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Supplementary Notes

Abstract

Problems with water penetrating into pavement were observed with the early coarse asphalt Superpave mixtures. There was justified concern that water would cause early deterioration; therefore, an effort was made to investigate the permeability problem and correct it. After an initial investigation revealed excessive permeability in many newly constructed Superpave pavements, the Virginia Department of Transportation's (VDOT) Materials Division decided that the potential permeability of mixtures should be determined during the mixture design phase prior to the start of construction. A technique of performing regressions of air voids and permeability with specimens prepared and tested in the laboratory was developed and refined at the Virginia Transportation Research Council. This investigation examined how well different labs agreed in two phases: one in which two VDOT laboratories participated and one in which contractors and VDOT laboratories participated.

There was general agreement between laboratories in determining the acceptability of field samples of mixtures with regard to permeability. Potential difficulties and solutions in specimen preparation and regression analysis were discussed. The technique is currently being implemented by VDOT as a mixture design tool. It is estimated that the elimination of permeable mixtures that are not durable will save VDOT as much as $350,000 annually.

FINAL REPORT

ASPHALT PERMEABILITY TESTING BETWEEN LABORATORIES

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(A Cooperative Organization Sponsored Jointly by the
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ABSTRACT

Problems with water penetrating into pavement were observed with the early coarse asphalt Superpave mixtures. There was justified concern that water would cause early deterioration; therefore, an effort was made to investigate the permeability problem and correct it. After an initial investigation revealed excessive permeability in many newly constructed Superpave pavements, the Virginia Department of Transportation's (VDOT) Materials Division decided that the potential permeability of mixtures should be determined during the mixture design phase prior to the start of construction. A technique of performing regressions of air voids and permeability with specimens prepared and tested in the laboratory was developed and refined at the Virginia Transportation Research Council. This investigation examined how well different labs agreed in two phases: one in which two VDOT laboratories participated and one in which contractors and VDOT laboratories participated.

There was general agreement between laboratories in determining the acceptability of field samples of mixtures with regard to permeability. Potential difficulties and solutions in specimen preparation and regression analysis were discussed. The technique is currently being implemented by VDOT as a mixture design tool. It is estimated that the elimination of permeable mixtures that are not durable will save VDOT as much as $350,000 annually.

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INTRODUCTION

The new Superpave mixture design system resulted in gradations that were coarser than those used previously, and although previous rutting problems were solved, permeability problems began to become apparent as evidenced by wet spots remaining on some pavement surfaces several days after a rain. Therefore, there was concern that the durability of the new Superpave mixtures would be affected by their porous characteristics. The Florida Department of Transportation was one of the first state agencies to recognize the problem and investigate the permeability characteristics of their Superpave mixtures.[1] The National Center of Asphalt Technology also began a series of studies dealing primarily with the field measurement of permeability.[2-5]

The Virginia Department of Transportation (VDOT) began to investigate the permeability of their Superpave mixtures by researching test methods and performing tests with field cores.[6-8] It was considered desirable to determine permeability in the mixture design process so that contractors would know that mixtures were impermeable before paving started. Therefore, work concentrated on the testing of mixtures in the laboratory using the falling head permeameter developed through the efforts of Subcommittee D04.23 of the American Society of Testing and Materials (ASTM).

The author proposed that permeability tests be performed on several specimens with different void contents prepared in the laboratory and that a regression be developed similar to that shown in Figure 1.[6] Then, the maximum allowable permeability could be checked at the maximum void content permitted in the pavement by VDOT specifications.

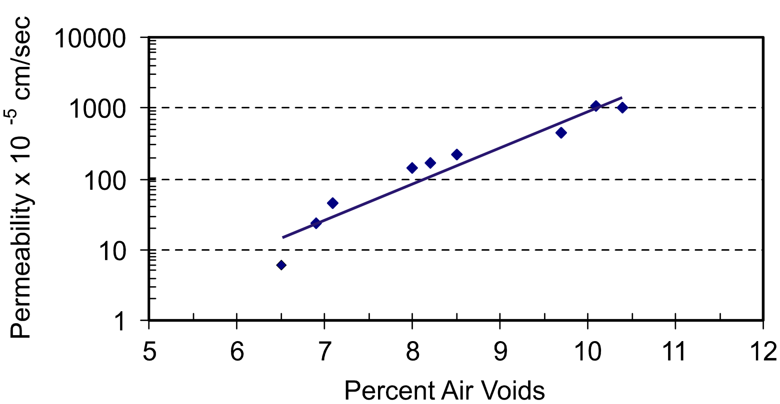

Figure 1. Typical Laboratory Regression for Permeability

To the author's knowledge, comparison testing between laboratories using the regression design method described previously has not been done, although some unpublished round robin precision testing has been done by the ASTM task group that refined and standardized the basic permeability test method. In the early stages of development, a comparison was made between regression results of permeability testing by two VDOT laboratories on a variety of Superpave mixtures, and the results are presented in this report. In addition, the results of a pilot study in which an attempt was made to have participants in each VDOT district including the contractor producing the mixture, the VDOT district laboratory, and either the Virginia Transportation Research Council (VTRC) or the VDOT State Materials Laboratory to test identical field samples are presented.

PURPOSE AND SCOPE

The purpose of this study was to examine the regression permeability-voids method of checking an asphalt mixture for permeability. In Phase I, field samples of loose mixture were collected from 11 paving projects and two VDOT laboratories performed the testing on duplicate samples. In Phase II, asphalt field samples of loose mixture were collected from a paving project in eight VDOT districts. Contractors, VDOT district laboratories, and either the VTRC laboratory or the VDOT State Materials Lab tested duplicate samples of the same mixture. An attempt was made to determine how well the test results compared, to familiarize the various laboratory technicians with the test procedure, and to identify any problems.

METHODS

Phase I

The plan for the investigation was to collect samples of mixture from paving projects and develop air void–permeability regressions from the laboratory testing. The semi-log regressions (see Figure 1) would then be used to determine the permeability of each mixture at 7.5 percent air voids for each laboratory. The comparison of the estimated permeability for each laboratory would indicate whether different laboratories could be expected to agree on the degree of permeability of a given asphalt mixture. This comparison would provide a good trial to determine if this test method could be used for mixture design approval.

Mixture Description and Specimen Preparation

The 9.5 mm and 12.5 mm mixtures listed in Table 1 were sampled from paving projects. On each project, samples were taken from the same truck for both laboratories in such a way to make them as identical as possible. "A" mixtures contained PG 64-22 binder and were designed with 65 gyrations, and "D" mixtures contained PG 70-22 binder and were designed with 75 gyrations.

Table 1. Estimated Permeability and Air Voids from Regressions for Phase I

Mix ID	Mix Type	% Voids @ 125 x 10^{-5}cm/s		Permeability x 10^{-5}cm/s @ 7.5% VTM	
		Lab 1	Lab 2	Lab 1	Lab 2
1086	SM-9.5D	9.0	9.2	58	15
1089	SM-12.5A	8.0	---	95	---
1091	SM-9.5D	7.9	8.3	90	60
1093	SM-12.5A	8.0	8.2	84	55
1095	SM-12.5D	9.3	8.8	27	50
1097	SM-12.5D	9.6	9.2	30	40
1098	SM-9.5D	7.4	8.1	150	50
1101	SM-12.5D	9.4	8.5	13	30
1103	SM-12.5A	7.4	6.7	130	600
1105	SM-12.5D	---	7.8	---	90
1106	SM-12.5D	6.5	6.2	260	290

Laboratory specimens were compacted in the Superpave gyratory compactor in each laboratory in accordance with AASHTO Standard T 312-01[9] except that the weight of mixture for each specimen was adjusted to yield the desired void content in the compacted specimens. The target thickness of the laboratory specimens was 38 mm, which corresponded closely to the thickness of the pavement layers being placed in the field.

Several cores were taken from the pavement where the placed mixture was sampled and were tested for permeability. The aim was to see how core permeability compared to permeability measured on specimens made in the laboratory. Pavement cores were wet cored. The layer of each core to be tested was separated from the other layers with a sharp chisel or by wet sawing when necessary. Care was taken to prevent damaging the core.

The percentage of air voids in the cores and laboratory specimens was determined in accordance with ASTM D 3203; the bulk specific gravity in accordance with ASTM D 2726; and the theoretical maximum specific gravity in accordance with ASTM D 2041.[10] The specimens were then placed in a vacuum vessel filled with water and vacuumed at 28 $\pm$ 2 mm Hg residual pressure for 15 $\pm$ 2 minutes before the permeability test was performed.

Permeability Testing

The test method is based on a provisional standard developed by ASTM Subcommittee D04.23. The testing apparatus consists of a metal cylinder with a flexible membrane on the inside of the cylinder where air pressure can be applied. The cylinder consists of removable plastic plates at the top and bottom that can be sealed. The top plate has a hole with an attached graduated cylinder for the introduction of water, and the bottom plate has an outlet hole and valve so that the water can flow out.

The circumferential surface of the laboratory specimen was coated with a layer of petroleum jelly before the specimen was placed in the permeameter to prevent the flow of water along its surface. The specimen was then placed on top of the bottom plate, and then the metal cylinder containing the membrane was placed around the specimen. The top plate containing the graduated cylinder was then placed on top of the specimen. Clamps were then used to compress and seal the bottom and top plates, and the hand pump on the apparatus was used to apply a sealing confining pressure of 96 $\pm$ 7 kPa to the membrane surrounding the sides of the specimen.

Next, the attached graduated cylinder was filled with water and the permeameter was tilted and tapped gently to remove air bubbles. Then, the valve on the bottom of the permeameter was opened so that water could flow through the specimen. This step is to ensure that all air is removed from the specimen and critical water passageways in the equipment. The graduated cylinder was then refilled to the top mark (approximately 800-mm head), the valve was opened, and the time required for the water to reach the lower mark (approximately 200-mm head) was recorded. The coefficient of permeability was computed using Equation 1.

$$k = \left(\frac{A_2 L}{A_1 t}\right) \ln\left(\frac{h_1}{h_2}\right) \qquad \text{(Eq. 1)}$$

where

k = coefficient of permeability, mm/s
A_2 = graduated cylinder area, mm^2
L = specimen height, mm
A_1 = specimen area, mm^2
t = time to flow between heads, s
h_1 = initial head of water, mm
h_2 = final head of water, mm.

Three tests were conducted with the same specimen, and the results were averaged. Although the correct engineering term for the quantitative measurement of permeability is *coefficient of permeability*, the term *permeability* is used in this report.

Phase II

In Phase II, an attempt was made to involve a wider group of technicians in performing the testing. One mixture was sampled from each of eight VDOT districts and tested by multiple laboratories including that of the contractor that produced and placed the mixture, the VDOT district laboratory, and either the VTRC laboratory or the VDOT State Materials Laboratory. The study was designed not only to indicate how well the laboratories agreed but also to familiarize the non-users with the test method and identify any associated problems.

The mixtures were composed of one 12.5 mm and seven 9.5 mm Superpave surface mixtures. The samples were collected and tested as previously described under Phase I. In addition, several field cores were taken from some of the projects to try to determine how field permeability compared with laboratory permeability.

TEST RESULTS

Phase I

An examination of the regression plots showed good agreement between the two laboratories in most cases when the estimated permeability was compared at 7.5 percent air voids. Table 1 shows the estimated permeability at 7.5 percent air voids. It was assumed that 125 x 10^{-5} cm/s defined approximately the maximum allowable permeability for pavements that perform well. The estimated permeability was less than 130 x 10^{-5} cm/s for both laboratories for six of the nine mixtures for which comparisons were possible. In those cases, there was good agreement concerning the prediction of whether the mixtures would be susceptible to the passage of water. Two of the mixtures, 1098 and 1103, had larger differences. Examination of the data revealed that part of the reason for these differences was that different maximum theoretical specific gravities obtained in the two laboratories were used to compute the air voids. Generally, there was good agreement in the comparison of predicted permeability values from the regressions.

Also listed in Table 1 are the estimated pavement air voids necessary to maintain permeability less than 125 x 10^{-5} cm/s. These values give contractors an indication of the density necessary to produce pavements with low permeability. Most of the comparisons between the two laboratories agreed within 0.5 percent air voids, and all were within 0.9 percent air voids.

Another point to consider when designing mixtures is that the change in permeability with a change in air voids should be low. If a small change in air voids produces a large change in permeability, it is likely that permeability will fluctuate excessively during production. The regression plot for mixture 1098 in Figure 2 shows that permeability changes substantially with a small change in air voids. In fact, the change was approximately twice the rate of that for mixture 1093. This means that the normal fluctuation in field air voids for mixture 1098 may have led to pavement that varied between being acceptable and unacceptable with regard to permeability.

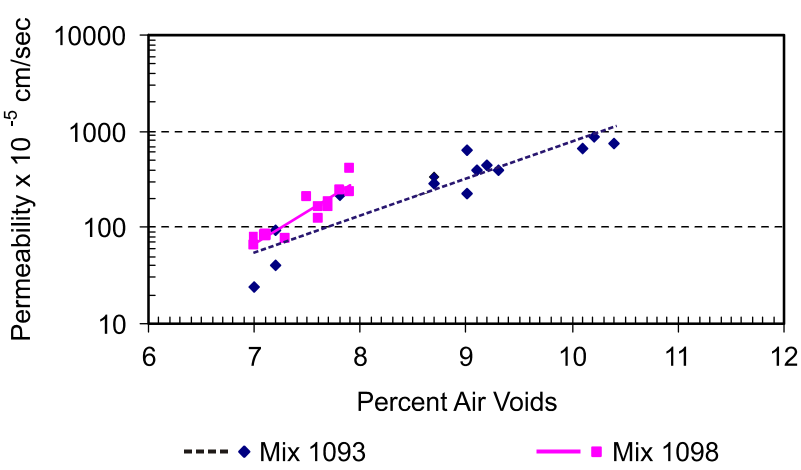

Figure 2. Mixtures With Different Regression Slopes

Phase II

The predicted permeability values at 7.5 percent voids for each mixture by each laboratory are listed in Table 2. If 125 x 10^{-5} cm/s is the assumed maximum allowable permeability, there was agreement between laboratories concerning whether the mixtures passed or failed except for mixtures from VDOT's Lynchburg and Northern Virginia (NOVA) districts. If the plot of the regressions for the mixture from the NOVA district is examined, it is evident that all of the tests by the VDOT State Materials Lab (Elko) were conducted at high void contents, resulting in very high permeability values (see Figure 3). The author has noticed in previous permeability work that the regression plot for some mixtures tends to flatten as permeability values approach and surpass 1000 x 10^{-5} cm/s. Therefore, if most of the data points are in the high permeability region, the projected permeability at 7.5 percent voids tends to be high. If the specimens by the VDOT State Materials Laboratory had been at lower voids, there would probably have been better agreement for the mixture from NOVA. The predicted permeability at 7.5 percent voids for the mixture from Lynchburg was judged acceptable by the district laboratory but unacceptable by the VTRC laboratory. A retest by VTRC verified the unacceptable value, and no explanation was found for the disagreement.

Table 2. Estimated Permeability and Air Voids from Regressions for Phase II

District	Mixture	% Voids @ 125 x 10^{-5}cm/s			Permeability x 10^{-5}cm/s @ 7.5% VTM		
		Contractor	District	VTRC/Elko	Contractor	District	VTRC/Elko
Bristol	9.5A	8.5	8.5	8.5	45	55	55
Culpeper	9.5A	9.4	9.4	9.2	50	10	30
Fredericksburg	9.5A	9.7	8.4	8	85	70	85
Hampton Roads	9.5A	9.2	8.5	8.8	10	60	45
Lynchburg	9.5D	---	8.6	6.8	---	40	190
NOVA	9.5A	---	7.8	6.1/7.6	---	90	240/115
Richmond	12.5D	7.6	---	7.5	110	---	125
Salem	9.5D	---	8.1	8.1	---	70	75

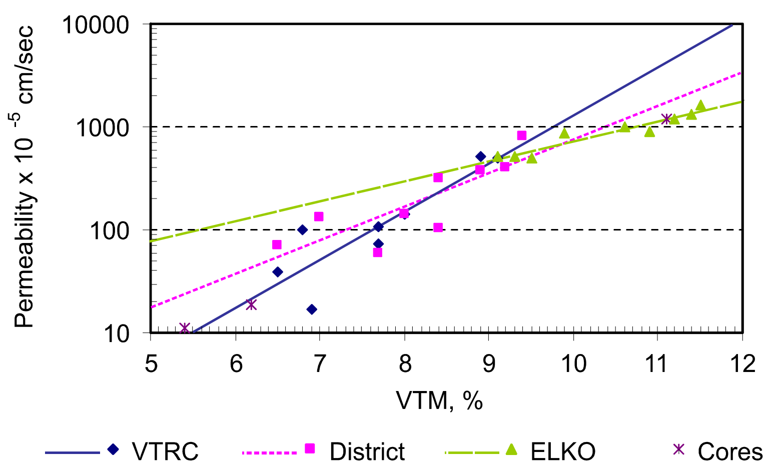

Figure 3. Permeability-Voids Regression for VDOT's Northern Virginia District

DISCUSSION

Phase II served as a learning experience for many who had little or no experience performing the permeability test. Questions received from participants about the testing were answered by VTRC personnel, and in some cases, VTRC personnel visited the laboratories to speak with participants face to face.

Some operators reported difficulty in compacting specimens for some mixtures down to approximately 7 percent air voids. This problem was investigated and verified, but it can be solved by compacting thicker specimens, which will reach the specified void content, and sawing them to the required 38-mm height. Previous unreported work in the development of the permeability test method by an ASTM task group found that sawing with a water-cooled saw did not affect permeability.

Although it was not feasible to show the permeability plots for each mixture tested, there was general agreement between the permeability of specimens produced in the laboratory and the permeability of cores removed from the pavement. This observation gives confidence that the permeability predicted in the laboratory is indicative of the permeability of the pavement after construction.

Since this round of testing was a “first” for many of the participants, it was surprisingly successful. Technicians will become more proficient as experience is gained. VDOT has implemented a permeability check requirement for mixture design approval in 2005.

CONCLUSIONS

- In Phase I, there was general agreement between two VDOT laboratories in regressions developed from permeability and air voids data.

- In Phase II, the contractor laboratories and VDOT laboratories generally agreed concerning the acceptability of mixtures with regard to permeability.

- In Phase II, difficulty in compacting specimens for some mixtures down to approximately 7 percent air voids was remedied by compacting thicker specimens and sawing them to the required 38-mm height.

- The regression curve sometimes flattens at high permeability/air voids; therefore, to obtain a reasonable prediction of permeability at construction air voids (7.5 percent), the regression permeability results should not be concentrated only in the high range.

RECOMMENDATION

VDOT'S Materials Division should use the permeability test described in this report to determine permeability at the mixture design phase. VDOT is currently implementing this recommendation.

COSTS AND BENEFITS ASSESSMENT

The elimination of permeable mixtures will ensure that freeze-thaw damage and moisture damage do not occur on susceptible projects, thus saving repaving and rehabilitation costs. Although no figures were available for the occurrence of this type of failure, eliminating only 10,000 tons of bad material (less than 1 percent of annual paving) would save VDOT $350,000 annually.

ACKNOWLEDGMENTS

The author thanks all of the VDOT and contractor personnel involved in the sampling and testing of mixtures covered in this study. Special thanks are extended to Mike Dudley and Troy Deeds of VTRC who coordinated collecting samples, coring, and testing for Phase I and Phase II, respectively.

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