exciting opportunity to help further industry research by going to page 79.*

Information and illustrations for this article were provided by SI Concrete Systems, Chattanooga, Tenn., and were originally published by E. Don Smith and Greg Moody in the Fibermesh Engineering Data Report.

To learn more about innovations in fiber-reinforced concrete used in insulating concrete from construction, visit the "what's new" section at www.fibermesh.com.

There's an interesting report on Vertiforce, a new product that is based on a special blend of steel and polypropylene fibers designed to strengthen poured-in-place concrete walls.