Comparison of Four Aggregates Using the Washington Hydraulic Fracture Test

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The importance of identifying D-cracking susceptible aggregates has led to a considerable number of aggregate identification test procedures. Unfortunately, the more reliable of the procedures may require 8 weeks or longer, expensive equipment, and highly skilled operators. In response to this problem, the Strategic Highway Research Program (SHRP) has issued a research contract to develop a rapid, reliable test method for identifying aggregates susceptible to D-cracking. The new test method being developed is used to examine four aggregates: two that have produced D-cracking in the field, and two with a performance history of no D-cracking. The test method involves covering an oven-dried aggregate sample with water, and then pressurizing the water to 1,150 psi (7,930 kPa). The pressure is quickly released, and then the pressurization and release cycle is repeated. Ten cycles per day are run for a total of 50 cycles. The amount of aggregate fracturing is determined and indicates D- cracking potential. The D-cracking susceptibility of the four aggregates tested was clearly identified even though the samples were different materials from diverse origins and locations

D-cracking refers to the distress in concrete that results from the disintegration of coarse aggregates after they have become saturated and have been subjected to repeated cycles of freezing and thawing (*1*). Although D-cracking has been known to exist since the 1930s (*2*), a fast, reliable, reproducible, easily performed, and inexpensive test for identifying aggregates susceptible to D-cracking has not been developed. The effectiveness of a modification to a newly developed procedure for identifying D-cracking susceptible aggregates is examined, and four aggregates—a D-cracking susceptible gravel, a non-D-cracking susceptible gravel, a D-cracking susceptible limestone, and a non-D-cracking susceptible limestone—are compared with the new test procedure.

BACKGROUND

The mechanisms of D-cracking have not yet been completely clarified and continue to be intensively studied (*3*). Some general characteristics about aggregates that are susceptible to D-cracking have been identified.

Kaneuji et al. (*4*) observed qualitative correlations between concrete durability and pore size distributions of aggregates. At a constant total pore volume, aggregates with smaller pore sizes have a lower durability. For aggregates with similar predominating pore sizes, a greater pore volume means a less durable aggregate. By correlating aggregate service records with mercury porosimeter studies, Marks and Dubberke (*5*) found that, with one exception, the nondurable aggregates they analyzed exhibited a predominance of pore sizes in the 0.04- to 0.2-μm-diameter range, whereas aggregates with good-to-excellent service records did not exhibit a predominance of 0.04- to 0.2-μm-diameter pore sizes.

Using Washburn's (*6*) equation:

$$P = 4T \cos \theta / d \qquad (1)$$

where

T = surface tension (72 dynes/cm for water),
θ = contact angle (assumed 0° for water-aggregate contact), and
d = pore diameter.

absolute pressures between 210 psi (1,450 kPa) and 1,050 psi (7,240 kPa) could be used to force water into aggregate pore diameters within the range 0.04 to 0.2 μm.

EXISTING TEST METHODS

Because of the complex interrelationship of variables that affect the performance of aggregates in concrete, many tests have been devised to provide a reliable means of separating durable and nondurable aggregate (*7*). The test methods developed identify the resistance of aggregate to frost action and can be placed into two primary groups (*8,9*). One group consists of tests that try to simulate the environmental conditions to which the concrete aggregate is exposed. The other group consists of tests that correlate aggregate properties with known field performances and results from environmental tests.

Environmental Simulation

The environmental simulation tests include the following:

1. Sulfate soundness test,
2. Unconfined aggregate freeze-thaw test,
3. Rapid freeze-thaw test,
4. Powers slow-cool test, and
5. VPI single-cycle slow-freeze test.

Sulfate Soundness (AASHTO T104)

This test is favored by many over other test methods because of the small amount of equipment involved and the short

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amount of time required to run the test (*7*). In the sulfate soundness test, aggregate is soaked in a sodium or magnesium sulfate solution and then dried. Repeated cycles result in salt crystal growth in the aggregate pores. The expansive forces generated by the crystal growth supposedly simulate the expansive forces caused by the formation of ice in aggregate pores. However, the major natural cause of disintegration in aggregates, according to some theories, is the hydraulic pressure produced when water attempts to leave the zone of freezing (*7*). The growth of the sulfate crystals may not generate hydraulic pressures, and may not be related to the pore sizes believed to contribute to damage from freezing. Additionally, the sulfate test does not account for the effects of confining the aggregate by mortar, which determines the rate and amount of moisture movement into and out of the aggregate.

Unconfined-Aggregate Freeze-Thaw (AASHTO T103)

The unconfined-aggregate freeze-thaw test is an outgrowth of the sulfate test (*7*). The test has three variations; however, the basic procedure consists of subjecting the aggregate to repeated freezing in water and thawing. As with the sulfate test, the unconfined freezing and thawing test does not duplicate confinement of the aggregate by mortar. This test can be less reproducible because of the number of variables involved. These variables include rate of cooling and final temperature, rate of thawing, the moisture conditions of the samples before each cycle, and the length of time the samples remain frozen and thawed.

Rapid Freezing and Thawing (ASTM C666)

The Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing has two methods, A and B. Method A consists of freezing and thawing specimens in water, and Method B consists of freezing specimens in air and thawing them in water (*10*). The test can be conducted with concrete cylinder or prism specimens, although prism specimens are most commonly used (*1*). A freeze-thaw cycle is completed by lowering the specimen temperature from 40°F (4°C) to 0°F (−18°C) and raising it back to 40°F (4°C) within a 2- to 5-hr period. Specimen length change and a durability factor, calculated from the relative dynamic modulus of elasticity (ASTM C215), are determined from the test. Measurements are initially taken and repeated after every 36 cycles until completion. The test is completed after 300 cycles or until the modulus is reduced to 60 percent of the initial modulus, whichever occurs first.

Presently, standard specifications provide limited guidance on what constitutes good or bad performance. Except for ranking in relative order of frost resistance, no criteria have been established nationally for the acceptance or rejection of aggregates on the basis of ASTM C666 (*11*), although some states have established their own criteria. Furthermore, although this test better simulates the confining nature of mortar in concrete, aggregate evaluations may take nearly 5 months to complete (*5*).

Powers Slow Cool (ASTM C671)

In this test, concrete specimens are maintained in a constant temperature bath at 35°F (2°C) (*10*). Once every 2 weeks, the specimens are immersed in a water-saturated kerosene bath and the temperature is lowered from 35°F (2°C) to 15°F (−9°C) at the rate of 5 F° (2.8 C°) per hour. Length changes are measured continuously during cooling. After having cooled, the specimens are returned to the original water bath. Typical behavior consists of an initial decrease in specimen length with cooling, followed by some amount of expansion and then an additional decrease in length. The dilation is determined by measuring the difference between the length at maximum expansion and the projected length had the specimen continued to decrease in length rather than expanding. Dilation typically remains relatively constant for a number of cycles and then increases sharply (by a factor of two or more). Critical dilation is the dilation during the last cycle before the dilation begins to increase by a factor of two or more. The test is terminated once the specimens have exceeded critical dilation or until the specimens have completed a desired number of cycles. The number of cycles before critical dilation is termed the period of frost immunity. Some highly frost-resistant aggregates may never produce critical dilations.

As with the rapid freeze-thaw test, this test is time intensive and requires costly equipment.

VPI Single-Cycle Slow Freeze (12)

This test uses concrete specimens made and cured in accordance with ASTM C192. Stainless steel strain plugs are placed, 10 in. (25 cm) apart, into prisms. Initial measurements of transverse frequency, weight, and length are recorded. The specimens are then placed in a freezing apparatus with an air temperature of 0°F (−18°C). Length change measurements are made at 5- to 15-min intervals over a 4-hr cooling period.

From the results, two primary correlations are developed. The first is temperature versus length change. The minimum 5°F (2.8°C) temperature slope, b_1, is the minimum slope that can be found, within a 5°F (2.8°C) or more range, on the length change-temperature curve obtained during the first freeze of a specimen. The second correlation is time versus length change. The cumulative length change is plotted versus time, and the time slope, b_1, is determined as the minimum slope that can be found within a ⅓-hr or greater time range.

This test requires approximately 3 days to perform once curing has been completed. It produces fairly accurate distinctions between durable and nondurable aggregates. However, for aggregates of questionable durability, the rapid freeze-thaw test should be performed.

Aggregate Properties and Field Performance

The tests developed to correlate aggregate properties and field performance are easy to run, relatively quick, and with one exception, require relatively inexpensive equipment. These tests include the following:

1. Mercury intrusion porosimeter,
2. Iowa pore index,
3. Absorption-adsorption, and
4. Petrographic analysis.

Mercury Intrusion Porosimeter

One of the primary methods of determining the pore size distribution of a porous solid is mercury porosimetry, which is based on a relation presented by Washburn (*13*). The mercury intrusion porosimeter apparatus has been used in many studies of the pore characteristics of aggregates (*4,5,14–17*). The nonwetting liquid is almost always mercury because of its low vapor pressure and relative inertness to chemical reaction with the aggregate, and because it is nonwetting for most surfaces (*14*). However, the problems with this test include the following:

1. Washburn's (*6*) equation is for pores that are cylindrical and interconnected. This is not normally the case with aggregate. The pore size distribution is weighted toward smaller pore sizes because the void volumes of pores with entrances narrower than the body, termed "ink-bottle pores," will be recorded according to the entrance size.
2. Values must be assumed for the contact angle and surface tension of the nonwetting liquid.
3. The sample size is small, usually 2 to 5 g. Therefore, the test may not yield a representative result, especially when the sample is from a heterogeneous source.
4. The equipment is expensive and requires special handling.
5. After testing, specimens may be considered hazardous waste because of mercury contamination.

Iowa Pore Index Test

The Iowa pore index test (IPIT) was developed on the basis of earlier evidence that D-cracking is related to freeze-thaw actions and, more specifically, to the pore sizes of coarse aggregate (*5*). The objective in developing the test was to readily identify a correlation between an aggregate's susceptibility to critical saturation and its potential to cause D-cracking (*1*).

The test procedure consists of placing a 9,000-g, oven-dried aggregate sample in a modified air pressure meter container, filling the container with water, and then applying 35 psi (242 kPa) of air pressure (*5*). The primary load is defined as the amount of water injected during the first minute. This reading corresponds to the filling of the aggregate's macropores. A large primary load is considered to indicate a beneficial limestone property.

The amount of water injected between 1 and 15 min is the secondary load and represents the quantity of water injected into the aggregate's micropore system. The secondary load is the pore index test result.

Aggregates with histories of producing D-cracking concrete have had pore index readings of 27 ml or more (*1,5*). After comparing the IPIT and the mercury intrusion porosimeter to aggregate field performance, Shakoor and Scholer (*16*) concluded that the pore index test is a reliable, less expensive, and quicker replacement for mercury intrusion porosimetry. They also stated that IPIT results are more representative of the parent rock because of the large sample volume used.

Other studies have found problems with the IPIT (*18,19*). These problems include variable and erroneous results for aggregates with reasonably rapid rates of early absorption and no discernible trends in the results from gravels. Furthermore, the IPIT cannot indicate to what extent a reduction in maximum aggregate size will improve performance, and the test does not discriminate between absorption by a few highly porous particles or absorption by many moderately porous particles.

Absorption-Adsorption

An extensive study of D-cracking by Klieger et al. (*20*) in Ohio included an attempt to develop a test that would distinguish between durable and nondurable aggregate and that would require a minimum amount of sample preparation, time, and test equipment. They developed an absorption-adsorption test and compared the test results to pavement service records.

After conducting this test with a large variety of aggregate sources, they concluded that the absorption-adsorption test tended to be overly conservative in its identification of durable and potentially nondurable aggregates. The test predicted poor freeze-thaw resistance for a large percentage of material from several sources with good service records.

Petrographic Analysis (ASTM C295)

Many studies of aggregate freeze-thaw resistance have incorporated petrographic analysis either to identify aggregate properties that affect concrete durability or to predict aggregate performance in freeze-thaw tests (*9,12,21–24*). Petrographic examination is a visual examination and analysis of aggregate in terms of both lithology and individual particle properties (*25,26*). It requires the skills of a well-trained and experienced petrographer. The examination uses small sample sizes, which require a large amount of work to provide accurate results (*26*). Also, the analysis is not able to provide definite specification limits because information so obtained is the result of subjective appraisal by the petrographer and can be reduced to a numerical quantity only through personal interpretation (*25*).

WASHINGTON HYDRAULIC FRACTURE TEST

This test method is based on the assumption that the hydraulic pressures expected in concrete aggregates during freeze-thaw cycling can be simulated by subjecting sample aggregates, submerged in water, to high pressures. As the external chamber pressure increases, the water penetrates into smaller and smaller pores. With adequate pressure, the water can penetrate pores in the size range associated with D-cracking. If this external pressure is rapidly released, air compressed within any pores will tend to push the water back out, thereby simulating the internal pressures generated during freezing. Aggregate fracturing should result if the pressure in the pores cannot be dissipated quickly and the aggregate is unable to elastically accommodate the high internal pressure. As discussed, a pressure in the range of 1,050 psi (7240 kPa) is necessary to force water into the pore size range generally associated with D-cracking aggregates; this test procedure uses a pressure of 1,150 psi (7930 kPa).

The advantages of this test are as follows:

1. Theoretically, the test should be able to simulate the internal pressures that are believed to cause D-cracking in nondurable aggregates;
2. The escape path necessary for pressure dissipation could make this procedure sensitive to aggregate size, which is in agreement with field experience (*2*);
3. The cost for special equipment is relatively low (under $10,000);
4. Compared to most tests, this test is relatively fast (approximately 6 days are required for testing, with daily operator time under 1 hr per specimen) and, therefore, economical; and
5. The uniform pressure applied to individual aggregate particles within the chamber, along with standardization of the pressure and holding time, should make this test highly reproducible.

TESTING APPARATUS

The main part of the testing apparatus is the pressure chamber (Figure 1), which was developed from a commercially available membrane extractor at 100-bar (1,500-psi) pressure. A schematic of the apparatus is shown in Figure 2, and a pho-

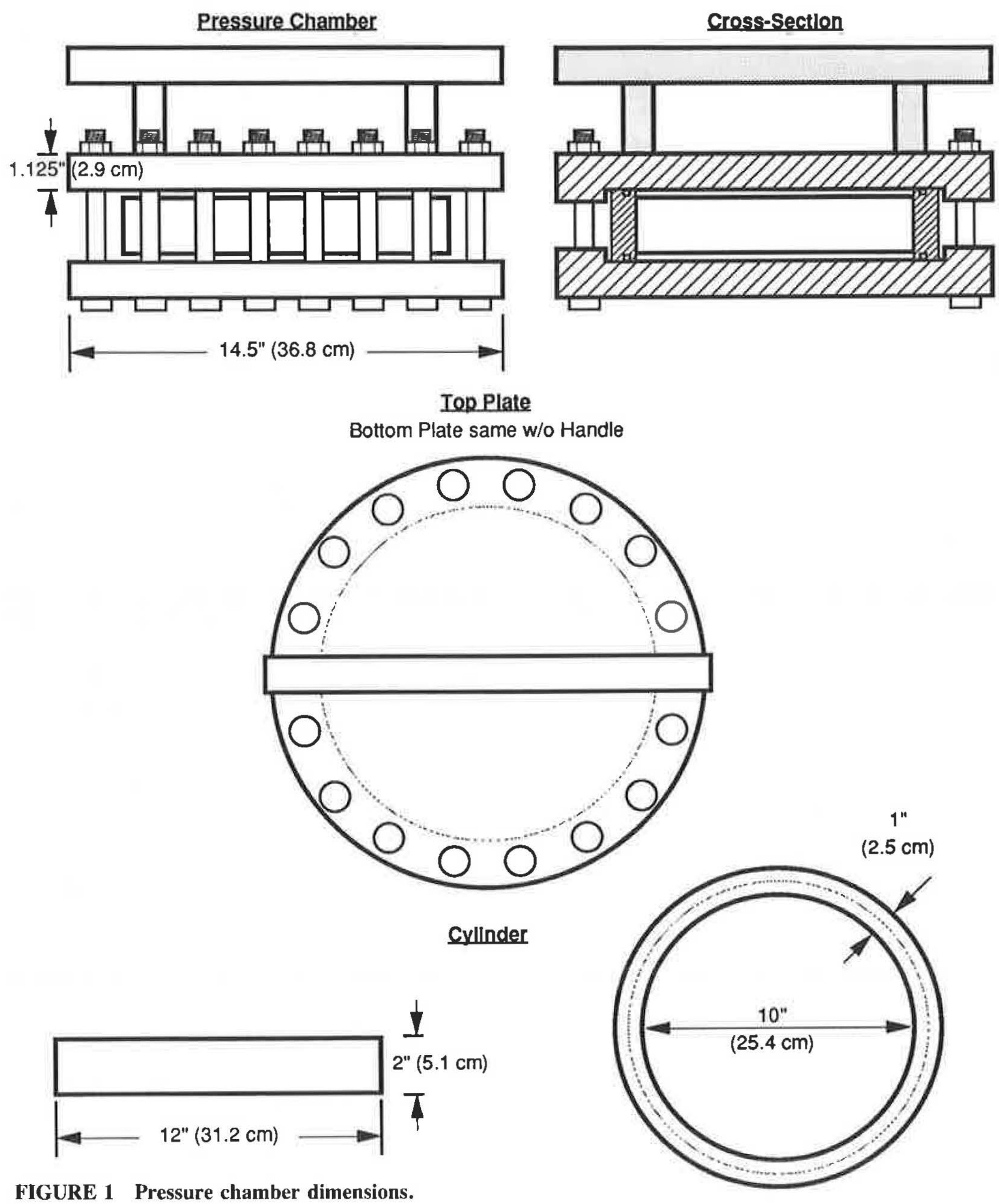

FIGURE 1 Pressure chamber dimensions.

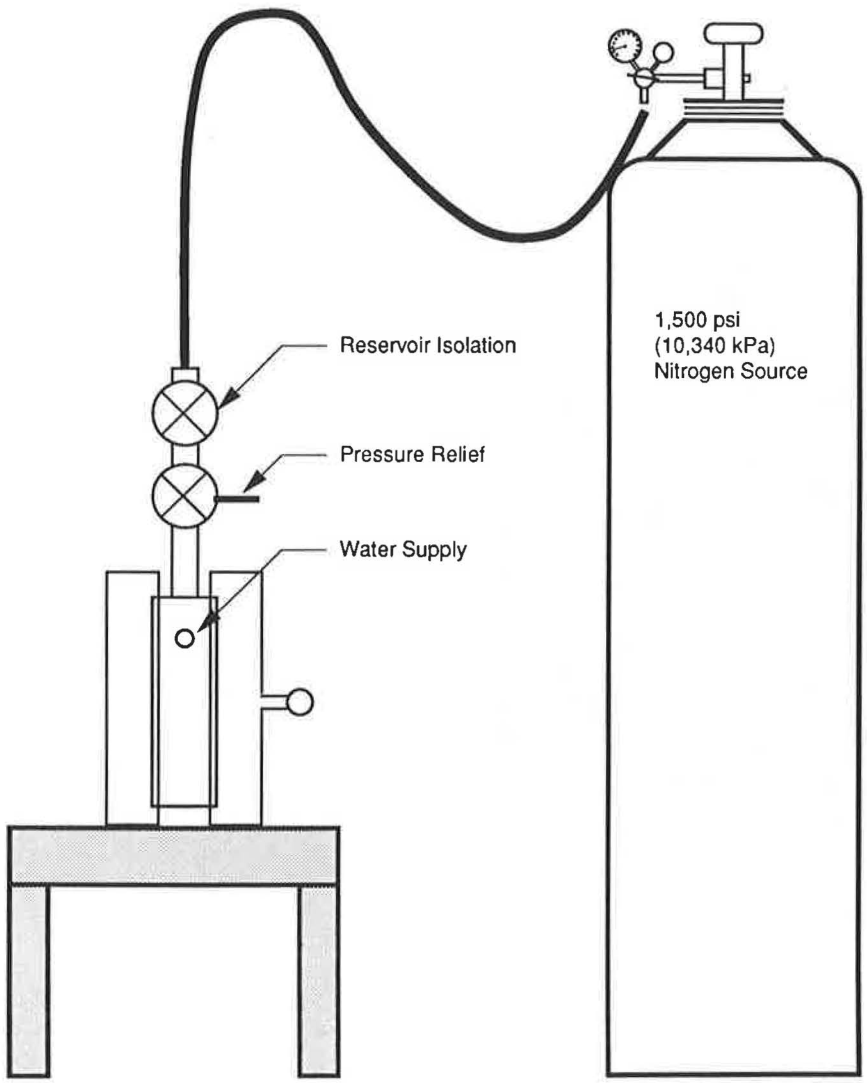

FIGURE 2 Equipment schematic.

tograph is shown in Figure 3. Full details of the testing apparatus have been presented elsewhere (*27,28*). Because the pressures used are quite high, 1,150 psi (7930 kPa), the authors do not recommend constructing the equipment from other than the commercially available pressure membrane extractor, unless appropriate pressure certification is obtained before the equipment is used.

TESTING PROCEDURE

The testing procedure consists of the following:

1. Placing a washed, oven-dried specimen of known mass, number of particles, and size range into the pressure chamber,
2. Bolting the chamber shut and filling it with water,
3. Applying an internal pressure of 1,150 psi (7930 kPa) to the chamber, and
4. Rapidly releasing the chamber pressure.

After 10 repetitions of Steps 3 and 4, the specimen is removed from the chamber, oven-dried, and counted. One day is required for specimen preparation, including washing, oven-drying, and grading. An additional day is needed for each 10 pressurization cycles (actual operator time is less than 1 hr per specimen per day), for a total of six required days. The result is an increase in the number of pieces larger than the No. 4 sieve, which is recorded as a percentage of the total number of initial pieces. This is termed the "percentage of fracture." Additional details on the testing procedure are presented elsewhere (*27,28*).

SPECIMEN SIZE

The pressure chamber is able to handle a sample size of approximately 3,200 g (7.0 lb), depending on the specimen particle shape and size range analyzed. This size is equivalent to approximately 450 pieces in the ½-in. (12.5-mm) to ¾-in. (19-mm) range and 125 to 225 pieces in the ¾-in. (19-mm) to 1¼-in. (32-mm) range. (The number of particles that can fit in the apparatus at one time is sensitive to particle angularity, especially at larger particle sizes.) Preliminary work suggests that a single filling of the chamber is sufficient for sizes

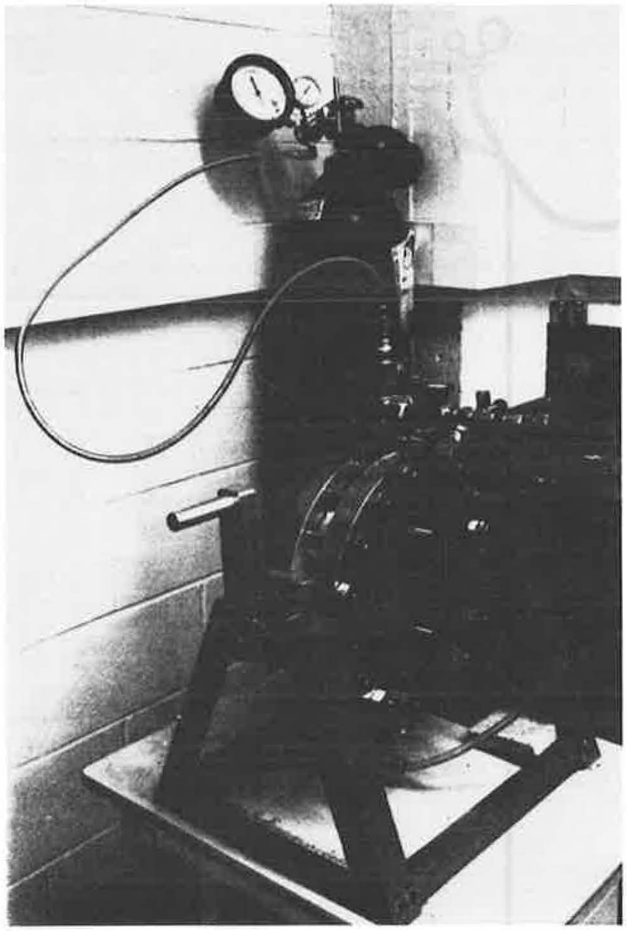

FIGURE 3 Photograph of equipment.

smaller than ¾ in. (19 mm), but combining results of multiple specimens is recommended for sizes larger than ¾ in. (19 mm) (*27*).

PROBLEMS WITH THE CURRENT PROCEDURE

The testing procedure depends on pressure forcing water into the aggregate pores, and then a release of the pressure from inside to outside the aggregate to create a sufficient critical gradient of pressure to cause fracturing. Winslow (*19*) pointed out that some aggregates absorb water extremely quickly. If an aggregate is at a relatively high degree of saturation before pressurization in the Washington hydraulic fracture procedure, the pressure gradient necessary for fracture after the pressure has been released may not develop. Modifications to the procedure are necessary to accommodate rapid-absorbing aggregates. Such a modification is described in the following sections.

MATERIALS

The aggregates tested in this comparison consisted of two gravels and two crushed limestones. One of the gravels and one of the limestones had histories of producing D-cracking in the field, and the other limestone and gravel produced durable concrete. The samples tested passed the 1¼-in (32-mm) and were retained on the ¾-in. (19-mm) sieve. The specific gravities and absorptions, along with the D-cracking susceptibilities of the four aggregates, are presented in Table 1.

Winslow absorption rates (*19*) are shown in Figure 4. Both gravels and one of the limestones (the non-D-cracking limestone) had similar absorption rates, whereas the other limestone (which is D-cracking susceptible) had a much higher absorption rate. Although absorption rate itself is not an indicator of D-cracking susceptibility (*19*), the higher absorption rate indicated possible problems with the results from the Washington hydraulic fracture test.

TESTING PROCEDURE

Two specimens of each of the four aggregates were tested according to the Washington hydraulic fracture test procedure. In addition, two specimens of each of the limestones were treated with a water-soluble silane-based sealer. The purpose of this treatment was to reduce the absorption rate of the rapidly absorbing limestone (ILA). The literature (*29,30*) suggests that the primary effect of the silane is to change the water-solid contact angle in the aggregate pores. This change does not affect the pore size, but it does affect the way surface tension absorbs water into the pore. Figure 5 is a plot of the absorption rates for the untreated and treated ILA limestone. As the figure shows, the absorption rate indeed decreased.

For comparison purposes, the slower absorbing limestone (ILB) was also treated. Almond (*27*) has shown that the treatment does not affect the fracture results of slow-absorbing

TABLE 1 SPECIFIC GRAVITIES AND ABSORPTIONS OF AGGREGATES TESTED

ID Number	Source	D-Cracking Suscept.	Apparent Specific Gravity	Absorption (percent)
ILA	Illinois Limestone	YES	2.70	1.46
ILB	Illinois Limestone	NO	2.69	0.92
MIA	Michigan Gravel	YES	2.76	1.15
MIB	Michigan Gravel	NO	2.72	1.06

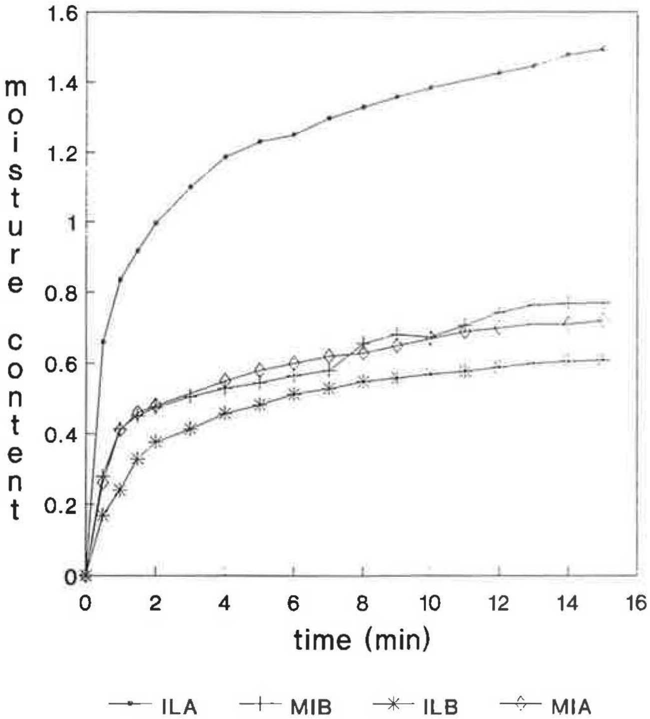

FIGURE 4 Winslow rapid absorptions (*19*).

aggregates. The treatment consisted of covering the washed and oven-dried specimens with the sealer solution, allowing the water in the sealer to evaporate at room temperature for 24 hr, and then oven-drying the specimens overnight. Testing was then continued in the normal Washington hydraulic fracture test procedure.

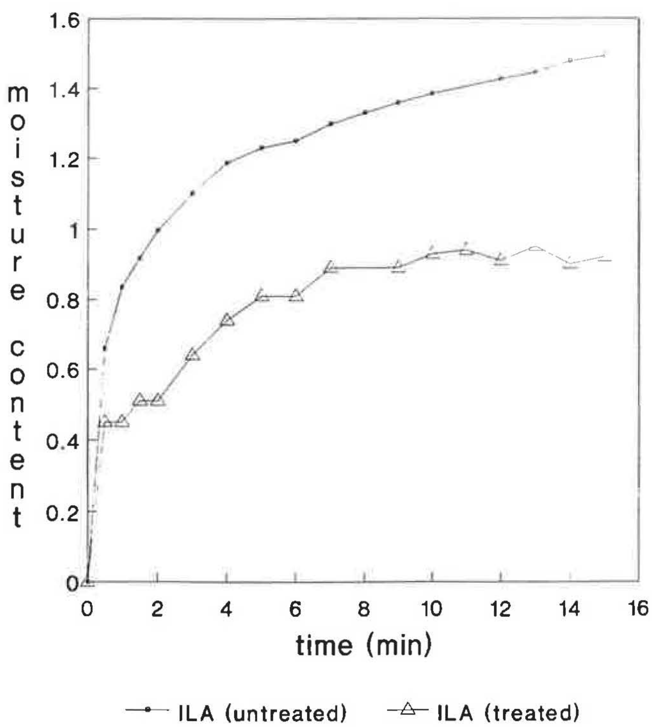

FIGURE 5 Winslow absorptions for untreated and treated ILA limestone (*19*).

RESULTS

Data

The total number of pieces counted after each series of 10 pressurization cycles for each duplication of the four aggregates is presented in Table 2. The numbers of pieces are given both for the plus ⅜-in. (9.5-mm) sieve and for the minus ⅜-in. (9.5-mm) sieve, and for the No. 4 sieve sizes. Material that passed the No. 4 sieve was not counted. The initial samples were all retained on the ¾-in. (19-mm) sieve. The results for the silane-treated limestones are also presented in Table 2. Table 3 gives the percentage of fractures for each series of 10 pressurization cycles for each of the aggregates. The results from the duplicate specimens were combined to determine these percentages. The percentage of fractures was calculated by dividing the number of additional pieces by the original number of aggregate pieces before any pressurization. This calculation is as follows:

$$FP_i = 100\,(n4_i + n_i - n_0)/n_0 \qquad (2)$$

where

FP_i = the percentage of fractures after i pressurization cycles,
$n4_i$ = The number of pieces that pass the ⅜-in. (9.5-mm) sieve but are retained on the No. 4 sieve after i pressurization cycles,
n_i = The number of pieces that are retained on the ⅜-in. (9.5-mm) sieve after i pressurization cycles, and
n_0 = The initial number of pieces tested.

Analysis

The effect of the silane treatment can be seen in Figure 6. Without treatment, the ILA aggregate (D-cracking susceptible) showed fracturing of less than about 6 percent after 50 pressurization cycles. With treatment, the fracturing increased to about 15 percent after 50 cycles. For this rapid-absorbing aggregate, the silane treatment appeared to increase the amount of fracturing, indicating that this aggregate was probably D-cracking susceptible. Without the treatment, the results indicated that the aggregate might not have D-cracking potential, which was contrary to field experience with this aggregate. Figure 7 shows the influence of the silane treatment on the non-D-cracking susceptible limestone. The treatment had almost no effect on this aggregate. This result agreed with previous work (*27*), which indicated that silane treatment of a non-D-cracking susceptible aggregate did not affect the amount of fracturing in the Washington hydraulic fracture test.

Figure 8 shows the combined results for all four aggregates tested. The two D-cracking susceptible aggregates showed similar fracture percentages, even though one was a limestone and one was a gravel. Both easily produced fracturing of greater than 10 percent in the 50 pressurization cycles. The two nonsusceptible aggregates showed similar results—fracturing of less than 5 percent in 50 pressurization cycles—

TABLE 2 PARTICLE COUNT RESULTS

Sample ID	Number of Cycles	+ 3/8 Pieces	- 3/8, + #4 Pieces
IL02A	0	135	0
	10	135	0
	20	135	0
	30	136	2
	40	136	3
	50	137	4
IL05A	0	150	0
	10	152	0
	20	152	2
	30	155	4
	40	156	5
	50	156	6
IL03A (Treated)	0	150	0
	10	155	6
	20	156	7
	30	156	9
	40	157	10
	50	158	15
IL04A (Treated)	0	150	0
	10	151	4
	20	156	12
	30	156	12
	40	156	12
	50	156	15
IL05B	0	200	0
	10	200	4
	20	201	6
	30	200	8
	40	200	8
	50	200	10
IL06B	0	200	0
	10	201	1
	20	201	2
	30	201	2
	40	201	4
	50	204	8
IL03B (treated)	0	200	0
	10	201	2
	20	201	2
	30	201	3
	40	201	3
	50	201	5
IL04B (Treated)	0	200	0
	10	200	0
	20	200	2
	30	201	2
	40	201	2
	50	201	5
MI06A	0	200	0
	10	209	14
	20	211	18
	30	211	23
	40	213	25
	50	214	30
MI08A	0	200	0
	10	200	4
	20	201	5
	30	201	9
	40	203	13
	50	205	22
MI01B	0	210	0
	10	210	0
	20	210	1
	30	211	2
	40	211	3
	50	211	6
MI03B	0	200	0
	10	202	1
	20	202	3
	30	203	3
	40	203	3
	50	203	3

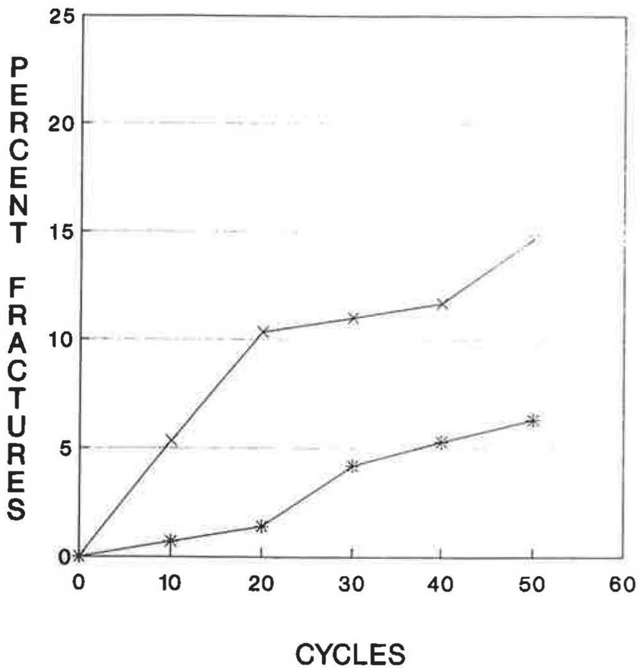

FIGURE 6 Comparison of treated and untreated ILA aggregate (D-cracking-susceptible limestone).

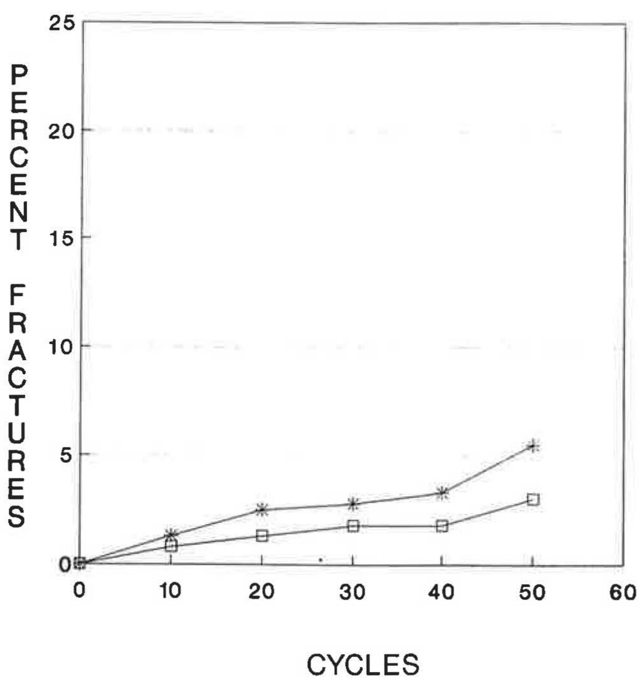

FIGURE 7 Comparison of treated and untreated ILB aggregate (non-D-cracking-susceptible limestone).

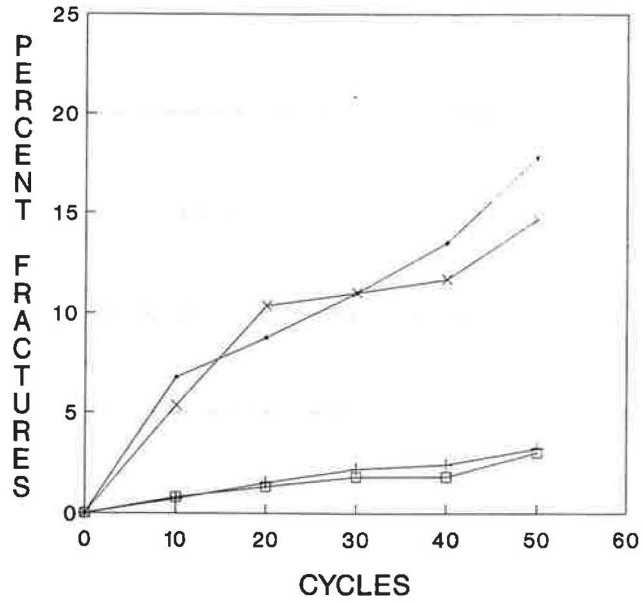

FIGURE 8 Comparison of four aggregates.

despite their different origins (one a gravel and one a limestone). The D-cracking susceptibility of the four aggregates tested was clearly indicated by the Washington hydraulic fracture test.

CONCLUSIONS AND RECOMMENDATIONS

The Washington hydraulic fracture test produces fracturing in concrete aggregates and produces substantially more fracturing in aggregates susceptible to D-cracking than in aggregates not susceptible to D-cracking. The procedure is not limited to relatively uniform aggregates, such as crushed limestones, but is also applicable to materials such as gravels from glaciated regions. The promising results from the tests of diverse aggregates support the validity of the mechanism used in the test procedure.

The major shortcoming of the test procedure, its inability to deal with rapidly absorbing aggregates, appears to be solved by use of a water-soluble, saline-based sealer. The assumed effect of the sealer treatment in reducing the surface tension absorption of water into the aggregate pores appears to allow the pressurization mechanism to function properly.

Ongoing research work is continuing to validate the procedure for a larger number of aggregates to determine pass or fail criteria (such as the number of cycles required to produce fracturing of 10 percent, or the total amount of fracturing produced at the end of 50 cycles), and to develop precision statements. Because of the pressures involved, building the equipment in-house is not recommended unless pressure certification is obtained for the finished equipment.

TABLE 3 PERCENT FRACTURE

Sample ID	Number of Cycles	Percent Fractures
ILA	10	0.7
	20	1.4
	30	4.2
	40	5.3
	50	6.3
ILA (Treated)	10	5.3
	20	10.3
	30	11.0
	40	11.7
	50	14.7
ILB	10	1.3
	20	2.5
	30	2.8
	40	3.3
	50	5.5
ILB (Treated)	10	0.8
	20	1.3
	30	1.8
	40	1.8
	50	3.0
MIA	10	6.8
	20	8.8
	30	11.0
	40	13.5
	50	17.8
MIB	10	0.7
	20	1.5
	30	2.2
	40	2.4
	50	3.2

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