AR-CRACKNON™ AN AR GLASS FIBER THAT IMPROVES CONCRETE DURABILITY BY CONTROLLING CRACKS.

Cracking affects the durability of concrete. Alkali Resistant (AR) Glass Fibers, like those found in AR-CRACKNON, have high tensile strength—three times higher than steel—and high Young's Modulus—over 10 times that of polypropylene—and three times that of cured concrete. These properties combine to provide effective control of cracking caused by plastic shrinkage and restrained drying shrinkage.

AR-CRACKNON will either prevent cracks from forming or will alter the cracking pattern from a few large, wide cracks to many smaller, finer cracks. Both these effects will improve concrete durability by reducing water permeability and absorption and reducing the depth of carbonation.

DEPTH OF WATER PENETRATION

(concrete for highways)

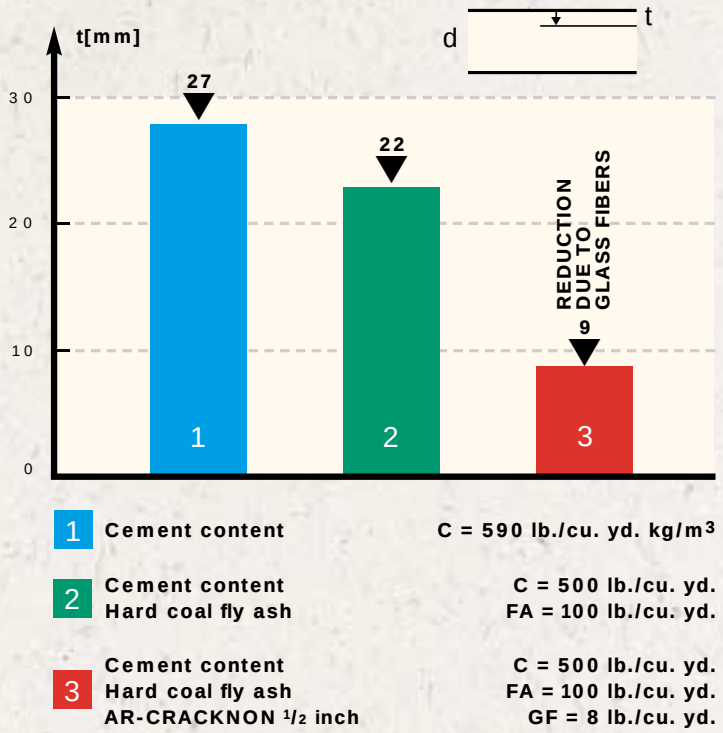

FIG. 1

DEPTH OF CARBONATION

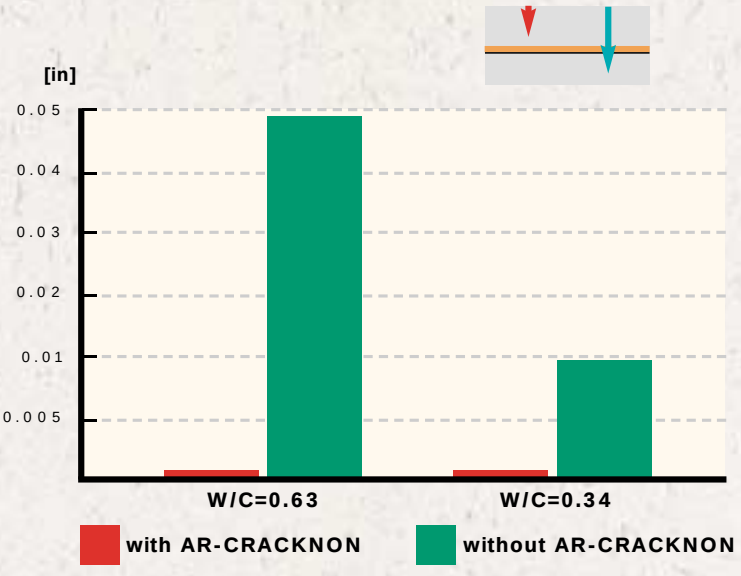

FIG. 2

Nippon Electric Glass America, Inc.

CONTROL CONCRETE CRACKING

When concrete cracks, the owner of the structure has three options: 1. Repair it. 2. Replace it, or 3. Ignore it. **But when AR-CRACKNON is added to the mix, cracks can be minimized, changed or eliminated so the owner never has to make this type of decision.**

The reason AR-CRACKNON can control cracking in concrete is based on these factors:

First, due to their high tensile strength, AR glass fibers, like those found in AR-CRACKNON, are not usually fractured by the stress induced by the crack meeting the fiber.

Secondly, AR-CRACKNON fibers have a Young's Modulus greater than the concrete matrix, which can prevent cracks from starting because the concrete can transfer tensile stresses and strain to the fibers.

Fiber content is important. AR-CRACKNON can be mixed in sufficient quantity and uniformly dispersed so any cracks that do start will have a high probability of being arrested by the fibers and will be prevented from progressing completely through the concrete.

CHARACTERISTIC	UNIT	PLASTIC	STEEL	AR GLASS	CONCRETE
TENSILE STRENGTH	psi	70,000	100,000	300,000	550
YOUNG'S MODULUS	psi	0.6×10^6	29×10^6	11×10^6	4.0×10^6
BREAKING ELONGATION	%	50-150	5-35	2	2-3
APPARENT SPECIFIC GRAVITY	g/cm^3	1.0	7.85	2.7	
LENGTH	in	0.75	1-2	0.5 - 1.5	
DIAMETER	in	0.0014	0.03	0.0005	
NUMBER OF FIBERS	per oz	$1.8 - 10^6$	650	6×10^6	

TABLE 1

Glass fibers, steel fibers, and plastic fibers are commonly used for controlling crack development in concrete. The above table illustrates typical physical properties of each of these fiber types.

Only AR-CRACKNON provides the unique combination of properties:

- **High Tensile Strength**
- **High Young's Modulus**
- **Small fiber diameter – more individual fibers per pound**
- **High fiber content possible**
- **Alkali Resistance**

IS YOUR GLASS FIBER AR?

Alkali Resistance (AR) is Key.

The glass fiber must be resistant to the alkaline condition of the concrete. Only a minimum amount of zirconia in the glass composition will provide true alkali resistance.

Concrete is very alkaline and as such it will quickly corrode "E" glass fibers, the type of glass fibers that are used to reinforce plastics. For effective reinforcement only glass fibers that have been specially developed to be alkali resistant, such as those containing zirconia should be used, and not those dependent on a surface coating for corrosion protection. The higher the zirconia content the better the alkali resistance, which is why AR-CRACKNON has a minimum zirconia content of 19%.

WITH NEGA'S AR-CRACKNON.

HOW AR-CRACKNON CONTROLS CONCRETE CRACKING.

Cracks are caused by plastic shrinkage, drying shrinkage and load induced stresses. When cracks form, any stresses present are transferred across the cracks by the fiber reinforcement. The widths of the cracks will depend on the number of fibers present, their cross-section and their Young's Modulus.

AR-CRACKNON has a high density and a high Young's Modulus. These properties combine to provide effective crack control. The higher the fiber content, the better the crack control.

AR-CRACKNON DOSAGE LEVELS

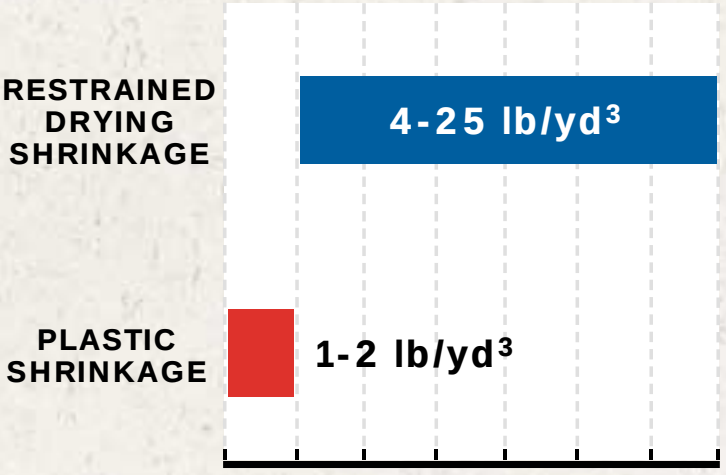

FIG. 3

The exact dosage depends on the concrete mix formulation and service conditions, consult NEGA technical service for recommendations.

DIFFERENT CROSS SECTIONAL AREA FOR THE SAME STRAIN

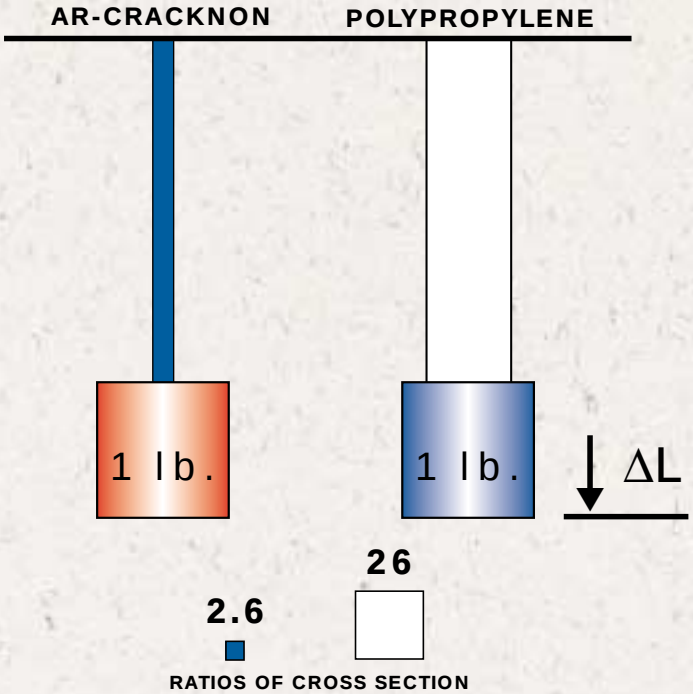

FIG. 4

Figure 4 shows that plastic fibers require 10 times the cross sectional area to carry the same amount of strain than AR glass fibers.

HOW AR-CRACKNON COMPARES TO OTHER FIBERS.

The efficiency of the fibers in concrete depends on how much the Young's Modulus of the fiber exceeds that of the concrete. The higher the Young's Modulus of the fiber, the greater its contribution is to resisting the forces and stresses in the concrete. Table 1 compares the Young's Modulus of different fibers. Glass fibers and steel have a Young's Modulus that is greater than hardened concrete and are therefore more efficient in controlling cracking in concrete.

AR-CRACKNON PROVEN ON NUMER

SHOTCRETE — **AR-CRACKNON is used in shotcrete applications for repair of structural concrete because it resists drying shrinkage cracks and is easy to handle, mix, pump, and spray. Finishing is easy since the fibers lie down smooth within the concrete (no hairiness) and are not visible on the surface. High fiber contents are possible so crack-free shotcrete can be produced.**

(Photos courtesy of U.S. Shotcrete.)

PRE-CAST OR PRE-STRESSED PANELS — **AR-CRACKNON nets have been used to help control cracking in pre-cast and pre-stressed panels. The net is rolled onto the mold bed, structural steel or pre-stress cables are placed, followed by the concrete. A second layer of net is rolled directly into the top surface of the concrete. The net helps reduce crack widths, or if heavy enough it will eliminate cracks, improving the durability of the concrete panel.**

Although it is not suggested that AR-CRACKNON can replace structural steel reinforcing in pre-cast panels, it can be used to replace temperature and shrinkage steel.

EROUS CONCRETE APPLICATIONS.

SLABS ON GRADE — **Foundation slab for a two-story building was poured using no steel reinforcing. An AR-CRACKNON net or scrim is first laid on the polyethylene damp proofing sheet. The concrete containing eight lb./cu.yd. of AR-CRACKNON chopped strands (1/2 inch length) is then poured directly onto the net. A second net is then placed on the concrete and lightly pressed—either by trowelling or screeding—into the top surface. The fines in the concrete encapsulate both layers of scrim so that they are just below the two surfaces of the slab. The AR-CRACKNON reinforced foundation slab will carry the light loads subjected by the two-story building and the slab will be far less prone to drying shrinkage cracking than a traditional steel mesh reinforced slab.**

(Photos courtesy of Novacrete.)

WATER PROOF STRUCTURES — **Because AR-CRACKNON in sufficient quantity or structure can eliminate drying shrinkage cracks—or allow only small narrow cracks in concrete—they can be used to provide water or liquid-proof structures. Figure 1 shows the result of water penetration tests. AR-CRACKNON chopped strands at the addition level of eight lb./cu.yd. reduced the depth of water penetration by two-thirds compared to plain concrete. This improvement in the liquid tightness not only can improve the durability of concrete but it can also allow the production of leak-proof concrete, a feature that was taken advantage of in the project shown in photo opposite.**

TESTS DEMONSTRATE AR-CRACKNON

HIGH FIBER CONTENT IS ANOTHER REASON AR-CRACKNON STOPS CRACKS.

Crack control is dependent on the number of fibers per unit volume of concrete. Because of the fine diameter of AR-CRACKNON, one pound will give three times the number fibers than plastic fibers and a hundred thousand more than steel fibers. As each fiber is a potential crack stop, AR-CRACKNON fibers are more effective than other fibers.

CRACK WIDTH CONTROL

The high Young's Modulus of AR-CRACKNON increases the stress at which cracks will start in concrete and also reduces the width of any cracks at a given stress. The durability of concrete has been shown in other tests to be very dependent on the absence of cracks over 4 x 10^{-3} in. Shotcrete trials with AR-CRACKNON under extreme drying conditions (Table 2) showed that a maximum crack width of 3.1 x 10^{-3} in. could be achieved whereas under similar conditions the crack width of a polypropylene reinforced concrete the maximum crack width was 9.8 x 10^{-3} in.

As well as preventing cracks in concrete, AR-CRACKNON can change the cracking behavior of steel reinforced concrete. Instead of large, wide cracks forming when steel reinforced concrete is stressed the AR glass fibers can cause the crack formation to change to that of many small cracks with small widths. This improves the durability of concrete structures.

NUMERICAL EVALUATION OF CRACKING CHARACTERISTICS, OBSERVATION AT AGE 14 DAYS

PROPERTY	DEFINITION	NEG	PLASTIC
(1) Strip Area	Shotcrete surface area [sq. ft.]	20.87	19.15
(2) Number	Crack count	22	36
(3) Length	Sum of length of all cracks [ft.]	10.89	21.78
(4) Crack Area	Sum of individual crack length x width [sq. in.]	0.22	0.53
(5) Specific Crack Count	= (2)/(1) [$ft.^{-2}$]	1.05	1.88
(6) Specific Crack Length	= (3)/(1) [$ft.^{-1}$]	0.52	1.14
(7) Specific Crack Area	= (4)/(1)/144 [%]	0.007	0.019
(8) Average Crack Length	[in.]	5.94	7.25
(9) Average Crack Width	[in.]	1.6 x 10^{-3}	2.0 x 10^{-3}
(10) Max Crack Width	[in.]	3.1 x 10^{-3}	9.8 x 10^{-3}

Table 2

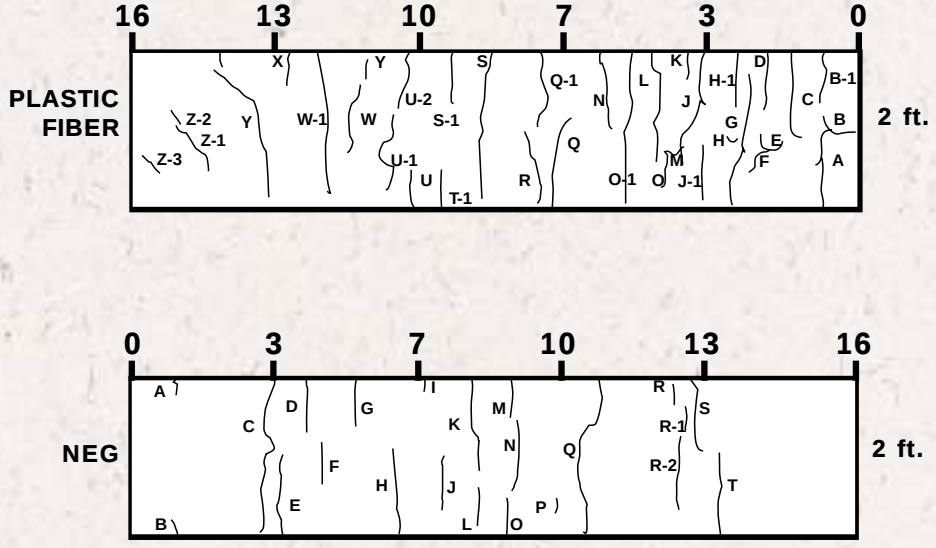

FIG. 7

CAN STOP CRACKS BEFORE THEY START.

CONTROL OF PLASTIC SHRINKAGE CRACKING OF CONCRETE WITH AR-CRACKNON CHOPPED STRANDS

MIX PROPORTIONS OF CONCRETE (lb./cu. yd.)

WATER	CEMENT	FINE AGGREGATE	COARSE AGGREGATE	AR-CRACKNON CHOPPED STRAND DOSAGE			
420	974	974	974	1	2	3	4
				plain	1 lb./cu. yd.	2 lb./cu. yd.	4 lb./cu. yd.
				0	1	2	4

SUMMARY OF OBSERVED CRACKS

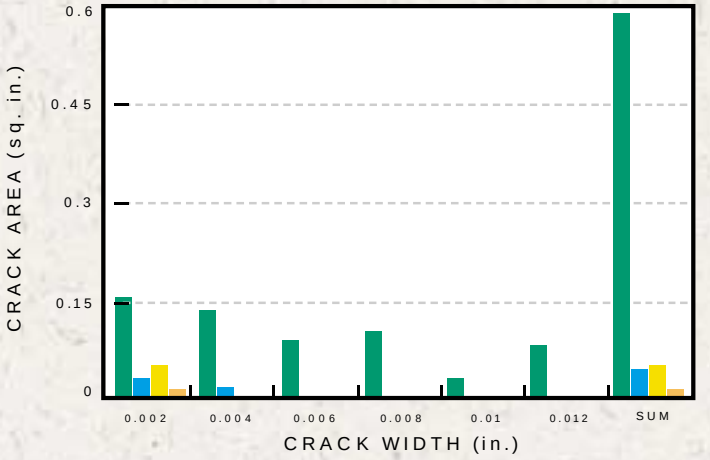

FIG. 5

CONTROL OF PLASTIC SHRINKAGE CRACKING OF CONCRETE WITH AR-CRACKNON NET

MIX PROPORTIONS OF CONCRETE (lb./cu. yd.)

WATER	CEMENT	FINE AGGREGATE	COARSE AGGREGATE	SPEC OF PROCESSED AR-CRACKNON PRODUCTS	
420	974	974	974	ITEM	PLAIN / NET LW110
				weight (02/sq. ft.)	0.36
				secondary binder (%)	20
				pitch (in.)	1.0 x 1.0

SUMMARY OF OBSERVED CRACKS

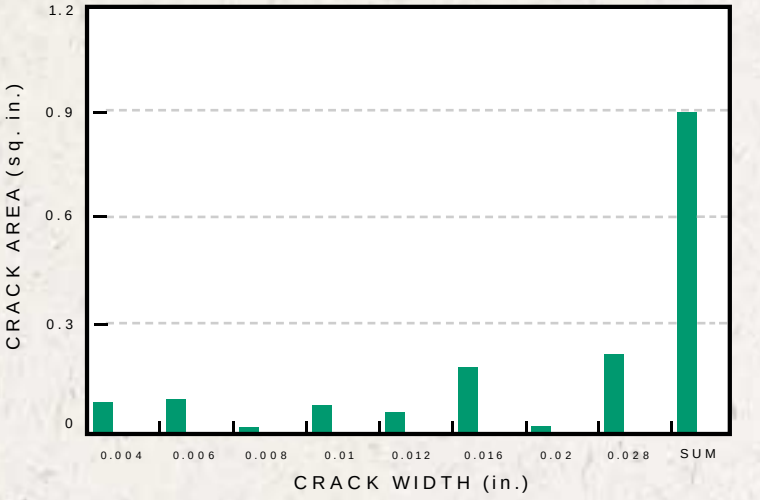

FIG. 6

WHAT ABOUT RESTRAINED SHRINKAGE CRACKING?

Table 2 and Figure 7 show the results of restrained shrinkage tests on shotcreted panels (2 ft. x 16 ft.) containing one-inch AR-CRACKNON chopped strands at the level of 25 lb./cu. yd. The drying conditions were extremely severe (100° F and <40% RH after one day). The cracks were mapped after 14 days' exposure. There were no cracks over 3.1 x 10^{-3} in. wide. A panel shot with plastic fibers had almost twice the number of cracks, with a maximum crack width of 9.8 x 10^{-3} in.

The test conclusion was that under most climatic conditions, not as severe as in the test, AR-CRACKNON would eliminate restrained shrinkage cracking.

HOW DOES THIS FIBER HANDLE PLASTIC SHRINKAGE CRACK CONTROL?

AR-CRACKNON, even at low dosage of one pound per cubic yard, significantly reduce plastic shrinkage cracking. Figure 5 shows the effect of 1/2 inch AR-CRACKNON at different fiber contents. A fiber content of over four lb./cu. yd. will greatly reduce plastic shrinkage cracks.

Structured AR-CRACKNON fabrics will also greatly reduce plastic shrinkage cracking. Figure 6 shows that AR-CRACKNON net LW110, which has an opening of one inch and a weight of 0.36 ounces per square foot did not exhibit any cracking.

A VARIETY OF AR-CRACKNON TYPES DESIGNED TO SUIT YOUR APPLICATIONS.

(Photo courtesy of Novacrete)

Chopped Strands

AR-CRACKNON chopped strands are made up in bundles of individual filaments. The filaments are very fine, typically 13 or 18 micron diameter. Bundles can be 50, 100, or 200 filaments with lengths of 0.5, 0.75, 1.0, and 1.5 inches. This allows the application to be matched with the optimum type of fiber. For example, what is best for plastic shrinkage crack control is not necessarily the best for drying shrinkage crack control.

The strands can be made such that the bundle of filaments either stays integral during mixing and placing or they can disperse into the individual filaments during mixing.

AR-CRACKNON chopped strands are easy to handle. They don't scratch, and disperse into the mix quickly and easily keeping mixing time to a minimum. Finishing is better than with any other type of fiber because there is no "hairiness" or rusting on the surface.

Nets

Continuous structured forms, or nets are another type of AR-CRACKNON. The benefit of nets is that they can be placed in the concrete where the maximum effect can be derived. As rusting is not a problem they can be placed on the outer surfaces of the concrete, where tensile stresses and therefore cracking tendencies are usually greatest.

Roving

AR-CRACKNON continuous roving provides a convenient way of metering the proper amount of chopped strands into the mixer. A chopping unit, set to cut continuous roving to the desired length of chopped strand, is mounted over the mixer or the conveyor that carries materials to the mixer. The chopping unit has a timer control that runs the unit until the required amount of fiber has been dispensed into the mixer or onto the conveyor.

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