BACK

MAIN PAGE

Correlation between the Laboratory and Field Permeability Values for the Superpave Pavements

Aneel Gogula, Mustaque Hossain, Stefan Romanoschi
Department of Civil Engineering
Kansas State University
Manhattan, KS 66506
mustak@ksu.edu, sromano@ksu.edu

Glenn A. Fager, P.E.
Materials & Research Center
Kansas Department of Transportation
2300 Van Buren
Topeka, KS 66611
glennf@ksdot.org

ABSTRACT

Permeability affects the performance of Superpave pavements. Percolation of water, through the interconnected voids of an asphalt pavement, causes stripping of the asphalt-bound layer as well as deterioration of the foundation layers of the roads. In this study, laboratory and field permeability tests, based on the principles of falling head, were conducted on different Superpave mixes with 19 mm and 12.5 mm nominal maximum aggregate sizes and coarse and fine gradations, to study the correlation between the laboratory and the field permeability values. The objective was to assess whether the field permeability values could be estimated during the mixture design process so that mix design can be adjusted depending upon the degree of permeability desired.

The results show that there was a significant difference between the laboratory- measured and the field permeability values. The field permeability values were very high compared to the laboratory-permeability values. The reason behind this discrepancy was further investigated and explained in this paper. Nevertheless, the field permeability values were found valuable in assessing compaction quality of the Superpave pavements.

Key words: pavement mixture—permeability—superpave pavements

Proceedings of the 2003 Mid-Continent Transportation Research Symposium, Ames, Iowa, August 2003.

INTRODUCTION

Proper compaction of the hot-mix asphalt (HMA) mixtures is vital for a stable and durable pavement. Low in-place air voids cause problems such as, rutting and shoving, while high in-place air voids reduce the pavement durability through moisture damage and excessive oxidation of the asphalt binder. For dense graded mixtures, numerous studies have shown that initial in-place air void contents should not be below three percent or above approximately eight percent *(1)*. As the in-place air voids increases, the permeability also increases. Past studies have also shown that mixtures with different Nominal Maximum Aggregate Size (NMAS) have different permeability characteristics *(2)*. Coarse-graded Superpave mixtures have a different internal air void structure than the dense-graded mixes used prior to Superpave *(3)*. As the NMAS increases, the size of individual air voids increases, and that leads to an increased potential for interconnected air voids. These interconnected air voids cause permeability in the Superpave pavements. Interconnected voids are the paths through which water can flow and hence mixtures with higher NMAS would be expected to be more permeable at a given air void content compared to the mixtures with a lower NMAS. The gradation characteristics of the aggregate structure also affect the permeability of the Superpave mixtures. Thickness of the Superpave mixture layer/lift is another factor that affects the permeability *(2)*. In normally constructed asphalt pavements all void spaces are not necessarily interconnected. Voids that are not interconnected do not allow water to flow thorough them. As the thickness of the pavement increases, the chance for voids being interconnected with a sufficient length to allow water to flow decreases. Because of this thinner pavements may have more potential for permeability.

During the mix design process it is not possible to know the actual permeability of a Superpave mix in the field without actually placing, compacting, and then measuring the field permeability value. In this study, in-place permeability testing was conducted on different Superpave pavements in Kansas to study the correlation between the laboratory and the field permeability values to see whether the field permeability values could be predicted during the mixture design process. By predicting field permeability values, mix design can be adjusted depending upon the degree of permeability desired. Correlations between the field and the lab permeability values and percent air voids were also investigated.

STUDY APPROACH

This study was conducted in two parts: (a) field-testing of Superpave mixtures, and (b) laboratory testing of gyratory compacted mixes obtained from the field. A commercially available field permeability-measuring device, available from Gilson, Inc., was used in this study. Figure 1 shows the schematic of this field permeability-measuring device. The device is based on the falling head principle of permeability and the Darcy's equation:

$$K = \frac{al}{At}\ln\left(\frac{h_1}{h_2}\right) \qquad (1)$$

where
K = Coefficient of permeability in cm/sec
a = inside cross sectional area of inlet standpipe in cm^2
l = thickness of the HMA specimen, cm
A = cross-sectional area of the HMA specimen, cm^2
t = time taken for water to flow from h_1 to h_2, seconds
h_1 = initial head of water, cm
h_2 = final head of water, cm

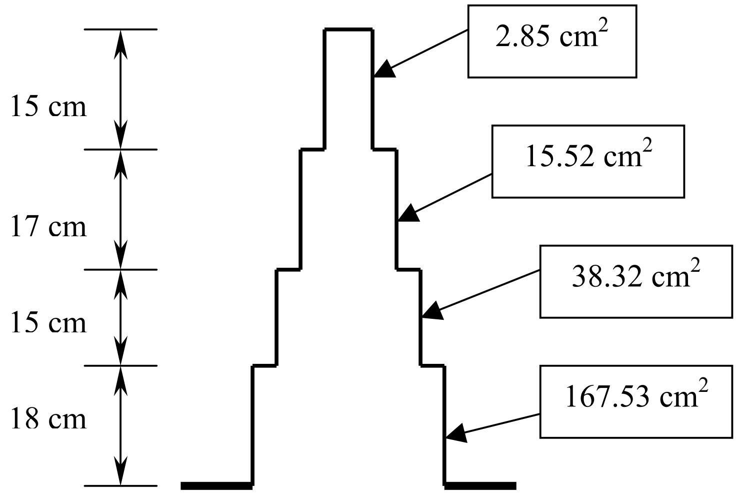


FIGURE 1. Schematic of the Field Permeameter

The permeameter consists of four conjoined segments or “tiers” of clear acrylic plastic, with varying cross section, so that a wide range of permeability can be tested. The area where the permeability test is conducted is cleaned thoroughly to remove the surface dust. Then the permeameter is fitted with a rubber gasket sealant, which ensures a watertight seal between the base of the permeameter and the pavement surface. About 2,500 grams weight is added to each corner of the permeameter to compensate for the head of pressure exerted by the water column. With out this counter weight, the water pressure can break the seal between the permeameter and the surface of the pavement. Water is then filled into the permeameter with a filling tube at a steady rate up to the top and then a tier is selected for monitoring the permeability, which is neither too fast nor too slow for accurate measurement of permeability. The large diameter of the second tier was used since the flow of water would be slow enough for efficient recording of data for most Superpave pavements tested in this study. The time taken for the water level to fall by 100 mm was noted.

For each project, tests were conducted at three locations on the newly compacted Superpave pavement, spaced at about 300 mm apart. At each test location, three replicate permeability tests were conducted before opening the section to traffic. All permeability measurements were made at a distance of about 600 mm from the pavement edge. The permeability device uses a rubber sealant to help seal the permeameter to the pavement surface. After the first test at a given test location, the device was lifted off the pavement and re-sealed immediately to conduct the second replicate test. Each replicate test was conducted at a spacing of approximately 250 mm. Field permeability testing was done in a direction longitudinal to the pavement, since the pavement density tends to be more uniform longitudinally than transversely. Also, plant produced mix was sampled from behind the paver for each project to carry out permeability testing on laboratory-compacted Superpave specimens.

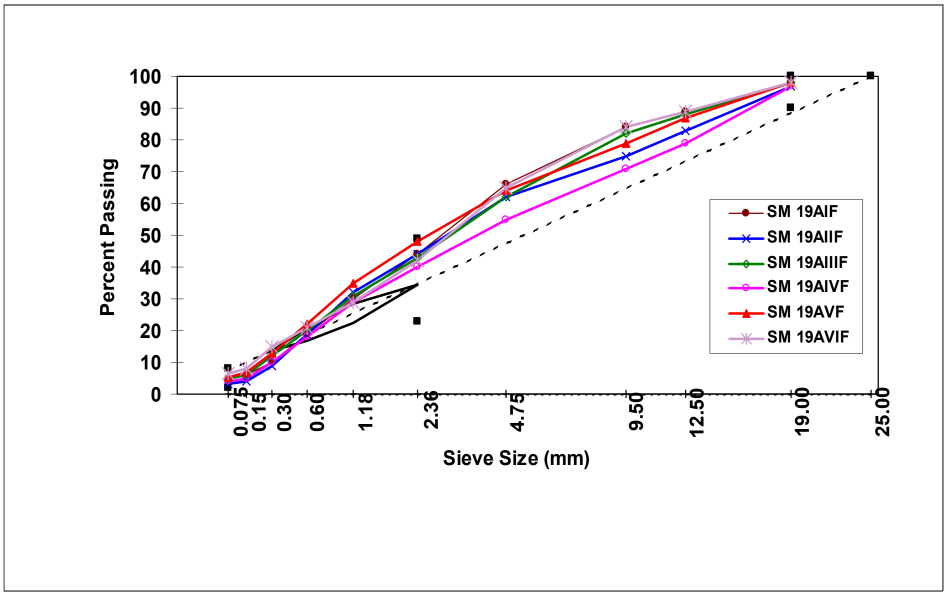
Table 1 summarizes the characteristics of the Superpave mixes obtained from different Superpave projects. All mixtures have either 19 mm or 12 mm nominal maximum aggregate size (NMAS). Figure 2 shows the aggregate gradation charts for the 19 mm and 12.5 mm Superpave mixes used.

All mixtures had gradations passing below the maximum density line in the finer sand sizes. Thus the mixtures are designated as “fine” in Kansas. The mixtures are from different lifts of the pavements. From the aggregate gradations, shown in Figure 2, it can be seen that all gradations pass through the restricted zone. The Kansas Department of Transportation (KDOT) has recently discontinued using restricted zone in the Superpave mixture gradation. The mixtures, however, met all requirements set by KDOT for the 19 mm and 12.5 mm NMAS Superpave mixtures.

TABLE 1. Properties of the Superpave Mixes used in the Field Study

Mixture/ Aggregate Blend Property	**Description**	**Design ESALs (millions)**	**N_{design}**	**PG Binder Grade**	**Asphalt Content (%)**	**Air Voids (%) at Ndes**	**VMA (%)**	**VFA (%)**	**Dust Binder Ratio**	**%Gmm at Nini**	**%Gmm at Nmax**
SM 19A(I)	Ritchie K-77	1.4	75	PG 58-28	5.2	4.26	13.96	69.56	1.2	89.1	96.6
SR 19A(II)	Venture I-70 Russell Shld	15	100	PG 64-23	3.6	4.7	14.79	68.21	0.73	90.66	96.08
SR 19A(III)	Venture I-70 Russell ML 1st Lift	15	100	PG 58-28	3.8	4.37	14.81	70.48	1.05	89.66	97.24
SR 19A(IV)	Venture I-70 Russell ML 2nd Lift	15	100	PG 70-28	4.2	4.15	14.12	70.53	0.96	89.71	97.26
SR 19A(V)	Venture I-70 Ellis ML 1st Lift	17.2	100	PG 64-22	3.9	4.4	14.68	76.43	1.2	90.65	97.55
SR 19A(VI)	Venture I-70 Ellis ML 2nd Lift	17.2	100	PG 70-28	4.3	3.6	13.5	73.36	1.4	88.8	97.6
SM 12.5A(I)	Hamm US-73	1.2	75	PG 64-22	6.5	4.74	14.58	67.49	1.29	87.5	96.4
SM 12.5A(II)	Ritchie K-4	0.7	75	PG 64-22	5.4	3.32	13.89	75.15	1.1	89.7	97.7
SM 12.5A(III)	Heckert US-56	1.2	75	PG 64-22	5.25	4.14	13.02	70.78	0.73	88.9	96.7

(a) SM 19 mm Mixes



(b) SM 12.5 mm Mixes

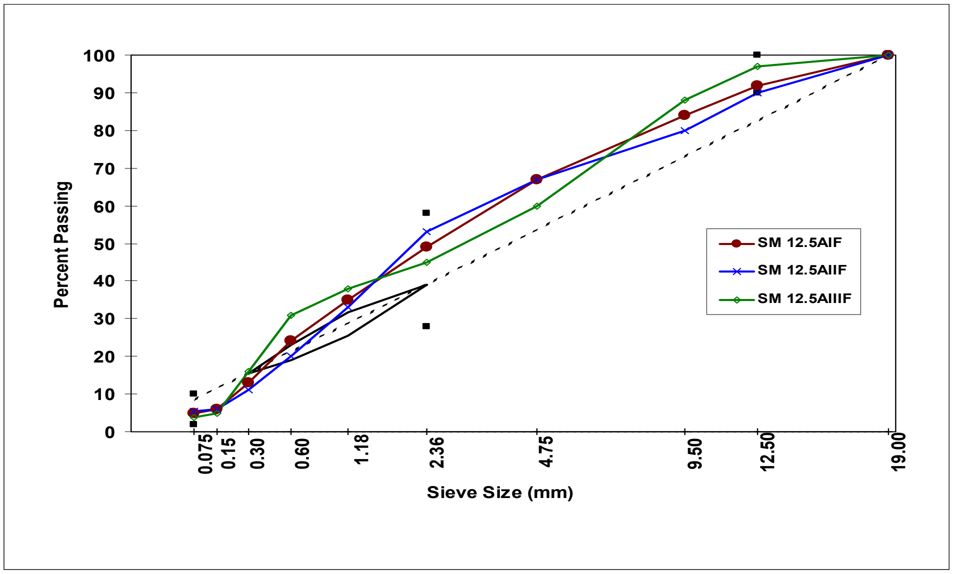


FIGURE 2. Combined Gradation Charts for NMAS 19 mm and 12.5 mm Superpave Mixes

POTENTIAL PROBLEMS IN MEASURING PERMEABILITY

A majority of the recent research work in permeability testing has been conducted on the core specimens that have been cut from the pavements or on the specimens compacted in the Superpave gyratory compactor. This is an important since Darcy's law is applicable for one-dimensional flow as would be encountered in a laboratory test. Measuring the in-situ permeability of an in-place pavement is theoretically more difficult, because water can flow in two dimensions.

Other potential problems include the degree of saturation, boundary conditions of the flow and the type of flow. The flow of water in the laboratory permeability test is in reality is one-dimensional.

Another potential boundary condition problem is the flow of water across (through) the pavement layers. Without some type of destructive test, such as, coring there is no way of knowing whether water flows across the layers *(3)*. Darcy's law was derived based on the experimentation on clean sands and the flow of water through the sand was determined to be laminar. Within a pavement section, it cannot be determined whether the flow of water is laminar or turbulent. Since we cannot use Darcy's law to calculate permeability if the flow is turbulent, hence the flow of water through the pavement *is assumed to be laminar*. While conducting the field permeability tests, it was observed that the drop in water level during the first test usually took lesser time compared to the subsequent replicate tests. One possible explanation is that during the first test, the water fills up the voids, including some that were not interconnected, and during the second and third tests, the water cannot go through these non interconnected voids, and only flows through the interconnected voids *(4)*.

RESULTS AND DISCUSSION

All laboratory test samples were compacted in a Superpave gyratory compactor to a target air void content of 7%. Table 2 summarizes the field and laboratory permeability values. Figure 3 illustrates the comparison of these measured permeability values. A large variation between the permeability values measured in the field and those in the laboratory was observed. These results show that there was a significant difference between the field and laboratory permeability values. The field permeability values are always much higher than the laboratory permeability values. This higher field permeability can be explained in terms of water flow in the field. Unlike laboratory tests, the flow in the in-situ pavement is not confined to one-dimensional flow. Water entering the pavement can flow in any direction (vertical and/or horizontal). Therefore, it would be expected that the field permeability values should be higher than the laboratory permeability values since both are estimated based on the falling head permeability test principles. The difference in the permeability value obtained would be most likely dependant upon the NMAS, aggregate gradation, and the interconnectivity of air voids. Past experience has shown that a large amount of flow took place in the coarser Superpave mixes with thick lifts in the horizontal direction, whereas finer mixes with thinner lifts tend to have more of a vertical flow *(4)*. During most field tests in this study, water was observed to come up through the mat a few centimeters away from the base of the permeameter. This could be due to the horizontal flow of water in the underlying layers of the pavement.

Figure 4 shows the relationship between the laboratory permeability values and the percent air voids for different mixtures tested in this study. The air voids were measured on the laboratory-compacted samples. No meaningful correlation among the field permeability, the laboratory permeability and the percentage air voids of the laboratory-compacted specimens was observed as shown in Figures 3 and 4.

Mat Tearing and Breakdown Rolling

The weight of the breakdown roller is one of the factors that influence the permeability of Superpave pavements during construction. Mat tearing was observed on one of the projects in this study. The mixture was a recycled Superpave mixture with 19 mm NMAS on I-70 in Ellis county, Kansas. The first lift of the pavement exhibited mat tearing at several locations. The permeability values at these locations were also very high. The average field permeability value on the sections which did not show mat tearing was found to be 6.18×10^{-3} cm/sec. The field permeability values on the torn mat was found to be 25.36×10^{-3} cm/sec, nearly four times the average field permeability value for the locations with no mat tearing. The thin cracks appeared on the surface of the HMA pavement, due to the heavy roller compacting a thin lift (65 mm) of HMA.

TABLE 2. Summary of Field and Laboratory Permeability Results

Field Permeability Results					Lab Permeability Results			
	Project	Location	Field Permeability (cm/sec)	Average Permeability (cm/sec)	Sample	% Air Voids	Lab Permeability (cm/sec)	Average Permeability (cm/sec)
1	Venture Russel County 1st Lift	1	1.8612E-03		1	9.02	6.8814E-05	
	SR 19A	2	1.2279E-03	1.6454E-03	2	7.90	4.6064E-05	5.7950E-05
		3	1.8471E-03		3	6.68	5.8970E-05	
2	Venture Russel County 2nd Lift	1	3.6090E-03		1	6.74	2.8985E-05	
	SR 19A	2	5.5294E-03	5.0507E-03	2	6.63	5.6808E-05	6.24124E-05
		3	6.0136E-03		3	6.65	1.0144E-04	
3	Venture Russel County Shoulder	1	3.4803E-03		1	6.51	4.2530E-05	
	SR 19A	2	3.0712E-03	3.1900E-03	2	6.54	3.0287E-05	3.55285E-05
		3	3.0185E-03		3	6.59	3.3768E-05	
4	Venture Ellis County 1st Lift	1	5.8534E-03		1	7.04	2.5835E-06	
	SR 19A	2	7.5438E-03	6.1797E-03	2	6.70	2.1712E-04	1.0846E-04
		3	5.1419E-03		3	5.56	1.0568E-04	
5	Venture Ellis County 2nd Lift	1	1.4095E-02		1	6.64	5.2743E-05	
	SR 19A	2	1.3210E-02	1.3008E-02	2	6.70	1.7263E-05	1.0846E-04
		3	1.1719E-02		3	6.68	2.2201E-05	
6	KDOT Marion County	1	8.6681E-03		1	6.97	6.8525E-07	
	SM 19A	2	8.6832E-03	8.3794E-03	2	6.85	2.1315E-06	3.37308E-06
		3	7.7867E-03		3	7.40	7.3025E-06	
7	Ritchie Paving K-4	1	3.4972E-03		1	6.91	1.06047E-05	
	SM 12.5 A	2	3.7896E-03	3.7523E-03	2	6.91	3.53998E-05	2.5104E-05
		3	3.9701E-03		3	6.66	2.93075E-05	
8	Hamm Const. US 73	1	5.1538E-03		1	6.88	3.64946E-06	
	SM 12.5 A	2	7.4717E-03	7.0719E-03	2	6.83	3.06385E-06	2.98136E-06
		3	8.5902E-03		3	6.83	2.23077E-06	
9	Heckert US 56	1	3.8079E-03		1	6.54	1.04708E-05	
	SM 12.5 A	2	3.6109E-03	3.6451E-03	2	5.03	5.26915E-07	5.00212E-06
		3	3.5164E-03		3	6.1	4.00864E-06	

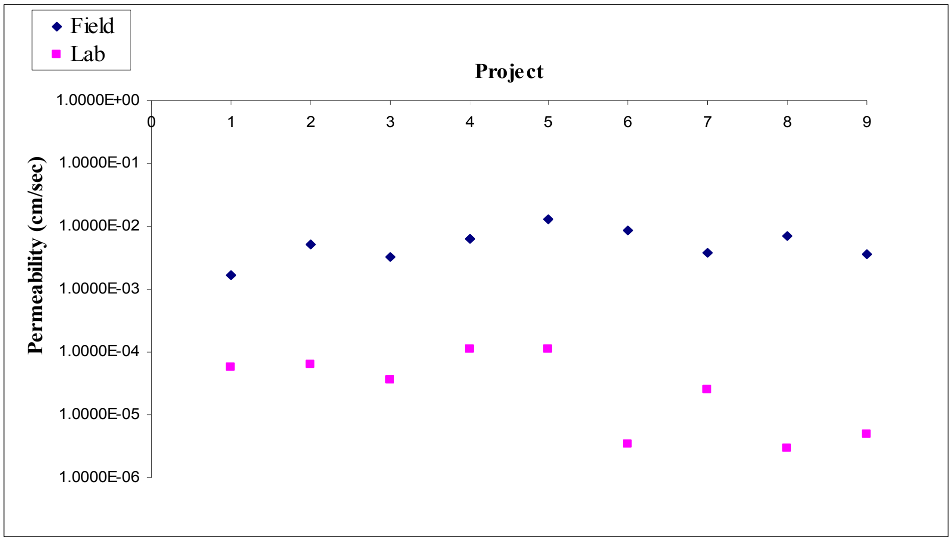


FIGURE 3. Comparison of Field and Laboratory Permeability Values

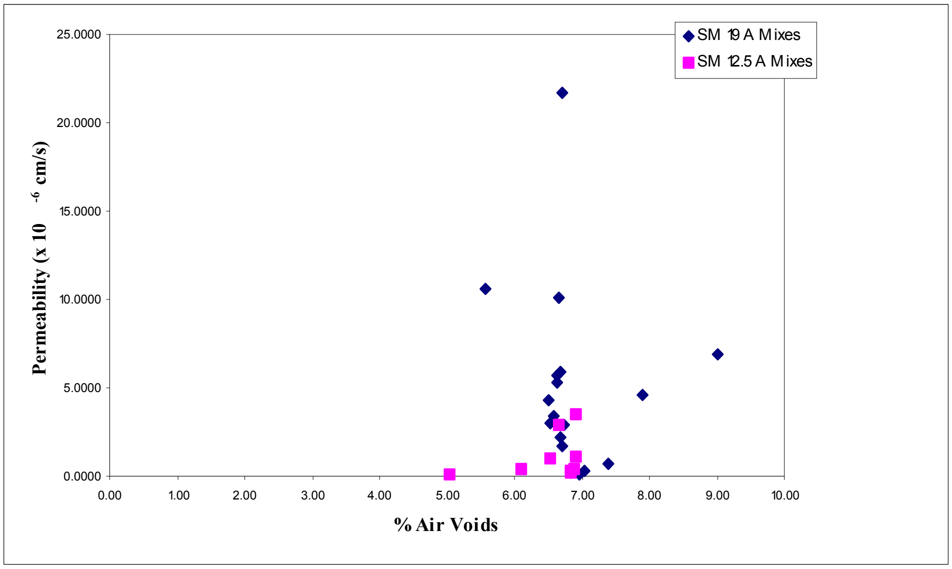


FIGURE 4. Relationship between Permeability and Air voids for the NMAS 19 mm and 12.5 mm Mixes

CONCLUSIONS

1. There is a significant difference between the permeability values obtained from the laboratory tests and the field tests using the same principles of measurement. The field permeability values are consistently higher than the laboratory permeability values.

2. There is no statistical correlation among the field permeability, the laboratory permeability and the percentage air voids of the laboratory-compacted specimens.

3. The mat tearing by heavy breakdown roller significantly increases the field permeability values.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the financial support for this study provided by the Kansas Department of Transportation under the K-TRAN program. The authors also would like to acknowledge the cooperation of Venture Corporation, Shilling Construction Co., Kansas Asphalt Paving Association, Ritchie Paving, Inc., and APAC Shears-Kansas, Inc. in this study. Mr. Bryce Barkus and Ms. Jennifer Hancock of Kansas State University helped out with the lab testing. Their contribution to the work reported here is gratefully acknowledged.

REFERENCES

1. Roberts, F.L., Kandhal, P.S., Brown, E.R., et al,. *Hot Mix Asphalt Materials, Mixture Design and Construction*, Second Edition, NAPA Educational Foundation, Lanham, Maryland, 1996.

2. Mallick, R.B., L.A.Cooley, Jr., and M.Teto. Evaluation of Permeability of Superpave Mixes in Maine. Final Report. Technical Report ME-001. Maine Department of Transportation, Augusta, Maine, 1999.

3. Cooley, L.A., and E.R. Brown. Selection and Evaluation of a Field Permeability Device for Asphalt Pavements. Transportation Research Record 1723, TRB, National Research Council, Washington, D.C., 2000.

1. Mallick, R.B., Cooley, A.L., Teto, M.R., and R.L. Bradbury. Development of A Simple Test for Evaluation of In-Place Permeability of Asphalt Mixes, *International Journal of Pavement Engineering*, Vol.2, No.2, 2001.