Field Control Test for Debonding of Asphaltic Concrete

R. A. JIMENEZ

A description of a test method considered appropriate for construction control of asphaltic paving mixtures is presented in this report. The test is for obtaining a measure of the debonding susceptibility of paving mixtures as obtained at the time of production at the plant. The testing method is comparable to most debonding tests in that the results are expressed as a retained strength that is the ratio of the "exposed" strength to the "unexposed" strength. The main differences of the new test are that the exposure of the compacted specimen is to a repeated pore water pressure, the strength test is done by a double-punch loading, and, most important, the results can be obtained within 6 hr of receiving the hot mixture immediately prior to compaction. The laboratory results obtained with the testing system indicate that a minimum retained strength should be 70 percent.

The debonding of asphalt film from the aggregate in asphaltic concrete has been of concern to asphalt paving technologists for many years. Conversations with a former personnel member of the Arizona Department of Transportation (H. H. Brown) indicate that in the early 1920s, Powers and O'Harra developed a test for detecting sand mixtures susceptible to the action of water. In 1940, Shaw (*1*) attributed the debonding or stripping of asphalt from aggregate to an adsorbed layer of oxygen on the surface of aggregates.

There is extensive literature on the mechanism and on testing methods related to the debonding of asphalt in paving mixtures. Excellent reviews of the stripping of asphaltic paving mixtures are given by Taylor and Khosla (*2*), Tunnicliff and Root (*3*), and Brown (*4*). As a consequence, this report is centered on the equipment and methodology of the debonding test method proposed for the field control of paving mixtures.

BACKGROUND

The basic concepts of the test method were reported elsewhere (*5*). A brief review of that method is given now because that report was presented in 1974. The test consisted of six standard specimens, 4 in. deep by 2 ½ in. high, divided into two sets of equal average density. One set, referred to as the "dry" set, was kept in a 77°F air environment. The other set, referred to as the "wet" one, was subjected to the stressing exposure. This exposure consisted of soaking in 122°F water, then being permeated with the warm water under a vacuum of 20 in. of mercury for a period of 5 min, followed by 5,800 applications of a cycling pore water pressure ranging from 5 to 30 psi at a frequency of 580 cycles/min. The wet set would then be brought to the 77°F test temperature in a water bath. Prior to testing for strength, the saturated surface dry (SSD) weight of the wet set was obtained for calculating the amount of water saturation of the stressed sample. The double-punch test was used for obtaining the indirect tensile strength of the wet and dry sets. The ratio of wet to dry strength (retained strength) was considered a measure of the resistance to debonding.

The old stressing procedure shown in Figure 1 was later considered rather bulky and impractical for field usage. As a consequence, a self-contained portable unit for stressing and testing was built and studied in order to compare results obtained with those derived from using the "old" method.

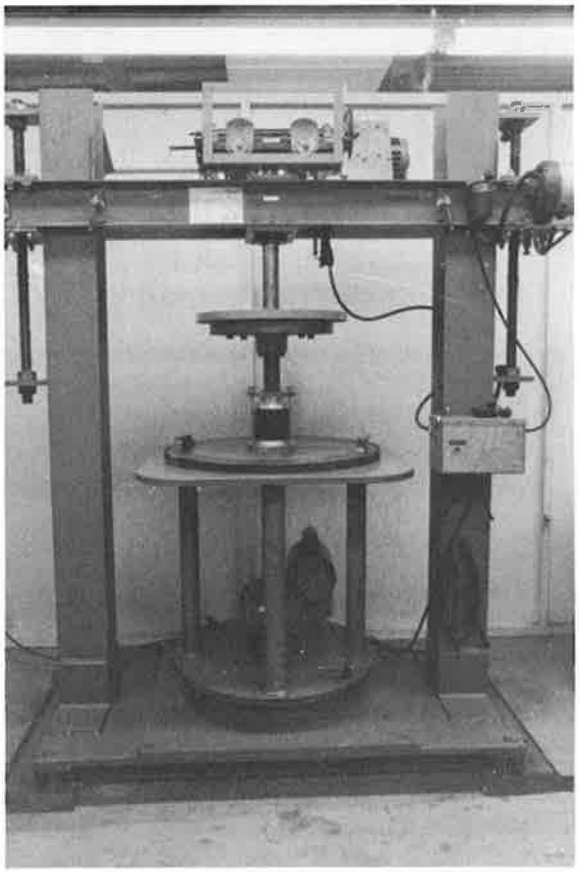

FIGURE 1 "Old" repeated pore water pressure stressing (*4*).

Arizona Transportation and Traffic Institute, College of Engineering, The University of Arizona, Tucson 85721.

NEW SETUP FOR TESTING

The new device was built for laboratory use as a self-contained unit. As will become apparent, however, portions of the total setup need not be tied to the testing unit.

Figure 2 is a photograph of the self-contained unit. A description of the parts labeled 1 to 6 follows:

1. Tank and pump for heating and circulating water at 122°F (50°C). This temperature was selected because it had been established that water-saturated pavements in Arizona had a surface temperature hovering around 120°F.
2. Air compressor unit producing air at 125 psi.
3. A vacuum pump, which is not visible, secured to the underside of the deck.
4. Bellofram and ram to produce alternating water pressures between 5 and 30 psi. This range of pressure duplicates that used in the "old" test; additionally, it is compatible with the operating characteristic of the air compressor and the frequency of stress repetition selected. Figure 3 is a close-up photograph of the loading system for pressuring water in the stressing chamber.
5. The stressing chamber can accommodate tiered trays for supporting three specimens and has heating coils to maintain the test temperature for the water, a vacuum pressure regulator, and connections for filling and emptying warm water.

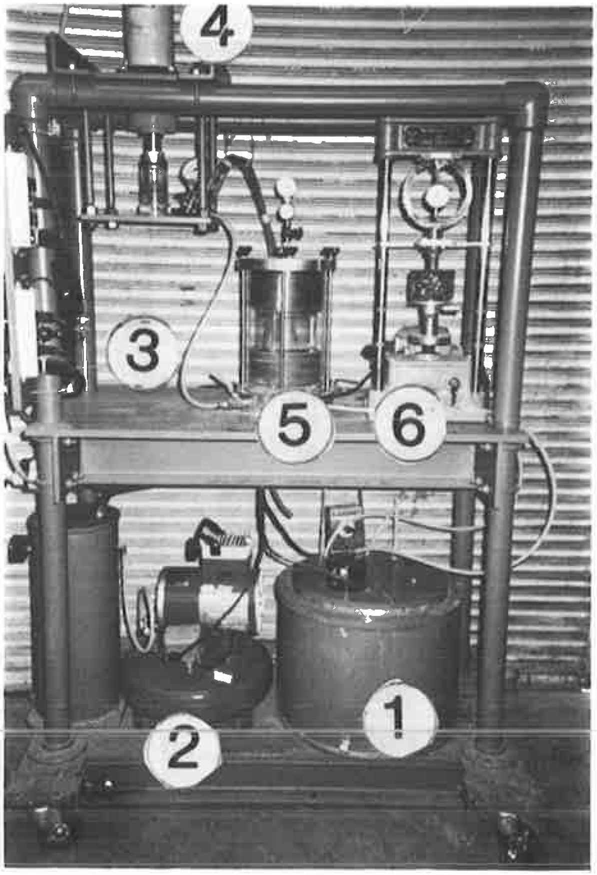

FIGURE 2 "New" pore water pressure debonding test device.

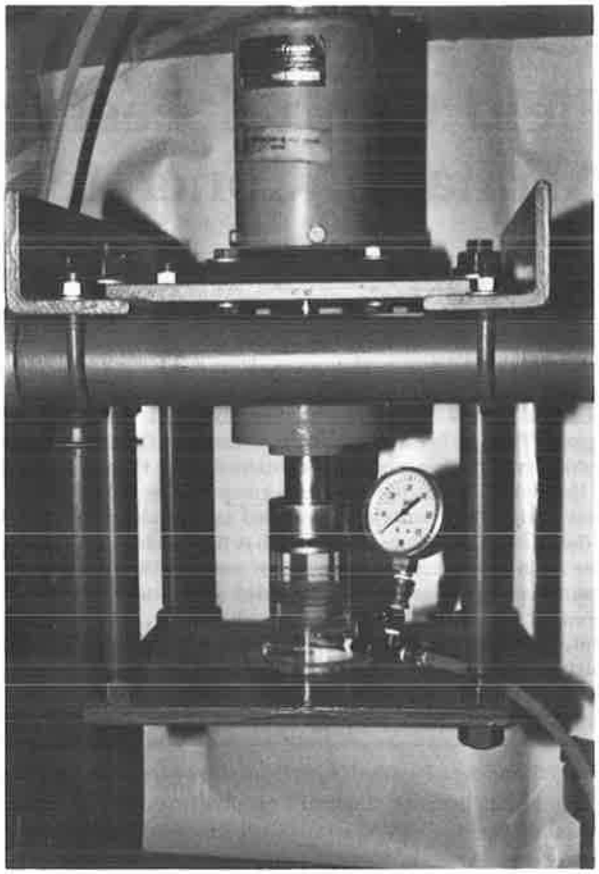

FIGURE 3 Close-up view of Bellofram loader and water pressure cylinder.

The capability of stressing three specimens at a time is an advantage over the old system. Also, the large-diameter stressing chamber can accept pavement cores that are not right-circular cylinders. Figure 4 is a photograph of the stressing chamber.

6. The Marshall Method loader was modified for performing the double-punch test. The loading punches are 1 in. in diameter, and the rate of displacement is 1 in./min. The close-up photograph of Figure 5 shows the punches and specimen centering disc.

Figure 6 presents a view of the controls for setting air pressure and frequency of loading to the Bellofram cylinder.

CONCEPTS OF TEST METHOD

The rationale of the test method and certain relationships found in evaluating paving materials are given next.

Forming Specimens

It can be anticipated that the compaction method used for making specimens affects particle orientation, distribution and connectivity of the air voids, and sealing the surface of the

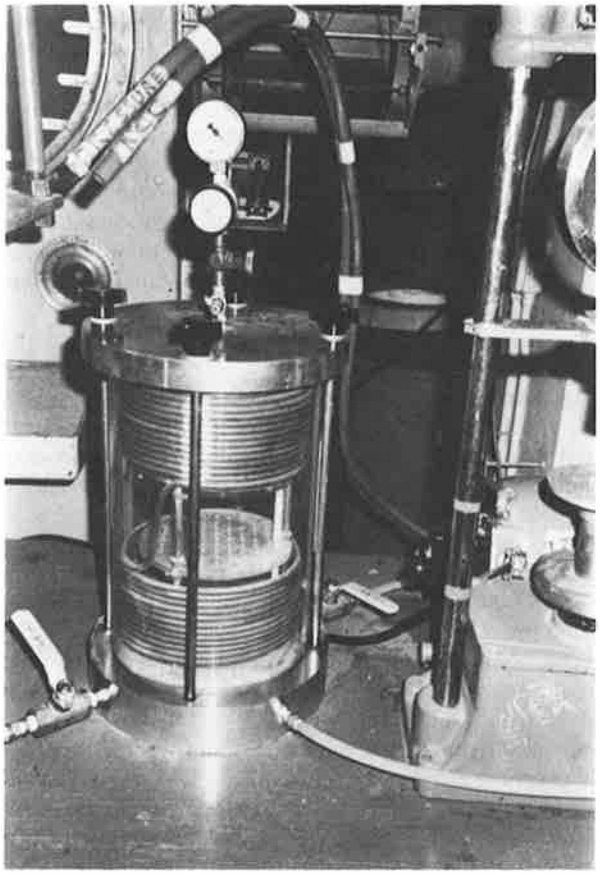

FIGURE 4 Stressing chamber with heating coils, three-specimen tray, and vacuum pressure regulator.

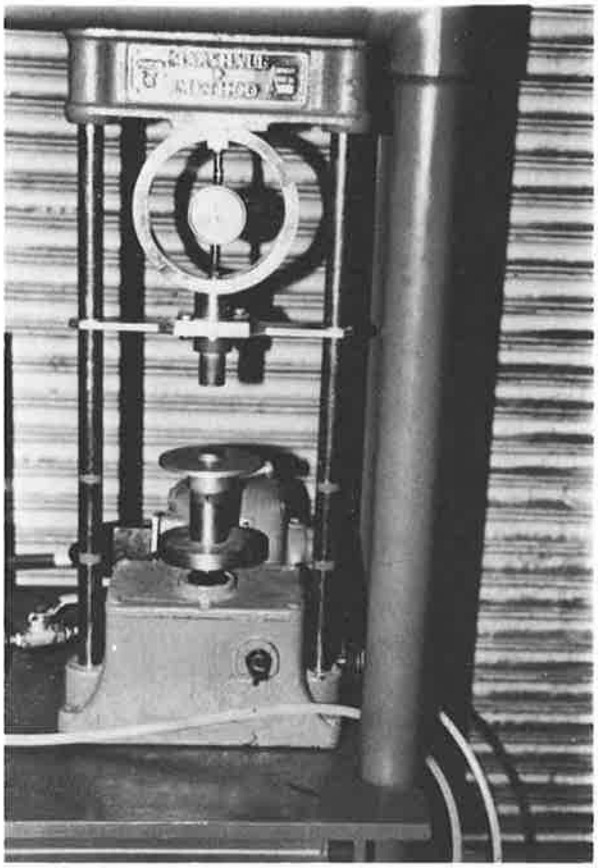

FIGURE 5 Marshall Method loader modified to perform the double-punch test.

specimen. Of course, these differences would be evaluated at equal air voids for compacted mixtures. Currently, most of the debonding test methods use specimens compacted to a density approaching what would be obtained at the time of construction. Consequently, this means that specimens used for debonding tests will require a compacting energy less than that used for the laboratory design of the mixture, and generally compaction energy would change as the paving mixture changes during the construction phase.

To use a debonding test for construction control, it will be necessary to determine the required field compactive effort when the mixture was designed. For example, under static compaction it is relatively easy to determine the unit weight of standard-sized specimens if the air-void content is known. Also, under 79 B/F Marshall Method compaction, a usual density range for field compaction is 95 to 97 percent of laboratory density. This density value can usually be obtained with 12-15 B/F for high-stability mixtures.

Curing Mixtures

Some testing procedures require that the asphaltic mixture be cured either in a loose or compacted state. A curing method that was used exposed the mixture for a period of 15 to 24 hr in a 140°F oven.

A study was reported in 1965 (*6*) on the effects of oven-curing asphaltic mixtures made with three different aggregates and three grades of asphalt cements, at four asphalt contents. The mixtures were exposed in the loose and molded conditions to air at 140°F for periods ranging from 0 to 30 hr. The conclusions given in that report included the following:

1. Oven-curing of both loose and molded mixtures for up to 30 hr did not alter the Hveem stability values.
2. The Hveem cohesiometer values were generally increased with increasing curing time.
3. Vacuum saturation (Rice) specific gravity values were not affected by curing periods of up to 30 hr.

It is recommended that air-void calculations be based on the Rice specific gravity of the mixture; as such, it is also recommended that no curing be made on the paving mixture.

Saturation of Specimens

The report of the new debonding test, given elsewhere (*5*), indicated an important effect of water permeation on retained strength. Then, as now, the amount of water intrusion is determined after the specimen has been subjected to repeated pore water stressing, although the specimen is soaked and

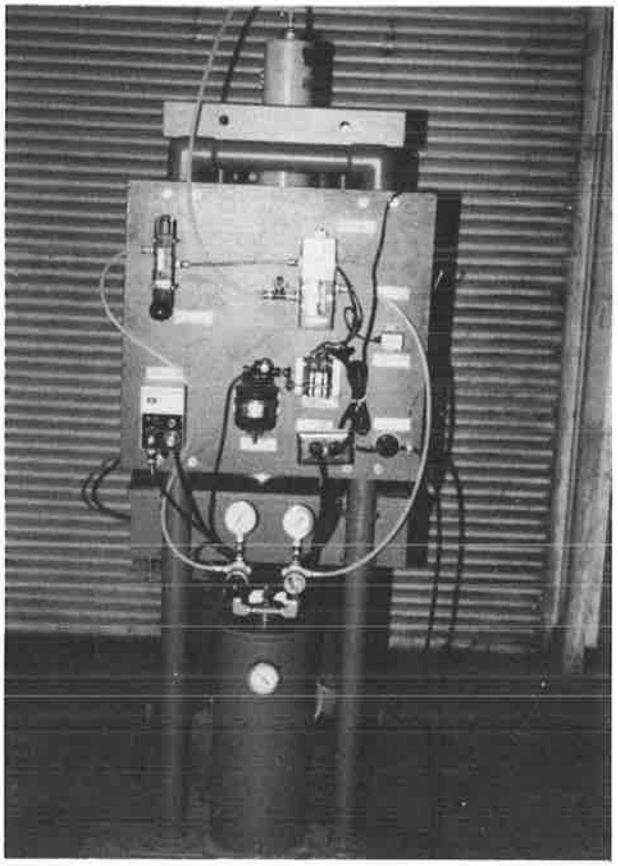

FIGURE 6 Control panel for setting water pressure and frequency of stressing in stressing chamber.

subjected to a vacuum of 20 in. of mercury for 5 min prior to stressing. During the early evaluation of the pore water pressure test, comments had been offered about the damaging effects of the 20 in. of mercury vacuum imposed on the soaked specimen. We do not believe that acceptable mixtures are damaged by the vacuum given to the specimens in this test method. The statement is based on comparisons made with other debonding test procedures, such as the immersion-compression test of the Arizona Department of Transportation (*7*), the Lottman procedure (*8*), and the Tunnicliff-Root procedure (*3*).

In 1980 a report entitled "Field and Laboratory Evaluation of Debonding Test Procedures" was prepared by Scott and Ritter (*9*) of the Arizona Department of Transportation. The conclusion and recommendations were as follows:

"The double punch method is easy to use, saves time and can easily test field cores. It is the authors' feeling that this method, with some minor modifications, should be incorporated into the mix design methods of the Arizona Department of Transportation.

The modifications that are suggested are as follows:

1. Compact the specimens to approximately the 92% level, which is the minimum required value in the field.
2. Increase the severity of the conditioning to simulate heavy truck loadings."

Our studies on the effects of air-void content on the debonding test results have indicated the expected results on retained strength; that is, the retained strength was reduced as the amount of air voids increased. It was also noted, however, that the degree of water saturation decreased as the amount of air voids increased. This would seem to be an anomalous behavior, except for the fact that the amount of water forced into the specimen increased as the amount of air voids increased. The relationships of air voids versus water intake, degree of saturation, and retained strength are generalized and shown in Figure 7.

Comparisons of Test Results

Most mixture evaluations and comparisons with other debonding test methods have been done with the "old" test setup. In modifying the equipment for field usage, several mixtures were used to establish a new stressing rate, one that would be compatible with the capacity of the compressor and solenoid valve controlling the air intake and release to the Bellofram.

A variety of mixtures and compaction methods were used in arriving at an acceptable stressing rate for the new debonding test device.

The next figures show general relationships found for specimens compacted by the Marshall Method. Figure 8 shows the effects of stress frequency and test temperature on the retained strength value of a paving mixture tested with the new device. It shows that the slower rates of stress application were more damaging than the faster rates. The effect of test temperature was included to determine if precise control of test temperature would be necessary. The adjacent curves shown have about 3 percentage points between them. Optimistically, one would think that a field laboratory could be maintained within the 7-degree span shown and, as such, testing at temperatures within 7 degrees of each other would

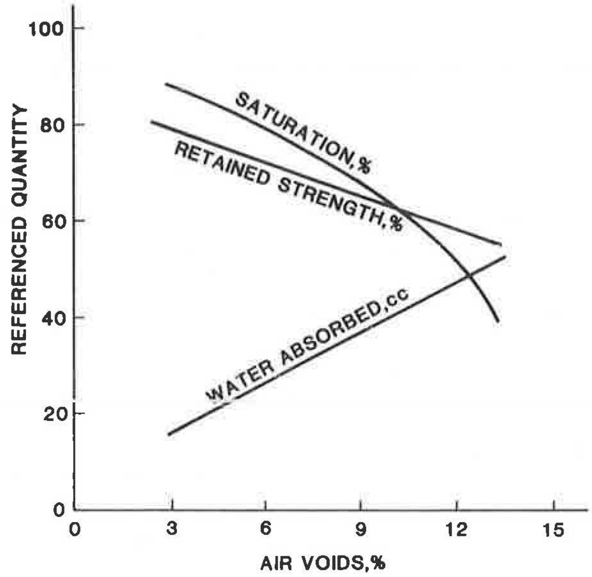

FIGURE 7 Relationships between air-void content and retained strength, degree of saturation, and water intake.

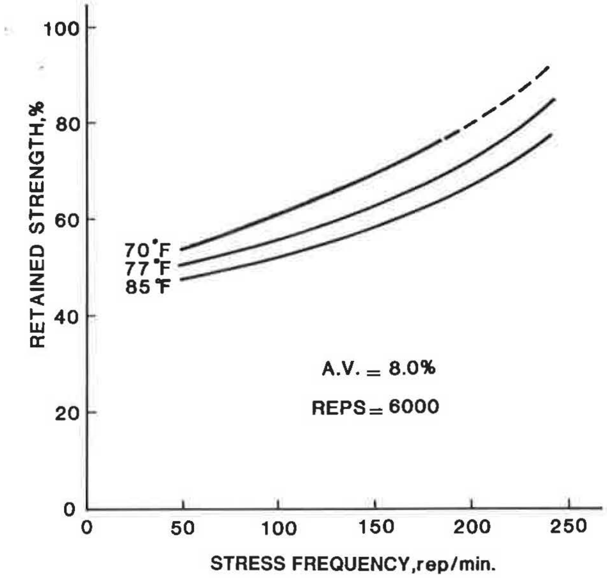

FIGURE 8 Relationship between stress frequency and retained strength as affected by test temperature.

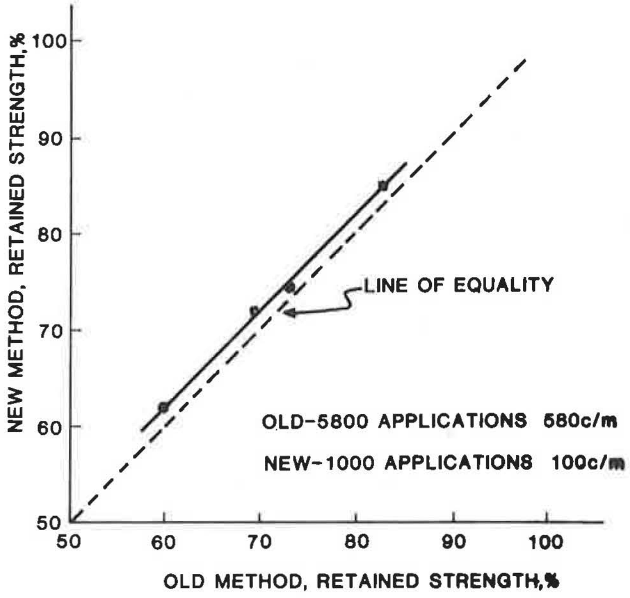

FIGURE 9 Relationship between "new" and "old" method values for retained strength.

have minimal effect on the retained strength obtained. At present, however, it is not proposed that a test temperature other than 77°F be specified.

In consideration of the duration of the test method and capability of the parts of the new device, a stressing frequency of 100 cycles/min for 1,000 applications of 5 to 30 psi was chosen for loading the "wet" specimens. Figure 9 shows a general relationship between the retained strength of specimens stressed the "old" way and the "new" way. It is apparent that the new method is slightly less severe than the old method; however, the relationship shows a 1:1 slope, as it should.

A brief description of the procedure for the pore water pressure debonding test follows.

PORE WATER PRESSURE DEBONDING TEST (PROCEDURE)

The debonding test is for the set of three specimens that have been compacted to the specified height and density. The Rice specific gravity of the mixture is known, as well as the effective specific gravity of the aggregate.

The testing equipment is shown in Figure 10. Prior to starting the pore water pressure exposure, the hot water bath must be up to 122°F (50°C), the air reservoir tank is at 125 psi, the load frequency controller is set for 100 cpm, and the water pressure pump and line are full of water, with the piston at the top of the cylinder. The chamber valve to the stressing line is closed.

1. Place the three specimens on the three-shelf carriage, and transfer into the stressing chamber.
2. Secure the lid to the stressing chamber, and open the two valves to fill with hot water and allow air to be displaced. The hot water is pumped into the chamber as well as circulated through the copper tubing coils.
3. Fill the stressing chamber to about ½ in. from the top. Close the filling valve at the bottom of the chamber as well as the air exhaust valve at the top. The specimens will arrive at stressing temperature in 45 min.
4. After 40 min in the 122°F (50°C) water, start the vacuum pump and connect it to the vacuum gage on the lid of the stressing chamber. However, the gage is not open to the chamber. Set the gage to 20 in. of mercury vacuum; then open the connecting valve, and apply to the chamber for 5 min.
5. Release the vacuum, and add hot water to fill and displace all air in the chamber through the top valve. Close the water inlet valve.
6. Start the timing motor, and adjust the air pressure regulator to approximately 10 psi; then set it so that the maximum water pressure developed through the Bellofram to the water

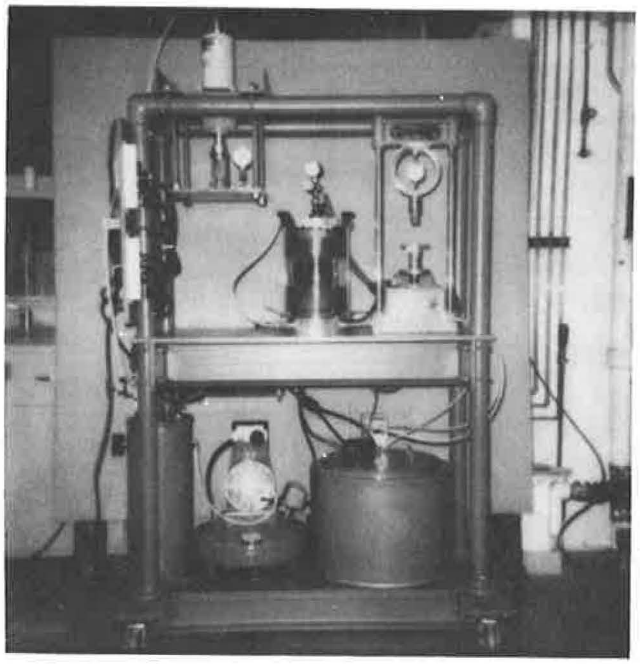

FIGURE 10 Pore water pressure debonding apparatus.

pump is 30 psi. Now connect the water pressure pump to the stressing chamber, and again adjust the pressure regulator to return (increase) the water pressure at the pump to 30 psi. Read the counter so that the loading is discontinued after 1,000 applications of water pressure varying from 5 to 30 psi. The valve between the water pump and the pressure gage is closed to relieve the gage.

7. After 1,000 repetitions (10 min), stop the timing motor, exhaust the air pressure in the Bellofram, and fill the water pressure pump to bring the piston to the top of the cylinder; then close the valve on the water pressure line and the chamber. Stop the hot water pump, and open the chamber water outlet valve.

8. Allow the water to drain out of the chamber through gravity flow for several seconds; then the water can be forced out by connecting the pressure side of the vacuum pump to the stressing chamber.

9. Close the water outlet valve, take the lid off, and remove the carriage with the specimens from the stressing chamber.

10. Place the specimens in the 77°F (25°C) water bath for 1 hr after having cooled them at ambient air temperature for ±10 min. If necessary, add ice to the bath to maintain water temperature of 77 ± 1°F.

11. After cooling for 1 hr at 77°F, the saturated surface dry (SSD) weight of the specimens is obtained.

12. The "wet strength" of the specimen is obtained using the double-punch procedure.

13. The "dry strength" of the three control specimens is obtained on specimens brought to test temperature by placing the plastic bagged specimens in the 77°F (25°C) water bath for 1 hr and at the same time as for the exposed set.

14. The "wet" strength is divided by the "dry" strength, and the ratio is expressed as a percent retained strength.

15. The wet, dry, and retained strengths, as well as degree of saturation, are recorded.

16. The degree of saturation is the increase in grams of SSD weight (volume) divided by the volume of air of the specimen, expressed as a percent.

FIELD TRIAL

Preliminary efforts have been made to use the new debonding test as a field control for paving mixtures. With the cooperation of Ted Haworth of Granite Construction Company in Tucson, Arizona, two paving mixtures were evaluated over

TABLE 1 DURABILITY MEASUREMENTS OF CONSTRUCTION A.C. WITH UNIVERSITY OF ARIZONA METHOD[a]

Mixture No. 1 November 23, 1987 A.C. = 5.50%						
Wet:	Spec.	A-2	A-3	A-6	Avg.	COV, %
	A.V., %	7.1	6.4	7.0	6.8	5.5
	Satur., %	54.7	59.7	63.9	59.4	7.7
	σ_T, psi	117.5	123.3	109.3	116.7	6.4
Dry:	Spec.	A-1	A-4	A-5		
	A.V., %	6.8	6.8	7.0	6.8	3.7
	σ_T, psi	139.1	135.5	129.3	134.6	3.7
Ret. Strength, %					86.7	
Mixture No. 2 November 24, 1987 A.C. = 4.83%						
Wet:	Spec.	B-1	B-3	B-5	Avg.	COV, %
	A.V., %	8.1	7.8	7.8	7.9	2.2
	Satur., %	63.1	64.7	60.5	62.8	3.4
	σ_T, psi	136.7	140.7	127.3	134.9	5.1
Dry:	Spec.	B-2	B-4	B-6		
	A.V., %	7.9	7.9	7.6	7.9	2.2
	σ_T, psi	137.2	140.7	140.7	139.5	1.5
Ret. Strength, %					96.7	
Mixture No. 3 November 29, 1987 A.C. = 4.63%						
Wet:	Spec.	C-2	C-4	C-6	Avg.	COV, %
	A.V., %	7.4	7.7	7.9	7.7	3.3
	Satur., %	66.3	67.2	68.6	67.4	1.7
	σ_T, psi	134.6	131.8	127.3	131.2	2.8
Dry:	Spec.	C-1	C-3	C-5		
	A.V., %	8.1	7.5	7.4	7.7	4.7
	σ_T, psi	123.9	141.7	138.0	134.5	7.0
Ret. Strength, %					97.6	

[a] Granite Report

a period of 3 and 4 days of production. It was not possible to take the new device to the plant site, and no prior information was available on the design of the two paving mixtures. Granite personnel were asked to furnish six specimens compacted by 15 B/F with the Marshall Method and, when available, extraction data for the representative mixture. As it turned out, it was not possible to receive the compacted specimens the same day they had been made; however, final test results were obtained within 2 ½ hr from the time height and density measurements were started.

The first mixture was for a recycling job in which there was a 50/50 blend of RAM and virgin aggregate. Table 1 is from a report made to Haworth and shows properties of the specimen made on three different days as well as the variability of test results. The table shows that repeatability of test results was quite good and, because it was a recycled mixture, the retained strengths were quite high. The variation in asphalt content is attributed to the fact that the mixture contained 50 percent old pavement.

The other mixture evaluated was a virgin mixture. Again the contractor provided six specimens compacted with 15 B/F. Table 2 presents the results of the debonding tests performed on mixtures made on four different days. Note that after the first day of testing using the water pressure debond-

TABLE 2 UNIVERSITY OF ARIZONA AND I-C TESTS ON FIELD-COMPACTED PAVING MIXTURES

		Water Pressure - UofA					I-C
MIX #1 December 7, 1987 A.C. = 6.03%							
Wet	Spec. #	1-A	1-B	1-C	Avg		
	A.V., %	7.4	7.0	7.4			
	Sat., %	89.0	70.5	88.9			
	σ_T, psi	132.3	125.8	128.7	128.9		
Dry	Spec. #	1-D	1-E	1-F			
	A.V., %	8.9	7.0	6.7			
	σ_T, psi	170.6	174.6	166.6	170.6		
Retained Strength, %					75.5		
MIX #2 December 9, 1987 A.C. = 5.79%							
Wet	Spec. #		2-B	2-C	Avg		2-F
	A.V., %		5.3	6.0			6.0
	Sat., %		100.0	90.3			43.2
	σ_T, psi		192.2	192.1	182.2		987.3
Dry	Spec. #	2-D	2-E				2-A
	A.V., %	5.9	5.9				5.9
	σ_T, psi	227.6	242.5		235.1		1325.6
Retained Strength, %					77.5		
MIX #3 December 10, 1987 A.C. = 5.69%							
Wet	Spec. #		3-B	3-D	Avg		3-C
	A.V., %		6.2	5.4			6.0
	Sat., %		90.1	107.0			57.0
	σ_T, psi		158.7	148.5	153.6		724.5
Dry	Spec. #	3-A	3-E				3-F
	A.V., %	5.8	6.0				5.9
	σ_T, psi	204.4	206.4		205.4		1174.4
Retained Strength, %					74.8		
MIX #4 December 11, 1987 A.C. = 5.95%							
Wet	Spec. #	4-A	4-D		Avg		4-F
	A.V., %	6.6	6.5				6.3
	Sat., %	105.8	111.0				62.3
	σ_T, psi	148.5	143.1		145.8		716.6
Dry	Spec. #	4-C	4-E				4-B
	A.V., %	6.7	6.7				6.2
	σ_T, psi	210.6	107.1		208.9		1174.4
Retained Strength, %					69.8	H = 2½"	66.1 [b]
						H = 4"	57.5

[a] Granite Report

[b] Test specimens were 2.5 inches high but retained strength corrected to height of four inches.

ing test, a modified immersion-compression test was run on a set of six specimens made from mixtures produced on three different days. A review of the data shows good repeatability of the paving mixture and of the test results obtained with the new test method. As noted, there were four specimens in the sets tested on three of the four days. This was done to obtain a measure of the retained strength obtained with the immersion-compression (I-C) test. The rate of displacement for the I-C test was 0.125 in./min because the specimens were 2.5 in. high. A limited amount of work indicates that near the 75 percent retained strength level, the 2.5-in.-high specimens yield values that are 1.15 higher than those for specimens 4.0 in. high. The table shows the corresponding decrease in retained strengths from the second to the fourth day of testing for both methods of testing.

CONCLUSIONS

The report presented is an extension of work presented earlier (*5*). The modifications to the equipment and test procedure have been developed to make a debonding test practical and suitable for field control of paving mixtures. The data presented here and earlier (*5*) indicate that the test method is quite repeatable. As important is the fact that results can be obtained within 6 hr of receiving a hot and loose paving mixture.

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