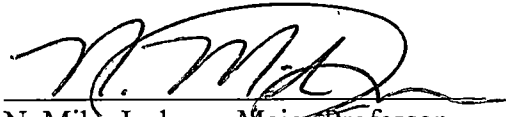


To the Graduate Council:

I am submitting herewith a thesis written by Thomas Dexter Justis entitled "Evaluation of HMA Laboratory Permeability Using the Karol-Warner Flexible Wall Permeameter." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Civil Engineering.


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Karen C. Chou
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Interim Vice Provost and
Dean of the Graduate School

**Evaluation of HMA Laboratory Permeability Using
the Karol-Warner Flexible Wall Permeameter**

A Thesis Presented for the Master of Science Degree
The University of Tennessee, Knoxville

Thomas D. Justis
May, 2001

Dedication

This thesis is dedicated to my parents and sister, Tommy, Sue and Libby Justis. Without your advice, encouragement, and love, this would not be possible.

Acknowledgements

I would like to thank the faculty and staff of the Civil and Environmental Engineering Department for their support and encouragement during my time at the University of Tennessee. A special thank you goes to Dr. Mike Jackson for his guidance and friendship along the way. I would like to thank Dr. Hal Deatherage and Dr. Karen Chou for being exceptional professors and taking the time to get to know their students personally. I would also like to thank the Tennessee Department of Transportation for their assistance with this project, especially Mr. Greg Duncan of the Materials and Test Division.

Special thanks to Mr. Ken Thomas and Mr. Larry Roberts for all their time and energy spent to help all students in any way possible. Special thanks to David Fuson, Danny Oliver, Neal Whitten, and Preston Breeding for their help on this project. Finally, I would like to thank my fiancée, Melanie, for her love, support, and understanding.

Abstract

This document presents the results of a study initiated to evaluate the laboratory permeability of Hot Mix Asphalt (HMA) mixes placed on Tennessee roadways. The study consisted of using a Karol-Warner Flexible Wall Permeameter to evaluate the permeability of eight SuperpaveTM-designed mixes and nine Marshall designed mixes produced in 1999 and 2000.

The focus of this study was to evaluate the correlation between field and laboratory measurements of permeability using linear regression analysis. Linear regression analysis was also used to evaluate the relationship between roadway core density (%G_{mm}) and laboratory permeability. Appropriate statistical methods were used to evaluate the difference between Marshall and SuperpaveTM designed mixes and the effect saw cutting has on laboratory permeability measurements.

This study shows that in genera, laboratory permeability falls below 100×10^{-5} (cm/sec) when 94% compaction is achieved. The results presented herein further demonstrate that a fair to poor relationship exists between field and laboratory measurements of permeability. It is also documented that there are significant problems achieving density requirements. This is evident by the fact that only 14 of 51 cores achieved 92% compaction as specified by the contract document. It was also observed that a difference exists between the laboratory permeability of Marshall and SuperpaveTM mixes as designed in Tennessee, while statistically speaking no difference exists. Finally, no definite trend was observed when evaluating the effects of saw cutting.

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Chapter 1.0 Introduction

Highway agencies in the United States, as well as in other countries, face increasing demands on their facilities and decreasing resources to maintain and preserve them. Historically, highway agencies in the U.S. focused on construction of new facilities. However, with the completion of the interstate highway system, the highway infrastructure is now largely in place. Consequently, preservation of existing assets is today's priority. It is believed that the relative permeability of compacted HMA is an indicator of the quality and durability of a given pavement. Increased wheel loads and soaked pavements have created high internal stresses inside the pavements matrix, in turn breaking down the bond between the aggregate and the asphalt binder. Therefore, it is important to investigate each pavement's ability to take on water as a preventive measure to reduce pavement failures.

Permeability is the measured ability of a fluid, such as water or air, to penetrate through a porous media. In asphalt paving technology it is accepted that proper compaction is needed to ensure proper durability of HMA's. While permeability is expected in the paving industry, excessive amounts of permeability can be attributed to poor compaction efforts. Recent studies suggest that the SuperpaveTM gyratory compactor tends to compact mixes in the laboratory in excess of what is achievable on the roadway with conventional paving equipment (Ownby, 1998). Compactability issues associated with SuperpaveTM have led many in the HMA industry to question whether some

mixes designed by this method are permeable enough to allow moisture to readily flow through the mix, resulting in premature failures. Research conducted by the Florida Department of Transportation (FDOT) has documented that SuperpaveTM-designed mixes may be permeable to water at air void contents below 8 percent. This suggests that compaction is very important to the long-term durability of HMA (DeStazio, 1999).

For dense graded mixes, research indicates that the initial in-place air voids should not fall below about 3 percent and should not exceed 8 percent. High air voids in a finished pavement will adversely affect durability and performance in various ways, especially if the voids are interconnected. The availability of oxygen within the pavement accelerates aging and the penetration of water may induce stripping. Both of these events will eventually result in premature failure of the pavement. Low air voids on the other hand may lead to rutting and shoving, which also leads to premature pavement failures (DeStazio, 1999).

A typical State Department of Transportation spends \$100-200 million per year on HMA. Estimates indicate that if actions can be taken to extend the pavement life by only 1% (30-60 days) one would expect to save \$150 million per year on HMA costs (Avera, 1988).

The objective of this study was to document the correlation between field permeability, as determined using the tiered permeameter developed at NCAT, and laboratory permeability, as determined using the Karol-Warner Flexible Wall Laboratory Permeameter. A secondary objective of this study was to evaluate if

there is a difference between laboratory permeability for SuperpaveTM designed mixes and conventional Marshall-designed mixes placed in Tennessee during the 1999 and 2000-paving seasons.

Chapter 2.0 Background

Permeability is the measurement of a fluids' ability to penetrate and pass through a porous media. In this study, the permeability of the asphalt layers as water passes through compacted HMA. In order for water to penetrate compacted HMA, the HMA must have air-voids that can be filled with water. If the water is to pass completely through the HMA layer, these air-voids must be interconnected. This section will provide background on test methods and previous research conducted on this topic.

2.1 Darcy's Law

Henry Darcy, a French scientist, was studying vertical flow through sand used for water filtration when, in 1856, he was the first to experimentally demonstrate that the flow rate of water is directly proportional to the hydraulic gradient as shown in Equation 1 (Franzini and Finnemore 1997):

$$Q=kiA \quad (1)$$

Where:

Q = Rate of flow,
k = Hydraulic conductivity, or coefficient of permeability,
i = Hydraulic gradient or head loss between two points, and
A = Cross-sectional area.

In using Darcy's law, several assumptions are made that include:

- 1.) Laminar flow
- 2.) Incompressible fluid
- 3.) Steady-state flow
- 4.) Homogenous material

- 5.) Saturated conditions
- 6.) One-dimensional flow

Over time, two general approaches were adopted to measure the permeability of construction materials. These include a constant head test and a falling head test. The constant head method is used on materials with high permeability readings such as open-graded HMA pavements. This study is focused on the permeability of dense-graded HMA surface mixes. The falling head test, used on surface mixes that have low permeability readings, involves determining the amount of head loss through a given sample, over a given time. The falling head test method was adopted for use on both the field and laboratory permeameters used in this study. The derivation of the equation for the falling head test method was previously documented by Fuson (Fuson 2000). For the falling head test, the coefficient of permeability is calculated as shown in

Equation 2:
$$k = \frac{aL}{A\Delta t} \ln \frac{h_1}{h_2} \quad (2)$$

Where:

- a = The area of the top tier or stand pipe,
- L = Pavement thickness,
- Δt = Final time minus initial time,
- h_1 = Initial head in the permeameter,
- h_2 = The final head in the permeameter.
- A = The area of the test specimen

2.2 Previous Research

In 1996, the Florida Department of Transportation made a concerted effort to implement the new HMA technology to address increased pavement failures

due to rutting. Immediately after construction of a large interstate rehabilitation project, it was observed that water seemed to be absorbed into the pavements and weeping out of the low side shoulder joint (Choubane 1997). This was the first documentation of permeability problems related with SuperpaveTM technology in Florida. It has been documented that when water penetrates an asphalt pavement, premature failures occur in the form of stripping and raveling. When the air voids inside the pavement become saturated with water, excess pore pressures are produced under traffic loads causing failure of the binder-aggregate bond, i.e. stripping (Roberts et al 1996).

The ability of water to penetrate into the inner portions of an HMA pavement is obviously a function of compaction. There are many issues that affect compaction of HMA, such as:

- 1.) Temperature
- 2.) Mix properties
- 3.) Roller patterns
- 4.) Layer thickness

The weather can adversely affect the temperature of the HMA layer and make it very difficult to get good compaction when the pavement cools at a high rate. When the pavement temperature is between 200°F and 245°F, the pavement is considered to be in the tender zone. It is important for the breakdown and intermediate rollers to obtain as much compaction as possible before the HMA layer enters this tender zone. SuperpaveTM technology defines the top-size and nominal maximum size aggregate one size smaller than does a typical state DOT.

This definition along with commonly used higher concentrations of coarse aggregate, requires increased lift thickness to achieve the workability needed for proper compaction. Since SuperpaveTM mixture design results in a coarse graded HMA that is much more porous than traditional asphalt mixes, it has been suggested that a ratio of 3 to 4 times the nominal aggregate size to the minimum lift thickness is recommended (Walker 2000).

In order for water to penetrate into the inner regions of the HMA layer, there must be interconnected voids available. It has been documented by Florida DOT that interconnected voids in SuperpaveTM pavements may occur at a much lower void content than those of a conventional 75-blow Marshall mix design. It has also been documented that as the nominal maximum aggregate size increases, the size of air voids within the compacted pavement also likely increases, especially in coarse-graded SuperpaveTM mixes. As the size of voids increase, the potential for interconnected air voids also increase (Mallick et al. 2001).

Finer aggregate results in a larger number of smaller pores, even though the total pore volume may be the same, the smaller pore size results in a lower permeability (Kanitpong et al. 2001). HMA permeability is directly related to the amount of interconnected voids within the pavement. As pavement thickness increases an interconnected void channel in a 50mm thick pavement may not be a channel through a 75mm thick pavement. Therefore, it has also been documented that as pavement thickness increases permeability decreases (Mallick et al 2001).

The Florida DOT report on permeability of HMA pavements suggest that there is no significant change in permeability when the amount of air voids falls

below seven percent and that, when the air void content is less than six percent, the pavement is “virtually impermeable” (permeability is negligible). However, they go on to say that a slight increase above seven percent air-voids would result in a pronounced increase in permeability (Choubane 1997). This indicates that interconnected voids may become prevalent shortly above seven percent voids in the mix (VTM) in SuperpaveTM mixes. This finding suggests that when a paving crew compacts an HMA pavement to eight percent VTM, that is required in specifications for a conventional 75-blow Marshall mix design in the state of Tennessee, that permeability problems may occur. This also suggests that it may be impractical to use density specifications written for conventional 75-blow Marshall mixes on coarse-graded SuperpaveTM mixes.

2.3 Laboratory Permeability Testing of HMA

In 1996, The Florida Department of Transportation (FDOT) developed a laboratory testing device and a standardized testing procedure to investigate the permeability of SuperpaveTM-designed HMA. This laboratory device, which was also used in this study and shown in Figure 1, utilized a falling head concept to test the permeability of cores cut from pavements. The results of the Florida DOT research revealed that for coarse-graded SuperpaveTM-designed mixes to remain impermeable to water, the desired air void content should be 6 percent or less. It was determined that Florida mixes produced a relative permeability reading of 60×10^{-5} (cm/sec) at seven percent air voids. Based on this research, FDOT proposed an upper limit on permeability of about 100×10^{-5} cm/sec (Choubane et al 1998).

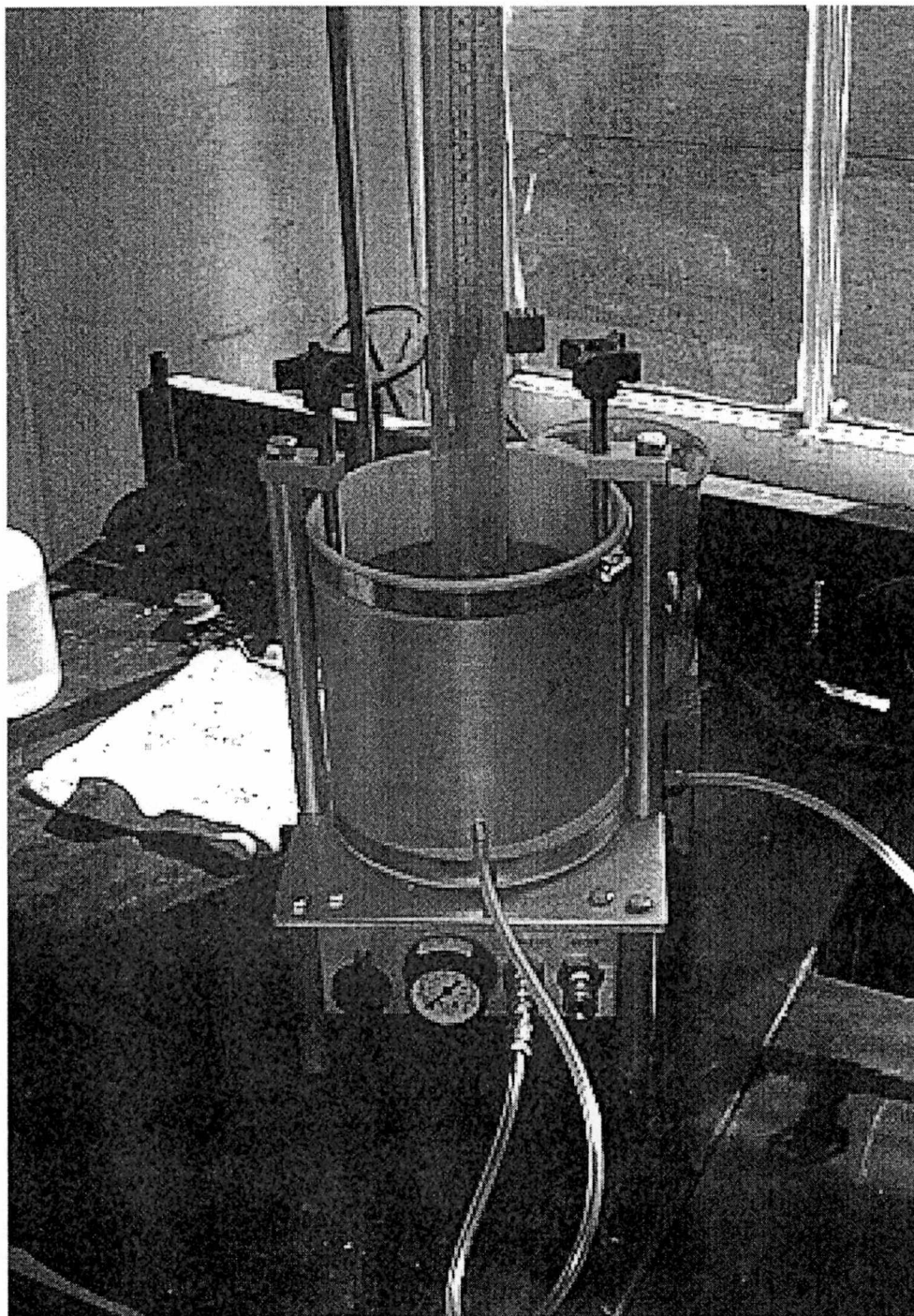


Figure 1 Karol-Warner Flexible Wall Permeameter

As part of this study, FDOT compared the relative permeability of SuperpaveTM-designed mixes to that of conventional Marshall-designed mixes. The results indicated that the conventional Marshall-designed mixes remained impermeable to water at air void contents well above 6 percent. FDOT concluded that the air voids in the course-graded SuperpaveTM mixes have greater potential to be interconnected (Choubane et al 1998).

Laboratory testing is time consuming and requires cores to be cut from the roadway. Cores cut from the roadway are soaked in a vacuum chamber and soaked until 95% saturation of the core is achieved. The core is then placed in the laboratory permeameter and a confining pressure of 17 ± 2 (psi) is applied. Water is allowed to pass through the core and the amount of time required for the head to fall from 30 cm to 10 cm is used to calculate the coefficient of permeability.

2.4 Field Measurements of Permeability of HMA

The National Center for Asphalt Technology (NCAT) conducted a study with the objective of evaluating four field permeameters and selecting the most suitable device. This evaluation was based on three criteria: best correlation with lab permeability, repeatability, and ease of use. The device selected was a tiered permeameter developed at NCAT. As a result of this study, The University of Tennessee graduate research program in materials engineering used the NCAT tiered permeameter in an ongoing field permeability study to evaluate the permeability of Tennessee pavements (Fuson 2000, Oliver 2001). The results

obtained from the University of Tennessee field study were also used in this study and correlated with the laboratory permeability readings obtained from cores taken from job sites at which the fore-mentioned study was performed. The NCAT field permeameter used is shown in Figure 2.

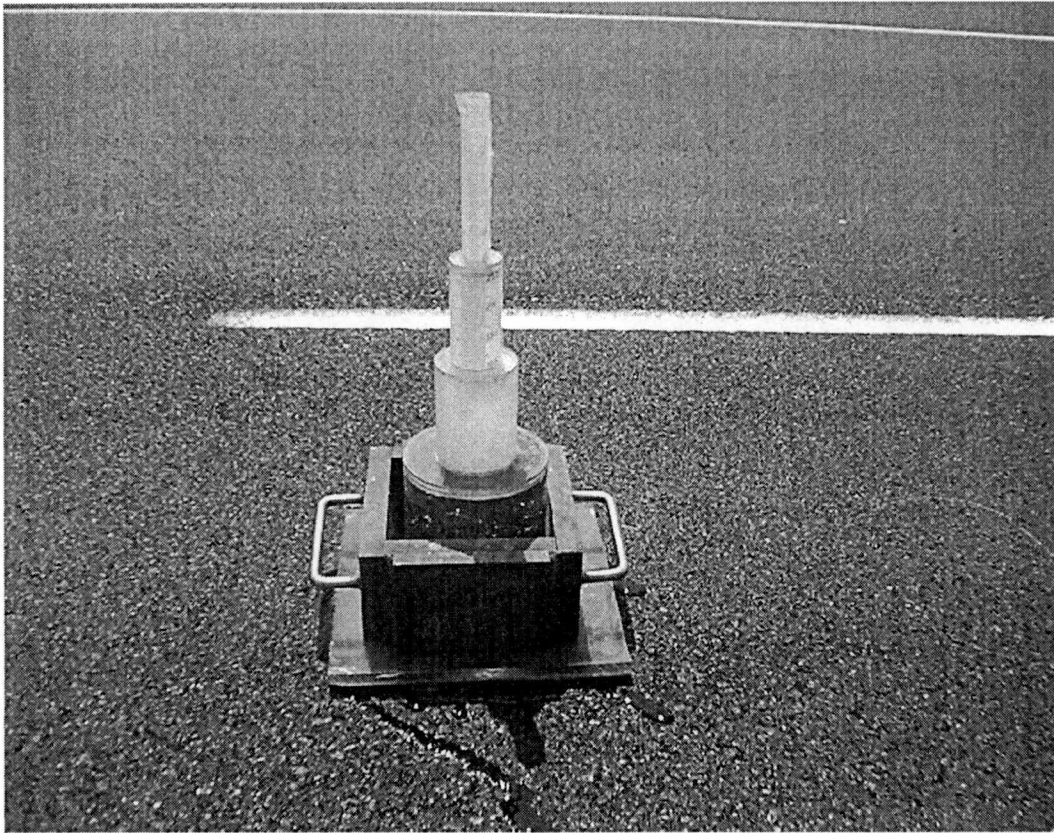


Figure 2 NCAT Tiered Permeameter

Chapter 3.0 Test Program

As previously noted, the purpose of this study was to identify the correlation between field measurements, as determined using a the tiered permeameter developed at NCAT, and laboratory permeability, as determined using the Karol-Warner Flexible Wall Laboratory Permeameter. Both SuperpaveTM (411-S) and conventional Marshall (411-D) designed surface mixes were tested as part of this study. The (411) identification number indicates that the mix is a surface mix, designed in accordance with Section 411 of the TDOT Standard Specifications for Road and Bridge Construction (TDOT 1995). The letter following the mix number indicates whether the mix is a SuperpaveTM mix design (S) or a conventional, 75-blow Marshall mix design (D).

With the assistance of TDOT personnel, field and laboratory permeability tests were conducted on a total of 17 different mixes. These include mix from four SuperpaveTM projects constructed during the 1999-paving season, four SuperpaveTM projects constructed during the 2000-paving season, four conventional Marshall mix projects constructed during the 1999-paving season, and five conventional Marshall mix projects constructed during the 2000-paving season. Job Mix Formula (JMF) sheets for each mix tested in this study are presented in Appendix A. Loose HMA and pavement cores were obtained from each of the projects tested. The loose mix and pavement cores were transported to the asphalt laboratory at the University of Tennessee for further testing and

evaluation. A summary of the specific paving projects included in this study is provided in Table 1.

The test protocol for performing the field permeability test has been documented by others (Fuson 2000, Oliver 2001). The following sections describe the layout of test sections used for performing the field permeability test and how samples were obtained to perform laboratory permeability test.

3.1 Testing Layout for Field Permeability Testing

A photographic description and protocol for of the testing procedure used in this study was documented by Fuson (Fuson 2000). The test locations for these projects were established by visiting the asphalt plant, obtaining ten buckets of loose HMA from a loaded haul truck, and following the loaded haul truck to the job site. The typical test section was 150-ft long and was subdivided into three sub-sections, spaced at 50-ft intervals. The first sub-section was located in the left wheel path, the second sub-section was located at the center of the roadway, and the third sub-section was located in the right wheel path. A sequence of three tests in a straight line were conducted within each sub-section, with a 1-foot spacing between the first and second test location and 3-feet spacing between the second and third test location, as shown in Figure 3. A typical field permeability test consisted of an average of three flow measurements that fell within a range of ± 2 ml/sec. One pavement core was cut from each sub-section, typically located between the second and third test location, as

Table 1 Mix Identification Summary.

Tennessee County	Year Constructed	TDOT Mix Type	TDOT Region	TDOT Project Number	Contract Number
Sullivan	1999	411-S	I	82012-4201-04	5800
Sullivan	1999	411-D	I	82001-8160-44	5405
Hamilton	1999	411-S	II	33036-4278-04	5822
Hamilton	1999	411-D	II	33042-4227-04	5621
Smith	1999	411-S	III	80001-8164-44	5706
Davidson	1999	411-D	III	19009-3163-44	5114
Fayette	1999	411-S	IV	24001-8140-44	5616
Fayette	1999	411-D	IV	24001-8140-44	5616
Hamblen	2000	411-D	I	32001-8121-44	1023
Campbell	2000	411-S	I	07100-8105-44	1010
Coffee-Grundy	2000	411-S	II	16001-8160-44	1014
Hamilton	2000	411-D	II	33003-8155-44	5530
Sumner	2000	411-S	III	83002-4252-04	1198
Dickson	2000	411-D	III	22004-4239-04	1165
Madison	2000	411-S	IV	57201-8110-44	1037
Madison	2000	411-D	IV	57201-8111-44	1037
Haywood	2000	411-D	IV	38001-8174-44	1027

shown in Figures 3 and 4. The pavement cores taken from each project were transported to the asphalt laboratory at the University of Tennessee for further testing and evaluation.

3.2 Laboratory Testing

Bulk specific gravity (G_{mb}) tests were conducted on the pavement cores obtained from each test location. This testing was performed in accordance with ASTM D 2726 (AASHTO T 166). The loose HMA was heated to approximately 110°C (230°F) and reduced to 3 representative test portions in accordance with ASTM C 702 (AASHTO T 248). Theoretical maximum (Rice) specific gravity (G_{mm}) tests were conducted on the loose HMA in accordance with ASTM D 2041 (AASHTO T 209). The theoretical maximum and bulk specific gravity test results were used to calculate the % G_{mm} for each mix. All theoretical maximum and bulk specific gravity test data is presented in Appendix B. After all specific gravity data was obtained, laboratory permeability tests were performed. The test protocol for performing the laboratory permeability test was the same for all projects and is presented in Appendix C.

3.3 Test Results

Table 2 provides a summary of the test results obtained in both the field and laboratory for this study. Columns 8 and 9 show a summary of average

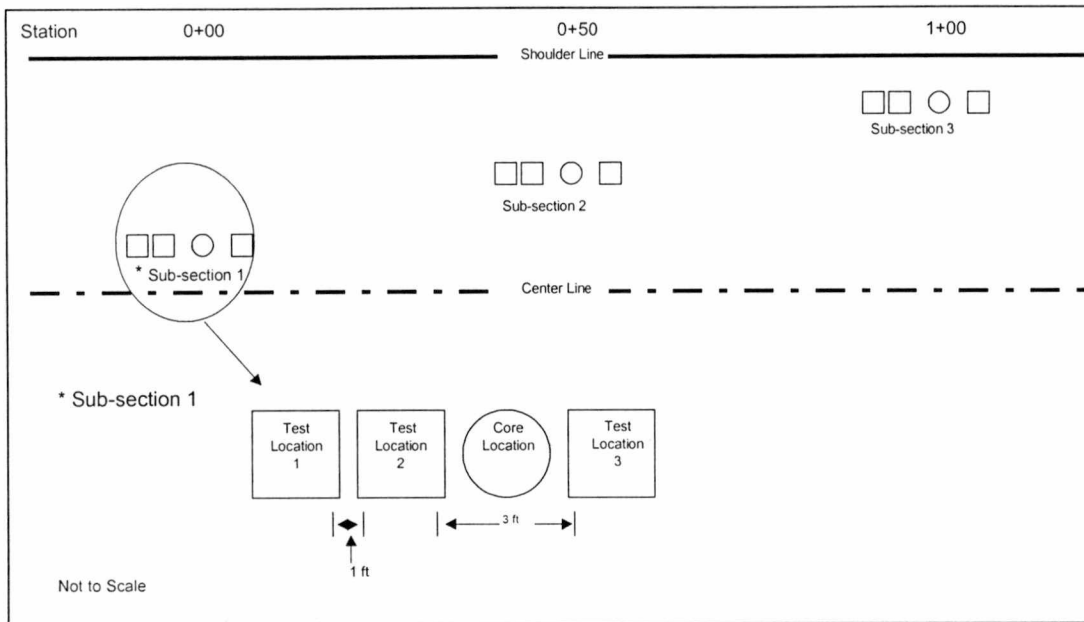


Figure 3 Typical Test Section Layout

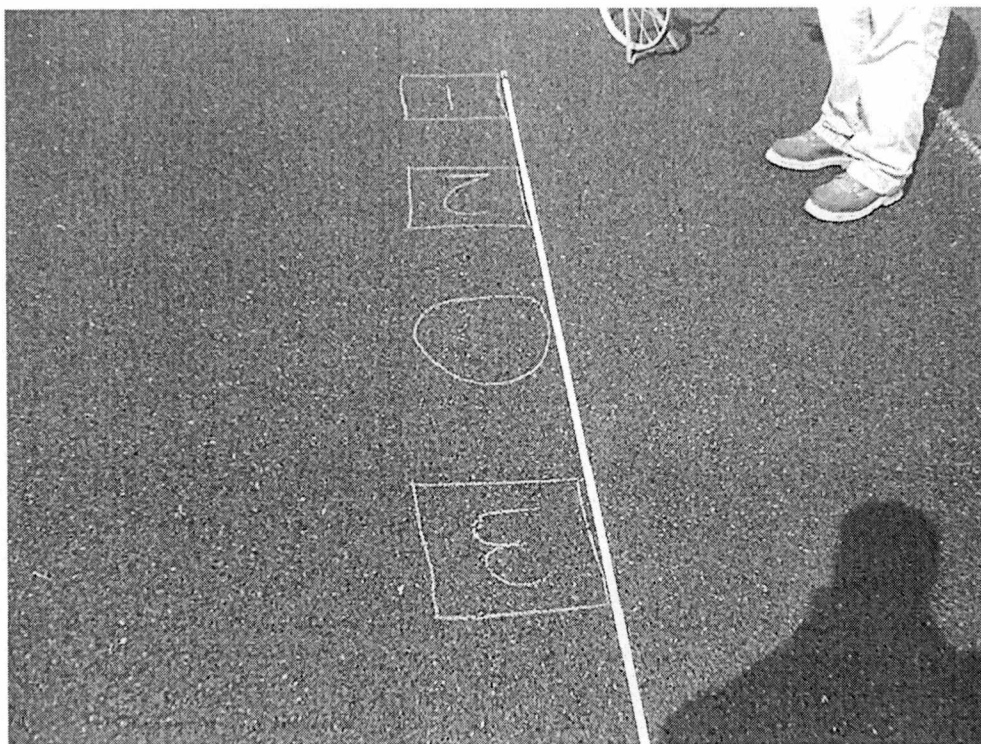


Figure 4 Typical Sub-Section Layout

Table 2 Summary of Test Results

County	Year Constructed	Mix Type	Test Sub- section	Bulk Specific Gravity	Rice Specific Gravity	Core Density (%G _{mm})	Field Permeability x10 ⁻⁵ (cm/sec)	Laboratory Permeability x10 ⁻⁵ (cm/sec)
1	2	3	4	5	6	7	8	9
Hamilton	1999	411-D	1	2.228	2.47	90.2	35.8	3
			2	2.245	2.47	90.9	69.7	4.81
			3	2.29	2.47	92.7	196.0	2.61
Fayette	1999	411-D	1	2.26	2.37	95.4	0.1	0.1
			2	2.26	2.37	95.4	6.5	0.1
			3	2.272	2.37	95.9	4.6	0.1
Davidson	1999	411-D	1	2.259	2.429	93.0	16.2	63.6
			2	2.288	2.429	94.2	20.9	25.1
			3	2.258	2.429	93.0	14.6	60.5
Sullivan	1999	411-D	1	2.147	2.47	86.9	2544.5	2037.96
			2	2.141	2.47	86.7	2668.6	1877.3
			3	2.133	2.47	86.4	3354.2	2822.92
Haywood	2000	411-D	L	2.067	2.343	88.2	186.9	626.1
			C	2.036	2.343	86.9	223.4	931.2
			R	1.992	2.343	85.0	431.2	1516.2
Madison	2000	411-D	L	2.19	2.37	92.4	1.5	20.89
			C	2.132	2.37	90.0	7.2	189.5
			R	2.269	2.37	95.7	0.1	4.1
Dickson	2000	411-D	L	2.136	2.446	87.3	74.1	559.3
			C	2.212	2.446	90.4	20.1	104.1
			R	2.196	2.446	89.8	75.0	284.6
Hamilton	2000	411-D	L	2.066	2.305	89.6	58.4	353.4
			C	2.108	2.305	91.5	57.6	119.4
			R	2.148	2.305	93.2	6.6	32.2
Hamblen	2000	411-D	L	2.23	2.455	90.8	8.8	51.7
			C	2.197	2.455	89.5	57.2	180.2
			R	2.189	2.455	89.2	78.8	394.6
Fayette	1999	411-S	1	2.211	2.418	91.4392	111.3	113.3
			2	2.261	2.418	93.507	47.6	0.1
			3	2.22	2.418	91.8114	17.0	137.2
Smith	1999	411-S	1	2.265	2.481	91.2938	66.6	243.9
			2	2.268	2.481	91.4148	51.8	688.6
			3	2.262	2.481	91.1729	86.5	367.8
Hamilton	1999	411-S	1	2.082	2.346	88.7468	92.1	441.3
			2	2.005	2.346	85.4646	245.6	1971.7
			3	1.985	2.346	84.6121	353.0	2301.1
Sullivan	1999	411-S	1	2.222	2.468	90.0324	544.0	678.3
			2	2.26	2.468	91.5721	377.4	285.1
			3	2.195	2.468	88.9384	1494.5	1339.9
Sumner	2000	411-S	L	2.154	2.442	88.2064	188.1	1271.8
			C	2.201	2.442	90.131	574.2	920.5
			R	2.253	2.442	92.2604	268.8	224.5
Coffee	2000	411-S	L	2.136	2.468	86.5478	1136.9	2399.1
			C	2.1	2.468	85.0891	1390.4	2784.8
			R	2.129	2.468	86.2642	1322.7	3879.8
Campbell	2000	411-S	L	2.336	2.479	94.2315	0.1	0.1
			C	2.335	2.479	94.1912	1.7	4.9
			R	2.347	2.479	94.6753	2.5	0.8
Madison	2000	411-S	L	2.128	2.363	90.055	489.26	284.5
			C	2.096	2.363	88.7008	535.1	605.5
			R	2.044	2.363	86.5002	789.01	1278.1

field and laboratory permeability measured for each test location noted in Column 4. The field and laboratory permeability data sheets are provided in Appendix D and E respectively. The permeability values shown have been corrected to 21°C (70 °F) to account for the differing water temperatures at each project. Column 7 provides the core density measured in the laboratory for each test location. Columns 5 and 6 show the bulk and the average theoretical maximum specific gravity test results.

Chapter 4.0 Analysis of Test Results

Appropriate statistical analyses were used to determine the correlation between laboratory permeability values obtained using the Karol-Warner flexible wall permeameter, in place density and field permeability values determined using the NCAT tierd permeameter and laboratory permeability values. Regression analysis was also used to assess the affect saw cutting the bottom layer of a core has on laboratory permeability test results. The following sections present the results of these correlations and observations.

4.1 Laboratory Permeability versus Core Density (%G_{mm})

Figures 5 and 6 show the correlation between laboratory permeability and core density for the surface mixes tested during the 1999 and 2000-paving season, including both the 411-S and 411-D mixes. There is a good correlation between laboratory permeability and core density, as evidenced by the coefficient of determination (R^2) of 0.76 for Marshall mixes, 0.69 for SuperpaveTM mixes and 0.70 for all mixes combined. As previously noted, (FDOT) has established a tentative permeability limit not to exceed 100×10^{-5} cm/sec (Choubane et al 1998). According to Figure 6, the trend line, and its 95% confidence interval, show that HMA produced in Tennessee falls well below Florida DOT limit of 100×10^{-5} cm/sec.

The graph also demonstrates that as air voids increase beyond 8%, permeability tends to increase at a much higher rate. This is also demonstrated in the field permeability studies, conducted by the University of Tennessee Materials

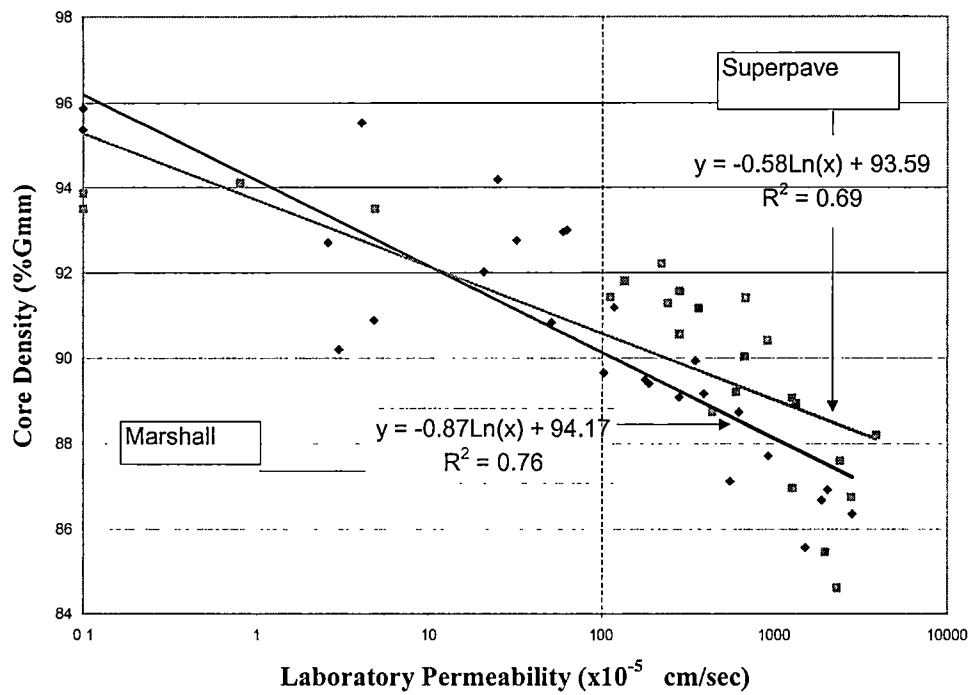


Figure 5 Graph of Laboratory Permeability vs. Core Density (%G_{mm})

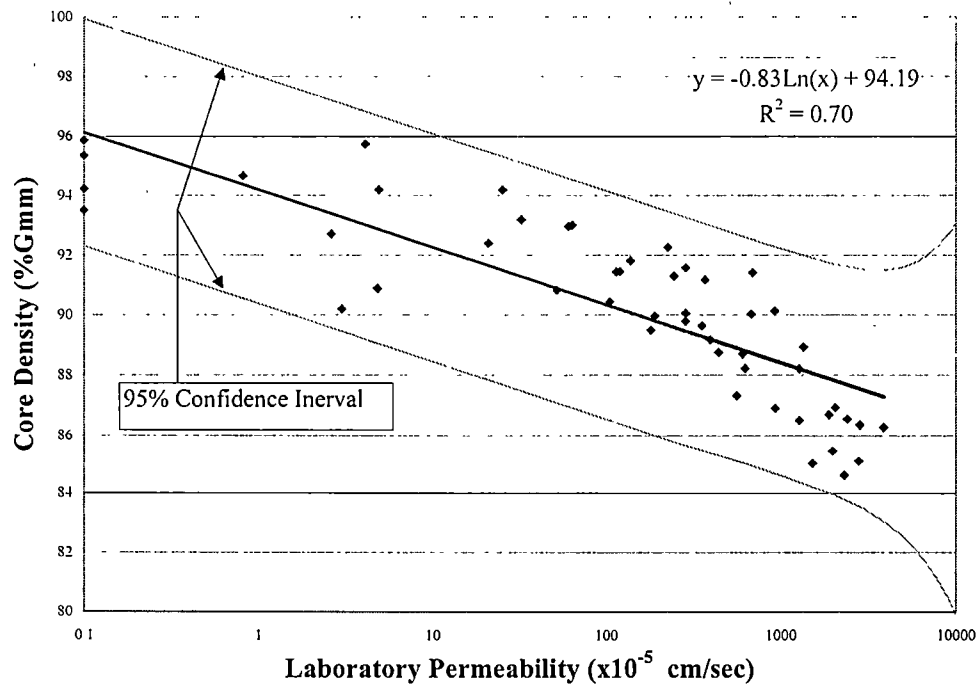


Figure 6 Graph of Laboratory Permeability vs. Core Density (%G_{mm})

Engineering research program, in 1999 and 2000 (Fuson 2000, Oliver 2001). While a great number of test results fell well below 100×10^{-5} cm/sec, it is important to note that almost every mix that had a core density above 92%, the TDOT specification on compaction, fell well within Florida DOT limit of 100×10^{-5} cm/sec. It is also observed that at 92% compaction, the TDOT lower limit on compaction, that the laboratory permeability reading is between 0 and 1000×10^{-5} cm/sec. It was also observed that only 14 of 51 cores used in this study meet TDOT's 92% compaction limit. Figure 6 also shows that at 94% compaction that a range of laboratory permeability between 0 and 100×10^{-5} cm/sec exists with 95% confidence.

4.2 Laboratory Permeability vs. Field Measurements of Permeability

Figures 7 and 8 show the correlation between laboratory permeability and field permeability for the surface mixes tested during the 1999 and 2000-paving season, including both the 411-S and 411-D mixes. There is a poor to fair correlation between laboratory permeability and field permeability as evidenced by the coefficient of determination (R^2) of 0.55. Figure 7 also shows a 95% confidence interval along with the regression line. FDOT suggest that a permeability value of 100×10^{-5} (cm/sec) is the upper limit for HMA. This number was developed using a laboratory permeameter. Figure 8 shows that a laboratory permeability reading of 100×10^{-5} cm/sec correlates to a field permeability reading of 0 to 1100×10^{-5} cm/sec with a 95% level of confidence.

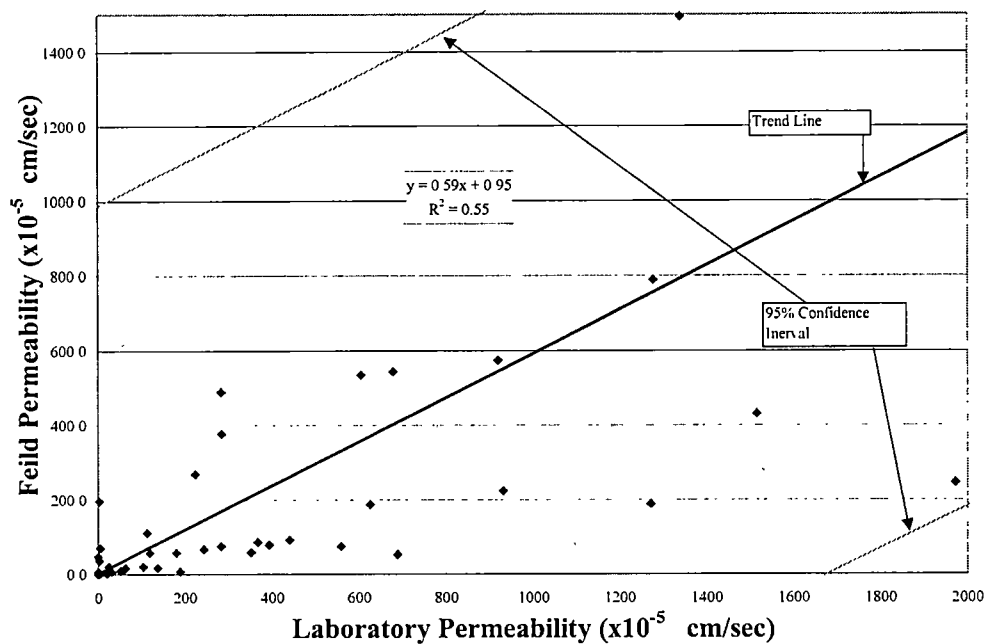


Figure 7 Graph of Laboratory Permeability vs. Field Permeability I

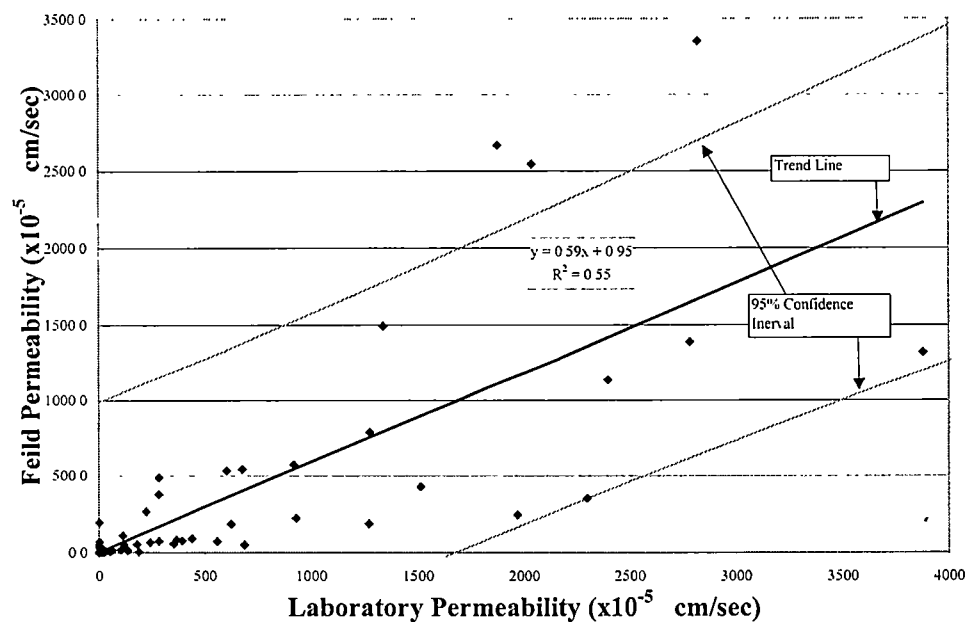


Figure 8 Graph of Laboratory Permeability vs. Field Permeability II

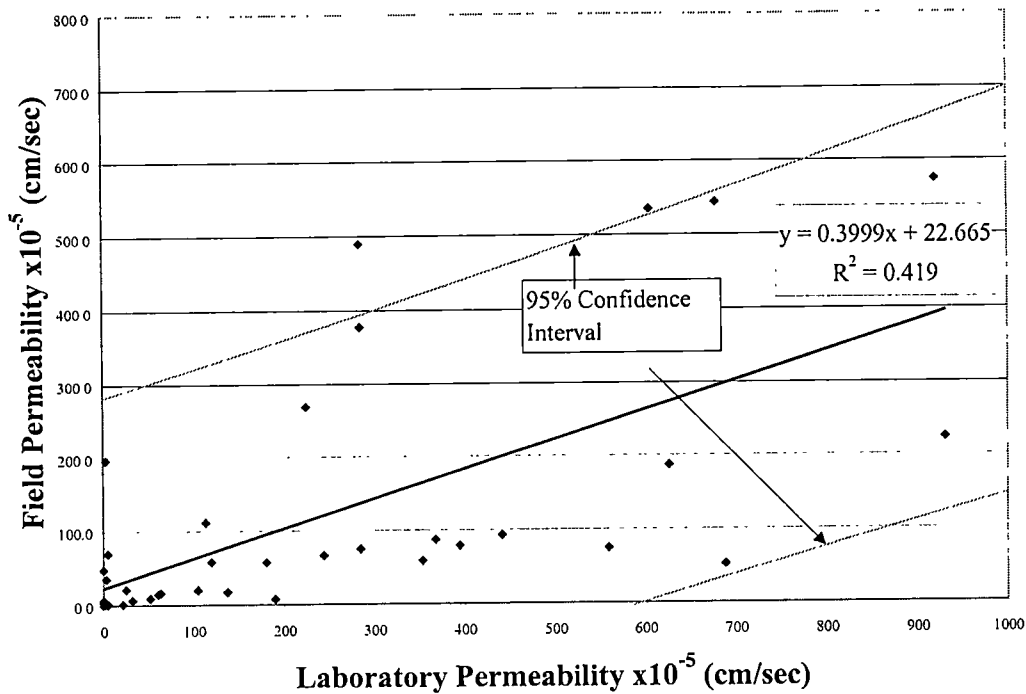


Figure 9 Graph of Laboratory Permeability less than 1000×10^{-5} (cm/sec)

It is out of the scope of this study to measure permeability greater than 1000×10^{-5} cm/sec. If we eliminate all readings above 1000×10^{-5} cm/sec we get a correlation of 0.42 and the 95% confidence range, for a field permeability reading with a laboratory permeability reading of 100×10^{-5} cm/sec, is 0 to 300×10^{-5} cm/sec as shown in figure 9. This demonstrates that permeability should be considered in orders of magnitude as opposed to discrete values.

4.3 Comparison of SuperpaveTM and Conventional 75-blow Marshall-Designed Mixes

Tables 3 and 4 provide detailed summaries of the permeability of conventional 75-blow Marshall mixes and SuperpaveTM-designed mixes, respectively. The average laboratory permeability for the SuperpaveTM-designed mixes was found to be 926×10^{-5} cm/sec whereas the average laboratory permeability of the Marshall-designed mixes was found to be 454.3×10^{-5} cm/sec. These values indicate that there is effectively no difference in laboratory permeability between the Marshall and SuperpaveTM designed mixes.

Statistical analysis of the test results was conducted using appropriate statistical test methods with JUMP statistical software. A student t-test was performed to evaluate if there is a significant difference between mean laboratory permeability values for Marshall and SuperpaveTM designed mixes. The results of this analysis can be found in Table 5. Figure 10 also shows the mean and standard deviations, for both SuperpaveTM and Marshall designed mixes, graphically. The null hypothesis was made that there was no significant difference in the means of the two mix designs. The acceptance criteria for this test is a p-value greater than 0.05. A p-value of 0.1473 was found, which is greater than 0.05, indicating that there is no significant difference between the two mix types. While no statistical difference exists between the two mix designs, there obviously is a functional difference between the two, as evident by a laboratory permeability for SuperpaveTM almost double of Marshall designed mixes.

Table 3 Summary of Averages for Marshall Mixes in 1999 and 2000

County	Year Constructed	Mix Type	Test Sub- section	Lab Permeability x10 ⁻⁵ (cm/sec)	Project Average	MarshallA verage
Hamilton	1999	411-D	1	3	3.5	
			2	4.81		
			3	2.61		
Fayette	1999	411-D	1	0.1	0.1	
			2	0.1		
			3	0.1		
Davidson	1999	411-D	1	63.6	49.7	
			2	25.1		
			3	60.5		
Sullivan	1999	411-D	1	2038.0	2246.1	
			2	1877.3		
			3	2822.9		
Haywood	2000	411-D	L	626.1	1024.5	454.3
			C	931.2		
			R	1516.2		
Madison	2000	411-D	L	20.9	71.5	
			C	189.5		
			R	4.1		
Dickson	2000	411-D	L	559.3	316.0	
			C	104.1		
			R	284.6		
Hamilton	2000	411-D	L	353.4	168.3	
			C	119.4		
			R	32.2		
Hamblen	2000	411-D	L	51.7	208.8	
			C	180.2		
			R	394.6		

Table 4 Summary of Averages for Superpave™ Mixes in 1999 and 2000

County	Year Constructed	Mix Type	Test Sub- section	Lab Permeability ×10 ⁻⁵ (cm/sec)	Project Average	Superpave™ Average
Fayette	1999	411-S	1	113.3	83.5	925.9
			2	0.1		
			3	137.2		
Smith	1999	411-S	1	243.9	433.4	
			2	688.6		
			3	367.8		
Hamilton	1999	411-S	1	441.3	1571.4	
			2	1971.7		
			3	2301.1		
Sullivan	1999	411-S	1	678.3	767.8	
			2	285.1		
			3	1339.9		
Sumner	2000	411-S	L	1271.8	805.6	
			C	920.5		
			R	224.5		
Coffee	2000	411-S	L	2399.1	3021.2	
			C	2784.8		
			R	3879.8		
Campbell	2000	411-S	L	0.1	1.9	
			C	4.88		
			R	0.81		
Madison	2000	411-S	L	284.5	722.7	
			C	605.5		
			R	1278.1		

Table 5 Summary of Statistical t-test Analysis for Mix Types

Mix Type	Mean	Std. Deviation	Df	p-value
Marshall vs.	454×10^{-5}	743×10^{-5}	46	0.1473
Superpave™	926×10^{-5}	978×10^{-5}		

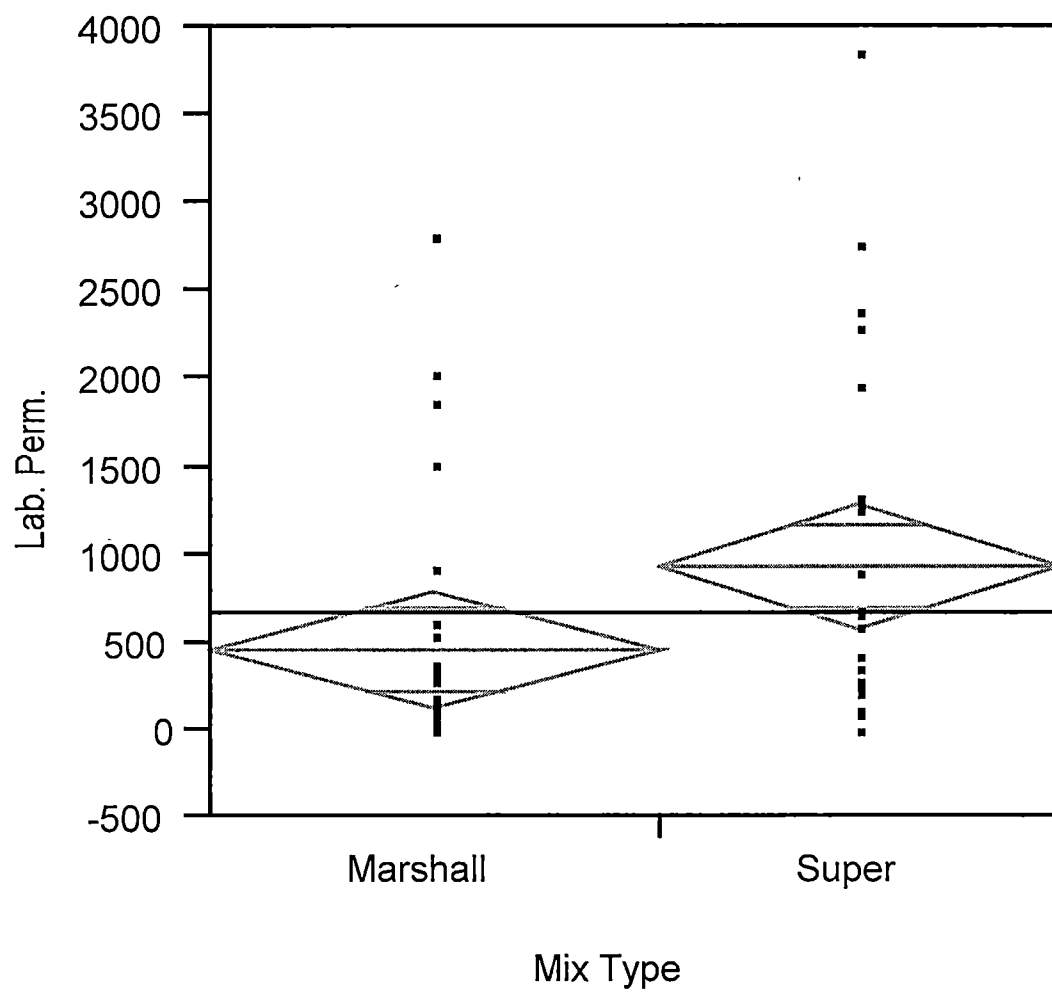


Figure 10 Graphical Representations of Mean and Standard Deviation for Mix Types

4.4 Comparison of Laboratory Permeability between Placement Location in Lane

Statistical analysis of the test results was conducted using appropriate statistical test methods with JUMP statistical software. A student t-test was performed to evaluate if there is a significant difference between mean laboratory permeability values for asphalt cores taken from the left (L), center (C) and right (R) of the lane. The results of this analysis can be found in Table 6. Figure 11 also shows the mean and standard deviations, for all locations in the lane, graphically. The null hypothesis was made that there was no significant difference in the means of the three lane locations. The acceptance criteria for this test is a p-value greater than 0.05. A p-value of 0.338 between location L and R, 0.736 between location L and C and 0.509 between location C and R were found, which is greater than 0.05, indicating that there is no significant difference between the three lane locations.

Table 6 Summary of Statistical t-test Analysis for Lane Location

Lane Location	Mean	Std. Deviation	Df	p-value
L vs. R	538×10^{-5} 861×10^{-5}	718×10^{-5} 1169×10^{-5}	32	0.338
L vs. C	538×10^{-5} 629×10^{-5}	718×10^{-5} 836×10^{-5}	32	0.736
C vs. R	629×10^{-5} 861×10^{-5}	836×10^{-5} 1169×10^{-5}	32	0.509

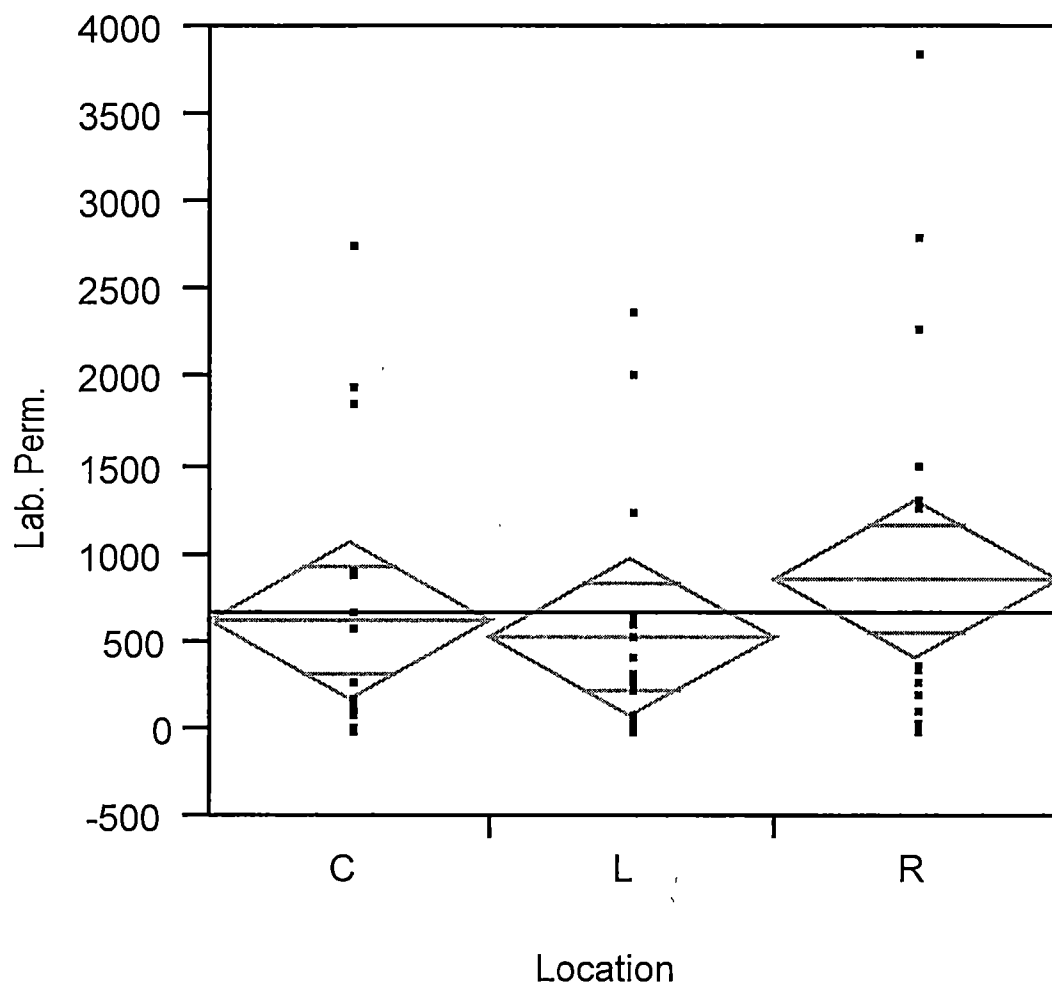


Figure 11 Graphical Representations of Mean and Standard Deviation for Lane Locations

4.5 Effect Saw Cutting has on Cores

It is often necessary to separate the layers of asphalt in field cores before various tests are performed, including permeability tests. Wet sawing not only isolates the layer of interest but also can be used to remove tack or unwanted material. Since the wet sawing process could potentially smear the asphalt at the sawed interface, there was concern that the permeability may be affected

Table 7 shows the results of cut and uncut cores and Figure 12 shows the percent change in laboratory permeability readings after saw cutting has been executed, including both the 411-S and 411-D mixes. Figure 12 shows that some mixes had increases in permeability readings while others had decreased in permeability readings due to saw cutting. Obviously significant change in permeability was observed, but no obvious trend was observed as some readings increased while others decreased as listed in Table 7.

It has not been proven, but it stands to reason that a decrease in permeability due to saw cutting is the direct result of smearing asphalt binder across the saw cut of the specimen. Increases in permeability can be attributed to opening of interconnected voids through out the specimen.

Table 7 Results of Saw-Cutting

County	Mix Type	Uncut Bulk Specific Gravity	Cut Bulk Specific Gravity	% change in specific gravity	Uncut Lab. Permeability $\times 10^{-5}$ (cm/sec)	Cut Lab. Permeability $\times 10^{-5}$ (cm/sec)	% Change in Perm.	Average % Change at Location
Campbell	411-S	2.327	2.336	-0.39	0.1	0.1	0.00	37.12
		2.318	2.335	-0.73	7.66	4.88	36.29	
		2.333	2.347	-0.60	3.25	0.81	75.08	
Coffee	411-S	2.162	2.136	1.20	2318.4	2399.07	-3.48	21.16
		2.141	2.1	1.91	4489.35	2784.79	37.97	
		2.177	2.129	2.20	5462.62	3879.79	28.98	
Hamilton	411-D	2.073	2.066	0.34	211.05	353.4	-40.28	-23.87
		2.102	2.108	-0.29	78.6	119.4	-34.17	
		2.138	2.148	-0.47	33.14	32.2	2.84	
Sumner	411-S	2.175	2.154	0.97	2667.25	1271.8	52.32	45.59
		2.208	2.201	0.32	1394.96	920.5	34.01	
		2.252	2.253	-0.04	453.09	224.5	50.45	
Dickson	411-D	2.131	2.136	-0.23	808.37	559.3	30.81	33.82
		2.193	2.212	-0.87	188.12	104.1	44.66	
		2.179	2.196	-0.78	384.48	284.6	25.98	
Madison	411-S	2.14	2.128	0.56	395	284.5	27.97	-0.59
		2.108	2.096	0.57	436.46	605.5	-27.92	
		2.055	2.044	0.54	1254.62	1278.1	-1.84	
Madison	411-D	2.181	2.19	-0.41	5.82	20.89	-72.14	-64.19
		2.119	2.132	-0.61	146.16	189.5	-22.87	
		2.264	2.269	-0.22	0.1	4.1	-97.56	
Haywood	411-D	2.079	2.067	0.58	844.6	626.1	25.87	1.18
		2.055	2.036	0.92	636.9	931.2	-31.60	
		2.005	1.992	0.65	1671.3	1516.2	9.28	

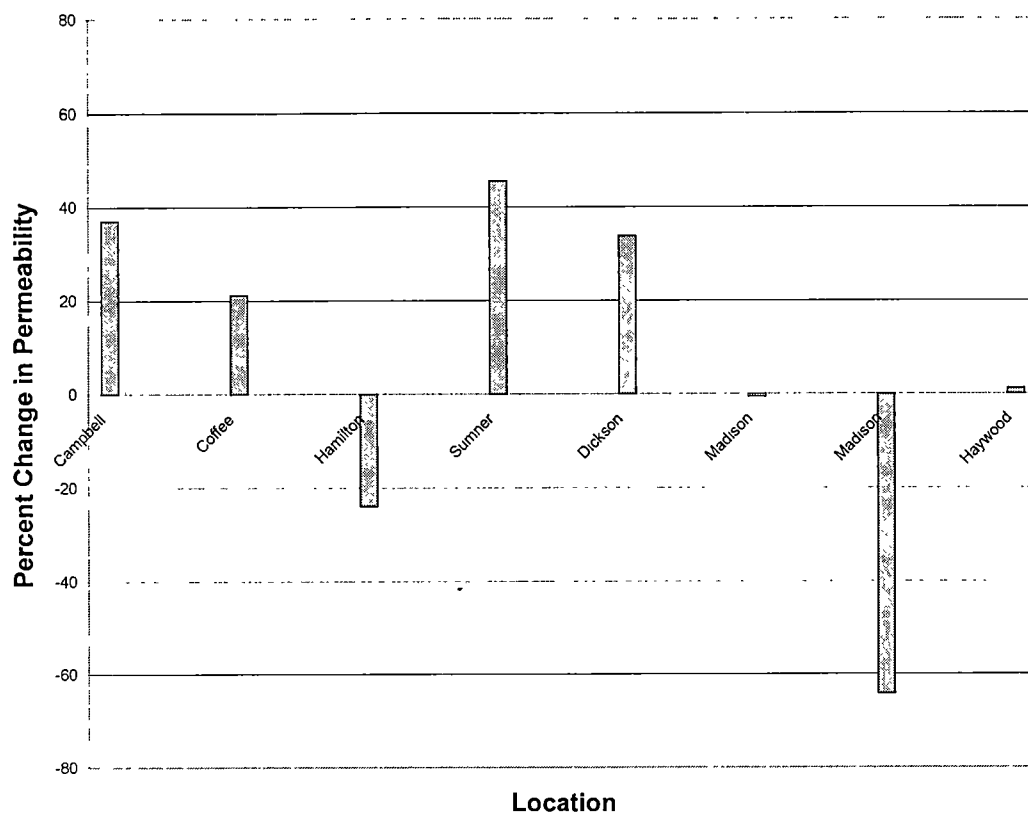


Figure 12 (Cut and uncut cores) Percent Change in Lab. Permeability

5.0 Conclusions

It is believed that the relative permeability of compacted HMA is an indicator of the quality and durability of a given pavement. The objective of this study was to document the correlation between field measurements of permeability, as obtained with the tiered permeameter developed at NCAT, and laboratory permeability, as determined using the Karol-Warner Flexible Wall Laboratory Permeameter. A secondary objective of this study was to evaluate if there is a difference between laboratory permeability for Superpave™ designed mixes and conventional Marshall-designed mixes placed in Tennessee during the 1999 and 2000-paving seasons.

Regression analysis was used to compare field permeability with laboratory permeability values. Graphical analysis was also used to assess the affect saw cutting a pavement core has on the laboratory permeability. The following conclusions were drawn based on the results of this study:

- In general, the permeability increases as air voids increase. It has also been shown that as air voids increase above 8%, permeability increases by an order of magnitude at a higher rate.
- An R^2 value of 0.70 is in agreement with the study conducted by AHTD. A range of $0-1000 \times 10^{-5}$ cm/sec, with 95% confidence, is observed at TDOT compaction limit of 92 % G_{mm} . A range of $0-100 \times 10^{-5}$ cm/sec, with 95% confidence, is observed at a compaction limit of 94% G_{mm} , which is in agreement with the FDOT study indicating a minimum of 6% voids should achieved during compaction.
- An R^2 value of 0.55 indicates a fair to poor correlation when comparing laboratory permeability with field permeability. However, based on this study, laboratory permeability value of 100×10^{-5} cm/sec relates to a wide range for field permeability of 0 to 1000×10^{-5} cm/sec with a 95% level of confidence.

- Using graphical analysis, it was found that very small differences in permeability readings occur when cores are saw cut versus when they were not. No recognizable pattern was shown to occur after cores were cut.
- After running a student t-test on laboratory permeability readings of nine conventional Marshall-designed and eight SuperpaveTM-designed mixes it has been shown that their average permeability readings are not statistically different
- Laboratory permeability values should be considered in terms of orders of magnitude as opposed to discrete values.

6.0 Recommendations

The purpose of this study was to evaluate the laboratory permeability of HMA produced in Tennessee using a Karol-Warner Flexible Wall Permeameter. The results this study indicate that most HMA mixes produced have laboratory permeability values less than 200×10^{-5} cm/sec when compacted beyond 92% G_{mm} , and all mixes meeting 94 % G_{mm} compaction achieve the upper limit for permeability of 100×10^{-5} cm/sec. This suggests that most mixes placed in Tennessee are well designed, relative to permeability.

In this study we have shown that a fair to poor correlation exists between laboratory permeability and relative field permeability, therefore, it is recommended that field measurements of permeability not be used as an indicator of the laboratory permeability. Also documented in this study is that no statistical difference in laboratory permeability appears to exist between Marshall and SuperpaveTM designed mixes. It has also been shown that only 14 out of 51 cores meet the TDOT compaction criteria of 92%.

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Appendices

Appendices

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Appendix A

Job Mix Formula's

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Plant # 2 Date: 3/30/99
 L-R Job # 99-095
 Project Ref. No. IME-40-1-(270)27 County Fayette Region IV
 Proj. No. 24001-8104-44 Contract No. 5616
 Type ASCS-HM Sec. No. 411-D W/Poly Article 01.01-01.02
 Contractor Lehman-Roberts Co. Subcontractor: Lehman-Roberts Co.
 State Rt. I-40 **TOTAL MIX INCLUDING BITUMEN** Date of Letting 3/19/99

MATERIAL	Size Range of Type	PRODUCER AND ADDRESS	% USED
C.A.			
Med C.A.	5/8"- #200	Memphis Stone & Gravel pit # 516	47.05
Screenings	3/8"- #200	Fullen Dock pit # 382	18.82
Nat Sand	3/8"- #200	Memphis Stone & Gravel pit # 516	23.53
Ag. Lime	3/8"- #200	Fullen Dock pit # 382	4.71
Anti-Strip	Morelife	Dosage Rate 0.30%	
Asphalt Cement	PG 76-22	Koch Petroleum	5.90
Anti-Strip	TYPE:	DOSAGE RATE:	

% Fractured Faces on +4 Material: 91% % Glassy Particles on +4 Material N/A 100 %

100 PERCENT MINERAL AGGREGATE				AGGREGATE ANALYSIS TOTAL PERCENT PASSING					
SCREEN	Til Passing Design Range	Requested Percent		C.A. Percent	Med C.A. Percent	Screenings Percent	Nat Sand Percent	Ag Lime Percent	Calculated Mix
Temp	300-340	320.0		0	50	20	25	5.0	100.0
% A.C.	4.2-6.2	5.90			(Washed Gradations)				
	Compaction Temp:	320			NCAT Furnace Corr Factor:				
	Mixing Temp:	330			LOI: 9.3				
					Theo: 2.4				
2"					A.C. in Rap: 0.0				
1 1/2"									
1"		100.0			100.0	100.0	100.0	100.0	100.0
3/4"	100	100.0			100.0	100.0	100.0	100.0	100.0
1/2"	95-100	96.0			92.0	100.0	100.0	100.0	96.0
3/8"	80-93	86.0			71.0	100.0	100.0	100.0	85.5
#4	54-76	68.0			40.0	93.0	99.0	100.0	68.4
#8	35-57	48.0			19.0	60.0	88.0	97.0	48.4
#16									
#30	17-29	26.0			9.0	27.0	52.0	61.0	26.0
#50	10-18	11.0			7.0	20.0	6.0	46.0	11.3
#100	3-10	7.7			5.0	15.0	2.0	33.0	7.7
#200	0-6.5	5.1			3.0	11.0	0.5	25.0	5.1

Requested _____

Approved _____

Contractor

Region Materials Engineer

Approved _____

Approved _____

Region Construction Engineer

Engineer of Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Date: 10/1/99

Project Ref. No. IME-81-1(95)57 County Sullivan Region Clinton Hwy
 Proj. No. 82001-8160-44 Contract No. 5405
 Type BPMP-HM Sec. No. 411-D Polymer Article No: 01.01 & .02
 Contractor Summers-Taylor MTLs. Subcontractor: _____
 State Rt. 181 **TOTAL MIX INCLUDING BITUMEN** Date of Letting Jun-99
 Design Number: _____ Mix No: _____

MATERIAL	Screen	% Passing	PRODUCER AND ADDRESS	% USED
C.A.	1/2"-#200			
Med. C.A.	#8 3/8"-#200		MAYMEADE MOUNTAIN CITY	32.90
Screenings	#10 #4-#200		MAYMEADE MOUNTAIN CITY	56.40
Sand	#10W #4-#200		MAYMEADE MOUNTAIN CITY	4.70
Asphalt Cement	PG 76-22		SHELL OIL CO. BRISTOL TN.	6.00
Anti-Strip	TYPE: <u>Pave Bond Lite</u>		DOSAGE RATE: <u>0.50%</u>	
Angularity		45%		

100 PERCENT MINERAL AGGREGATE				AGGREGATE ANALYSIS TOTAL PERCENT PASSING				
SCREEN	Ttl Passing	Requested Percent			#8	#10	#10	Calculated Mix
Temp	275-325	300.0	280-320	0	0	35.0	60.0	5
% A.C.	5.3%-7.0%	6.00%			(Washed Gradations)			
					DAR:	1.0		
					Theo:	2.450		
					TSR:	85.0		
					LOI:	2.8		
5/8"	100	100.0			100.0	100.0	100.0	100.0
1/2"	95-100	99.0			98.0	100.0	100.0	99
3/8"	80-93	91.0			73.0	100.0	100.0	91
#4	54-76	66.0			8.0	98.0	95.0	66
#8	35-57	42.0			2.0	66.0	40.0	42
#30	17-29	19.0			1.0	30.0	8.0	19
#50	10-18	11.0			1.0	18.0	6.0	11
#100	3-10	8.2			0.7	12.9	3.9	8.2
#200	2-6.5	6.0			0.6	9.5	2.7	6.0

Requested _____

Approved _____

Contractor

Region Materials Engineer

Approved _____

Approved _____

Region Construction Engineer

Engineer of Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Date: 9/29/99

Clinton Hwy

Project Ref. No. _____ County Hamilton Region II
 Proj. No. 33042-4227-04 Contract No. 5621
 Type BPMB (HM) Sec. No. 411-D Article _____
 Contractor Hillis Group L.L.C. Subcontractor: _____
 State Rt. 58 **TOTAL MIX INCLUDING BITUMEN** Date of Letting 1/2/99

MATERIAL	Screen	% Passing	PRODUCER AND ADDRESS	% USED
C.A.				
Med. C.A.				
Med. C.A.	5/8"-Pan		Vulcan Stone Ellijay, GA.	37.60
Screenings	3/8"-Pan		Bradley Stone Cleveland, TN.	23.50
Sand	3/8"-Pan		Bradley Stone and Sand Jasper, TN.	32.90
Asphalt Cement	PG 74-22		Marathon Oil, Knoxville, Tn.	6.00
Anti-Strip	Adhere LOF 65-00		DOSAGE RATE:	0.30%
% Fractured Faces on +4 Material:		98.8	% Glassy Particles on +4 Material	0.1 100 %

100 PERCENT MINERAL AGGREGATE				AGGREGATE ANALYSIS TOTAL PERCENT PASSING					
SCREEN	Ttl Passing Design Range	Requested Percent		C A Percent	Med. C A Percent	Screenings Percent	River Sand Percent		Calculated Mix
Temp				0	40	25.0	35.0		
% A.C.	5.3-7.0	6.00			NCAT Furnace Corr Factor		N/A		
	Compaction Temp:				LOI:		12		
	Mixing Temp:				Theo:		2.470		
					(Washed Gradations)				
3/4"	100	100.0			100.0	100.0	100.0		100.0
5/8"	100	100.0			100.0	100.0	100.0		100.0
1/2"	95-100	98.0			96.0	100.0	100.0		98.4
3/8"	80-93	89.0			73.0	100.0	100.0		89.2
#4	54-76	63.0			13.0	95.0	97.0		62.9
#8	35-57	49.0			6.0	71.0	84.0		49.6
#30	17-29	29.0			3.0	30.0	58.0		29.0
#50	10-18	14.0			2.0	25.0	19.0		13.7
#100	3-10	7.2			1.0	20.0	5.0		7.2
#200	0-6.5	6.1			1.0	17.0	4.0		6.1

Requested _____

Approved _____

Contractor

Region Materials Engineer

Approved _____

Approved _____

Region Construction Engineer

Engineer of Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Date: 1/21/99

Project Ref. No. STP-M-NH-255(4) County Davidson Region III
 Proj. No. 19009-3163-44 Contract No. 5114
 Type ACS-HM Grading D Sec. No. 411-D Article 411-01.50/01.01
 Contractor Rogers Group Inc. Subcontractor: _____
 State Rt. I-65 **TOTAL MIX INCLUDING BITUMEN** Date of Letting 03/20/98

MATERIAL	Screen	% Passing	PRODUCER AND ADDRESS	% USED
Med. C.A.	5/8"/16.0mm Pan		American Limestone Spingfield, Tn.	47.33
Screenings	3/8"/9.50mm Pan		Rodgers Group Inc. Gatlin, Tn.	9.46
Nat Sand	3/8"/9.50mm Pan		Ingram Materials, Nashville, Tn.	23.66
Wash/Scrn	3/8"/9.50mm Pan		Rodgers Group Inc. Gatlin, Tn.	14.20
Asphalt Cement	PG 64-22		Marathon Ashland, Nashville, Tn.	5.35
Anti-Strip	AD-HERE 65-00		DOSAGE RATE: 0.5	
% Fractured Faces on +4 Material:		N/A	% Glassy Particles on +4 Material	N/A 100 %

100 PERCENT MINERAL AGGREGATE				AGGREGATE ANALYSIS TOTAL PERCENT PASSING					
SCREEN	Ttl Passing	Requested Percent		Med. C. A. Percent	Med C A Percent	Screenings Percent	Sand Percent	RAP Percent	Calculated Mix
Temp	300-340	305.0			50	10.0	25.0	15	100.0
% A.C.	5.35-7.0	5.35			(Washed Gradations)				
	Compaction Temp:	305			LOI:	20.5			
	Mixing Temp:	325			Theo:	2.444			
					NCAT Furnace Corr Factor	0.4			
2"		100.0							
1 1/2"		100.0							
1"		100.0							
3/4"	100	100.0			100.0	100.0	100.0	100.0	100.0
1/2"	95-100	98.5			97.0	100.0	100.0	100.0	98.5
3/8"	80-93	88.0			76.0	100.0	100.0	100.0	88.0
#4	54-76	60.6			25.0	95.0	98.0	94.0	60.6
#8	35-57	42.4			7.0	63.0	93.0	62.0	42.4
#16									
#30	17-29	24.5			4.0	30.0	66.0	20.0	24.5
#50	10-18	10.4			3.5	22.0	17.5	13.0	10.4
#100	3-10	4.9			3.0	17.5	2.5	6.5	4.9
#200	0-6.5	3.8			2.0	14.5	2.0	4.5	3.8

Requested _____

Approved _____

Contractor

Region Materials Engineer

Approved _____

Approved _____

Region Construction Engineer

Engineer of Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Plant # 2 Date: 5/10/99
 L-R Job # 99095
 Project Ref. No. IME-40-1(270)27 County Fayette Region IV
 Proj. No. 24001-8104-44 Contract No. 5616
 Type ASCS-HM Sec. No. 411-S Article 01.01-01.02
 Contractor Lehman-Roberts Co. Subcontractor: Lehman-Roberts Co.
 State Rt. I-40 TOTAL MIX INCLUDING BITUMEN Date of Letting 3/19/99

MATERIAL	Size Range of Type	PRODUCER AND ADDRESS	% USED
5/8" Cr Gravel	5/8"- #200	Memphis Stone & Gravel pit # 516	52.92
Nat Sand	3/8"- #200	Memphis Stone & Gravel pit # 558	17.96
# 10 Limestone	3/8"- #200	Fullen Dock pit # 382	23.83
Ag. Lime	3/8"- #200	Fullen Dock pit # 382	0.00
Anti-Strip	Morelife	Dosage Rate 0.30%	
Asphalt Cement	PG 76-22	Koch Petroleum	5.50
Anti-Strip	TYPE:	DOSAGE RATE:	

% Fractured Faces on +4 Material: 100 % Glassy Particles on +4 Material N/A 100 %

100 PERCENT MINERAL AGGREGATE				AGGREGATE ANALYSIS TOTAL PERCENT PASSING					
SCREEN	Ttl Passing Design Range	Requested Percent		Percent	5/8" Cr Gravel Percent	Nat Sand Percent	# 10 Limestone Percent	Ag Lime Percent	Calculated Mix
Temp	320-380			0	56	19	25	0	100.0
% A.C.		5.45			(Washed Gradations)				
	Compaction Temp:	335			Latex Brand	None			
	Mixing Temp:	350			% Latex Used	N/A			
					LOI:	8.4			
					Theo:	2.412			
50									
37.5									
25		100.0			100.0	100.0	100.0	100.0	100.0
19	100	100.0			100.0	100.0	100.0	100.0	100.0
12.5	90-100	95.0			91.0	100.0	100.0	100.0	95.0
9.5		79.0			62.1	100.0	100.0	100.0	78.8
4.75	50-71	58.0			28.0	99.4	95.4	99.0	58.4
2.36	33-58	39.0			13.5	84.7	62.7	98.0	39.3
1.18		28.0			7.4	70.3	42.7	92.0	28.2
0.6	16-29	19.0			4.9	48.9	26.6	79.0	18.7
0.3		8.0			2.8	8.2	19.2	62.0	7.9
0.425		4.5			1.6	0.2	14.5	44.0	4.6
0.075	2-6.5	3.5			1.1	0.1	11.3	30.0	3.5

Requested _____

Contractor

Approved _____

Region Materials Engineer

Approved _____

Region Construction Engineer

Approved _____

Engineer of Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Date: 10/1/99

Project Ref. No. SP County Sullivan Region 1
 Proj. No. 82102-4201-04 Contract No. 5123
 Type BPMP-HM Sec. No. 411-S Superpave Article No: 01.01 & .02
 Contractor Summers-Taylor MTLs. Subcontractor:
 State Rt. RT 37 TOTAL MIX INCLUDING BITUMEN Date of Letting Jun-99
 Design Number: Mix No:

MATERIAL	Screen	% Passing	PRODUCER AND ADDRESS	% USED
C.A.	#68	3/4" -#200	MAYMEADE MOUNTAIN CITY	9.36
Med. C.A.	#8	1/2" -#200	MAYMEADE MOUNTAIN CITY	28.08
Screenings	#10L	#4 -#200	AMERICAN LIMESTONE WATAUGA	23.40
Sand	#10	#4 -#200	MAYMEADE MOUNTAIN CITY	32.76
Asphalt Cement	PG 76-22		SHELL OIL CO. BRISTOL TN.	6.40
Anti-Strip	TYPE: Pave Bond Lite		DOSAGE RATE:	0.50%
Angularity		45%		

100 PERCENT MINERAL AGGREGATE				AGGREGATE ANALYSIS TOTAL PERCENT PASSING					
SCREEN	Til Passing	Requested Percent			#68	#8	#10L	#10	Calculated Mx
Temp	295-345	320.0	300-340	0	10	30.0	35.0	25	100.0
% A.C.	5.3%-7.0%	6.40%			(Washed Gradations)				
					DAR: 1.0				
					Theo: 2.460				
					TSR: 94.0				
					LOI: 11.8				
3/4"	100	100.0			100.0	100.0	100.0	100.0	100.0
1/2"	90-100	96.0			66.0	98.0	100.0	100.0	96.0
3/8"	76-91	89.0			26.0	88.0	100.0	100.0	89
#4	50-71	61.0			3.0	18.0	95.0	90.0	61
#8	33-58	38.0			3.0	6.0	62.0	58.0	38
#16		25.0			2.0	5.0	42.0	35.0	25
#30	16-29	17.0			2.0	4.0	26.0	25.0	17
#50		11.0			2.0	2.0	17.0	18.0	11
#100		7.7			1.0	1.1	12.0	12.4	7.7
#200	2-6.5	6.3			0.5	0.4	10.0	10.4	6.3

Requested _____

Contractor

Approved _____

Region Materials Engineer

Approved _____

Region Construction Engineer

Approved _____

Engineer of Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Date: 9/4/99

Clinton Hwy

Project Ref. No. Hwy. 29 County Hamilton Region II
 Proj. No. 33036-4278-04 Contract No. 5822
 Type ACSC (HM) (Superpave) Sec. No. 411-Surface Mix Article
 Contractor Vulcan Construction Co. Subcontractor:
 State Rt. 58 TOTAL MIX INCLUDING BITUMEN Date of Letting

MATERIAL	Screen	% Passing	PRODUCER AND ADDRESS	% USED
C.A.				
Med. C.A.	5/8's			
Med. C.A.	16mm-75um		Vulcan Sand and Gravel, Chattanooga, TN.	47.00
Screenings	9.5mm-75um		Vulcan Materials Company, Chattanooga, TN.	23.50
Sand River	4.5mm-75um		Vulcan Sand and Gravel, Chattanooga, TN.	23.50
Asphalt Cement	PG 76-22		Marathon Ashland Petroleum LLC, Chatt. TN.	6.00
Anti-Strip	Adhere LOF 65-00		DOSAGE RATE:	0.30%
% Fractured Faces on +4 Material:	98.8	% Glassy Particles on +4 Material	0.1	100 %

100 PERCENT MINERAL AGGREGATE				AGGREGATE ANALYSIS TOTAL PERCENT PASSING					
SCREEN	Ttl. Passing Design Range	Requested Percent		C.A. Percent	Med. C.A. Percent	Screenings Percent	River Sand Percent		Calculated Mix
Temp		310 F		0	50	25.0	25.0		
% A.C.	5.3-7.0	6.00			NCAT Furnace Corr Factor		N/A		
	Compaction Temp:	325-338			LOI:		10.47		
	Mixing Temp:	352-368			Theo:		2.278		
					(Washed Gradations)				
3/4"	100	100.0			100.0	100.0	100.0		100.0
5/8"	100	100.0			100.0	100.0	100.0		100.0
1/2"	95-100	98.0			96.0	100.0	100.0		98.0
3/8"	80-93	91.0			82.0	100.0	100.0		91.0
#4	54-76	69.4			46.0	90.0	95.7		69.4
#8	35-57	50.0			26.0	66.0	82.0		50.0
#30	17-29	24.3			9.0	28.0	51.1		24.3
#50	10-18	14.0			8.0	20.0	20.0		14.0
#100	3-10	7.0			6.0	14.0	2.0		7.0
#200	0-6.5	5.8			5.0	12.0	1.0		5.8

Requested _____

Approved _____

Contractor

Region Materials Engineer

Approved _____

Approved _____

Region Construction Engineer

Engineer of Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Date: 8/31/99

Project Ref. No. IME-40-5(115)259 County Smith Region III
 Proj. No. 80001-8164-44 Contract No. 5706
 Type ACS-HM Sec. No. 411-S Article 411-10.03
 Contractor Rogers Group Inc. Subcontractor: _____
 State Rt. TOTAL MIX INCLUDING BITUMEN Date of Letting 03/19/99

MATERIAL	Screen	% Passing	PRODUCER AND ADDRESS	% USED
Med. C.A.	5/8"		American Limestone Springfield, Tn.	26.54
Med. C.A.	5/8"		Rodgers Group Inc. Gordonsville, Tn.	25.60
Screenings	3/8"		Rodgers Group Inc. Gordonsville, Tn.	23.70
Nat Sand	3/8"		Cumberland Mt. Sand Hillsboro, Tn.	18.96

Asphalt Cement PG 64-22 Ergon Nashville, Tn. 5.20

Anti-Strip Armaz 65-00 DOSAGE RATE: 0.5

% Fractured Faces on +4 Material: 100 % Glassy Particles on +4 Material N/A 100 %

100 PERCENT MINERAL AGGREGATE				AGGREGATE ANALYSIS TOTAL PERCENT PASSING					
SCREEN	Til Passing	Requested Percent		Med. C A. Percent	Med. C A. Percent	Screenings Percent	Sand Percent	RAP Percent	Calculated Mix
Temp		305.0		28	27	25.0	20.0	0	100.0
% A.C.		5.20							
	Compaction Temp: 305				(Washed Gradations)				
	Mixing Temp: 340				LOI: 22.2				
					Theo: 2.509				
					NCAT Furnace Corr Factor 1.0				
2"		100.0							
1 1/2"		100.0							
1"		100.0							
3/4"	100	100.0		100.0	100.0	100.0	100.0		100.0
1/2"	90-100	97.3		95.0	95.0	100.0	100.0		97.3
3/8"	76-91	84.1		72.0	70.0	100.0	100.0		84.1
#4	50-71	54.5		27.0	18.0	92.0	98.0		54.5
#8	33-58	37.6		6.0	6.0	65.0	90.0		37.6
#16		29.0		5.0	5.0	41.0	80.0		29.0
#30	16-29	22.3		4.0	4.0	26.0	68.0		22.3
#50		10.2		3.5	3.5	18.0	19.0		10.2
#100		5.4		2.5	2.5	13.0	4.0		5.4
#200	2-6.5	4.0		2.0	2.0	10.0	2.0		4.0

Requested _____

Approved _____

Contractor

Region Materials Engineer

Approved _____

Approved _____

Region Construction Engineer

Engineer of Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Date: 4/14/00

Project Ref. No. IME-81-1(98)7 County Hamblen Region I
 Proj. No. 07100-8105-44 Contract No. 1023
 Type ACS-HM Sec. No. 411D Article 01.01.
 Contractor Renfro Construction Subcontractor: _____
 State Rt. I-81 **TOTAL MIX INCLUDING BITUMEN** Date of Letting 12/1/99

MATERIAL	Size Range of Type	PRODUCER AND ADDRESS	% USED
CA			
p. gravel	5/8" - #200	Nolichucky Sand & Gravel Greenville, TN	46.75
10's	5/8" - #200	Vulcan Materials, Lowland, TN	23.38
Nat. Sand	#4- #200	Nolichucky Sand & Gravel Greenville, TN	23.38
Rap/Filler			23.40
Anti-Strip	Pavebond Lite	Dosage Rate 0.50%	
Asphalt Cement	PG 76-22	Marathon, Knoxville, TN	6.50
% Fractured Faces on +4 Material: 91% % Glassy Particles on +4 Material N/A			100 %

100 PERCENT MINERAL AGGREGATE			AGGREGATE ANALYSIS TOTAL PERCENT PASSING					
SCREEN	Ttl Passing	Requested	C A.	p gravel	10s	Nat Sand	RAP/Filler	Calculated
	Design Range	Percent		Percent	Percent	Percent	Percent	
Temp	300-350	330.0	0	50	25	25	0.0	100.0
% A.C.	5.3-7.0	5.90		(Washed Gradations)				
Compaction Temp:		310-330		NCAT Furnace Corr Factor:				
Mixing Temp:		310-331		LOI:			9.3	
				Theo:			2.4	
2"				A.C. in Rap:			0.0	
1 1/2"								
1"	100	100.0		100.0	100.0	100.0	100.0	100.0
3/4"	100	100.0		100.0	100.0	100.0	100.0	100.0
1/2"	95-100	97.0		94.6	100.0	100.0	100.0	97.3
3/8"	80-93	90.0		79.9	100.0	100.0	100.0	90.0
#4	54-76	65.0		33.2	93.2	99.0	100.0	64.7
#8	35-57	51.0		20.8	64.3	99.5	100.0	51.4
#16								
#30	17-29	29.0		14.3	28.1	60.8	100.0	29.4
#50	10-18	12.0		9.6	19.9	8.4	100.0	11.9
#100	3-10	7.6		6.4	15.1	2.6	100.0	7.6
#200	0-6.5	5.7		4.5	12.4	1.4	100.0	5.7

Requested _____

Approved _____

Contractor

Region Materials Engineer

Approved _____

Approved _____

Region Construction Engineer

Engineer of Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Date: 3/7/00

Project Ref. No. IME-40-1(273)74 County Madison Region 4
 Proj. No. 57201-8111-44 Contract No. 1037
 Type ACS(HM) Sec. No. 411-D Article 07.11
 Contractor Dement Construction Co. Subcontractor: _____
 State Rt. I-40 **TOTAL MIX INCLUDING BITUMEN** Date of Letting Dec-99
 Design Number: _____ Mix No: _____

MATERIAL	Screen	% Passing	PRODUCER AND ADDRESS	% USED
C.A.				
Med. C.A.	CrGr 5/4" -#200		Adamsville Gravel, Adamsville, TN.	46.90
Screenings	#10 3/8" -#200		Vulcan MTLs. Parsons, TN.	23.45
Sand	N/S 3/8" -#200		Dement Construction co., Denmark, TN.	23.45
A. C.	KCHP PG 76-22		KOCH Materials Co., Memphis, TN.	6.20
Anti-Strip	TYPE: <u>AG-GRIP</u>		DOSAGE RATE: <u>0.50%</u>	
Angularity		85%		

100 PERCENT MINERAL AGGREGATE				AGGREGATE ANALYSIS TOTAL PERCENT PASSING					
SCREEN	Ttl Passing	Requested Percent		ASG	# 10-VP	Sand-DW		Calculated Mix	
Temp	275-325	330.0	310-350	50	25.0	25.0	0	100.0	
% A.C.	5.3%-7.0%	6.2		(Washed Gradations)					
				DAR:		1			
				Theo:		2.34			
				TSR:		93.4			
3/4"	100	100.0		100.0	100.0	100.0		100.0	
1/2"	95-100	98.0		95.0	100.0	100.0		96.0	
3/8"	80-93	89.0		78.0	100.0	100.0		89	
#4	54-76	65.0		34.0	92.0	100.0		65	
#8	35-57	53.0		22.0	68.0	98.0		53	
#16								0	
#30	17-29	29.0		8.0	36.0	65.0		29	
#50	18-Oct	14.0		6.0	28.0	16.0		14.0	
#100	10-Mar	9.0		4.0	23.0	4.7		8.9	
#200	2-10	6.4		3.1	17.1	2.1		6.4	

Requested _____

Approved _____

Contractor

Region Materials Engineer

Approved _____

Approved _____

Region Construction Engineer

Engineer of Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Date: 5/24/00

Project Ref. No. SP County Dickson Region III
 Proj. No. 22004-4239-04 Contract No. 1165
 Type ACS-HM Sec. No. 411-D-w/PG 76-22 Article 01.01-07.11
 Contractor Eubank Paving Subcontractor: _____
 State Rt. 46 **TOTAL MIX INCLUDING BITUMEN** Date of Letting 3/31/00

MATERIAL	Screen	% Passing	PRODUCER AND ADDRESS				% USED		
Hard 5/8	5/8"-Pan		Vulcan Materials, Dickson, TN				37.72		
Hard Scr.	1/4"-Pan		Vulcan Materials, Dickson, TN				18.86		
Soft Scr.	1/4"-Pan		Vulcan Materials, Dickson, TN				14.15		
Sand	3/8"-Pan		Teague Bros., Parsons, TN				23.58		
Asphalt Cement	PG 76-22		Ergon, Nashville, TN				5.70		
Anti-Strip	Pavebond Lite		DOSAGE RATE:				0.50%		
% Fractured Faces on +4 Material:			N/A		% Glassy Particles on +4 Material		N/A		
							100 %		
100 PERCENT MINERAL AGGREGATE			AGGREGATE ANALYSIS TOTAL PERCENT PASSING						
SCREEN	Til Passing	Requested		Hard 5/8	Hard Scr	Soft Scr	Sand		Calculated
	Design Range	Percent		Percent	Percent	Percent	Percent		Mix
Temp				40	20	15.0	25.0		
% A.C.	5.3-7.0	6.00			NCAT Furnace Corr Factor			0.52	
Compaction Temp:		310-350			LOI:		16.4		
Mixing Temp:		290-330			Theo:		2.409		
					TSR		89.7		
					DAR		0.89		
3/4"	100			100.0	100.0	100.0	100.0		100.0
5/8"	100			100.0	100.0	100.0	100.0		100.0
1/2"	95-100			93.0	100.0	100.0	100.0		97.2
3/8"	80-93			70.0	100.0	100.0	100.0		88.0
#4	54-76			12.0	97.0	98.0	98.0		63.4
#8	35-57			4.5	64.5	71.5	85.0		46.7
#30	17-29			2.5	26.5	33.0	66.0		27.8
#50	10-18			2.0	17.5	23.0	25.0		14.0
#100	3-10			1.5	12.5	18.0	3.0		6.6
#200	0-6.5			1.0	10.0	16.0	1.0		5.1

Requested _____

Approved _____

Contractor

Region Materials Engineer

Approved _____

Approved _____

Region Construction Engineer

Engineer of Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Date: 3/25/00

Project Ref. No. IME-124-3(80)173
 Proj. No. 33006-8129-44 / 33003-8155-44
 Type ACSC (HM)
 Contractor Vulcan Construction Co.
 State Rt. I-24
 Design Number: TOTAL MIX INCLUDING BITUMEN
 County Hamilton
 Sec. No. 411-D
 Region 2
 Contract No. 5530
 Article No:
 Subcontractor:
 Date of Letting
 Mix No:

MATERIAL	Screen	% Passing	PRODUCER AND ADDRESS	% USED
C.A.				
Med. C.A.	5/8s	16mm-75um	Vulcan Sand & Gravel, Chattanooga, TN	46.85
Screenings		9.5mm-75um	Vulcan Materials Company, Chattanooga, TN	23.42
Sand	Ohio Sand	4.75mm-75um	Vulcan Materials Company, Chattanooga, TN	23.43
Asphalt Cement		PG 76-22	Marathon Ashland Petroleum LLC Chatt. TN	6.30
Anti-Strip	TYPE: Pave Bond Lite		DOSAGE RATE:	0.30%
% Fractured Faces on +4 Material: 96.2		% Glassy Particles on +4 Material: 0.00		Total 100%

100 PERCENT MINERAL AGGREGATE				AGGREGATE ANALYSIS TOTAL PERCENT PASSING				
SCREEN	Ttl. Passing	Requested Percent	Tolerance Percent		C.A. Percent	Med. C.A. Percent	Screenings Percent	O'River Sand Percent
Temp		340.0	280-320	0	0	50.0	25.0	25
% A.C.	5.3-7.0	6.30%			(Washed Gradations)			
	Compaction Temp:		325-338		Theo:			2.296
	Mixing Temp:		352-368		LOI:			0.1
5/8"	100	100.0				100.0	100.0	100.0
1/2"	95-100	98.0				96.0	100.0	98.0
3/8"	80-93	91.0				82.0	100.0	91.0
#4	54-76	72.4				50.0	93.4	72.4
#8	35-57	51.9				28.0	63.5	51.9
#30	17-29	27.3				10.0	28.0	27.3
#50	10-18	12.8				7.0	22.0	12.8
#100	3-10	6.4				4.0	16.5	6.4
#200	0-6.5	4.7				2.0	14.0	4.6

Requested _____

Contractor

Approved _____

Region Materials Engineer

Approved _____

Region Construction Engineer

Approved _____

Engineer of Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Plant # _____ Date: 2/10/00
 L-R Job # _____
 Project Ref. No. IME-40-1-(275)46 County HAYWOOD Region IV
 Proj. No. 38001-8174-44 Contract No. 1027
 Type ASCS-HM Sec. No. 411-D Article _____
 Contractor Standard Constructin Co. Inc Subcontractor: Lehman-Roberts Co.
 State Rt. I-40 TOTAL MIX INCLUDING BITUMEN Date of Letting 12/10/99

MATERIAL	Size Range of Type	PRODUCER AND ADDRESS	% USED
C.A.			
C.A. "D"	5/8"- #200	Standard Const.-McNairy Co.	51.76
Screenings #10L/S	3/8"- #200	Vulcan Materials.-Savannah, TN	9.41
Sand	3/8"- 100	Standard Const.-Snow White	23.53
Ag. Lime	3/8"- #200	Vulcan Materials-Parsons, TN	9.41
		Dosage Rate	
Asphalt Cement	PG 76-22	Koch -Memphis, TN	5.90
Anti-Strip	TYPE: Morelife 3300	DOSAGE RATE: 0.30%	
% Fractured Faces on +4 Material: 82%		% Glassy Particles on +4 Material N/A	100 %
100 PERCENT MINERAL AGGREGATE			
SCREEN	Ttl Passing Master Range	Requested Percent	Tolerance Percent
Temp	300-340	330.0	310-350
% A.C.	5.3-7.0	5.90	
	Compaction Temp:		
	Mixing Temp:		
2"			
1 1/2"			
1"	100	100.0	
3/4"	100	100.0	100.0
1/2"	95-100	96.7	94.0
3/8"	80-93	85.2	73.0
#4	54-76	61.4	34.0
#8	35-57	45.5	20.0
#16			
#30	17-29	27.5	10.0
#50	10-18	13.5	6.0
#100	3-10	7.9	4.0
#200	0-6.5	5.5	2.0

AGGREGATE ANALYSIS TOTAL PERCENT PASSING					
C.A.	Med C.A.	Saverings	Nat Sand	Ag. Lime	Calculated
Percent	Percent	Percent	Percent	Percent	Mix
55	50	10	25	10.0	100.0
	(Washed Gradations)				
	NCAT Furnace Corr Factor:				
	LOI: 6.7				
	Theo: 2.4				
	A.C. in Rap: 0.0				

Requested _____

Contractor

Approved _____

Region Materials Engineer

Approved _____

Region Construction Engineer

Approved _____

Engineer of Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Date: 3/7/00

Project Ref. No. IME-40-1(272)80 County Madison Region 4
 Proj. No. 57201-8110-44 Contract No. 1037
 Type ACS(HM) Sec. No. 411-S Article 10.01.03
 Contractor Dement Construction Co. Subcontractor: _____
 State Rt. I-40 **TOTAL MIX INCLUDING BITUMEN** Date of Letting Dec-99
 Design Number: _____ Mix No: _____

MATERIAL	Screen	% Passing	PRODUCER AND ADDRESS	% USED
Filler Sand	3/8" -#200		Vulcan MTLs. Parsons, TN.	14.09
C.A.				
Med. C.A.	5/8" -#200		Adamsville Gravel, Adamsville, TN	56.34
Screenings #10	3/8" -#200		Vulcan MTLs. Parsons, TN.	9.39
Sand	3/8" -#200		Dement Construction Co. Denmark, TN.	14.09
A. C.	PG 76-22		KOCH Materials Co., Memphis, TN.	6.10
Anti-Strip	TYPE: <u>Kling-Beta</u>		DOSAGE RATE: <u>0.50%</u>	
Angularity		100%		

100 PERCENT MINERAL AGGREGATE				AGGREGATE ANALYSIS TOTAL PERCENT PASSING					
SCREEN	Til Passing	Requested Percent		ASG	#10-VP	Sand-DW	B10-VP	Calculated Mix	
Temp		330.0		60	10.0	15.0	15	100.0	
% A.C.	5.3-7.0	6.1		(Washed Gradations)					
				DAR:		0.6			
				Theo:		2.343			
				TSR:		90.7			
5/8"	100	100.0		100.0	100.0	100.0	100.0	100	
1/2"	90-100	99.0		98.0	100.0	100.0	100.0	99	
3/8"	76-91	90.0		84.0	100.0	100.0	100.0	90	
#4	50-71	71.0		58.0	93.0	100.0	76.0	71	
#8	33-58	44.0		34.0	67.0	98.0	12.0	44	
#16		29.0		15.0	48.0	90.0	10.0	29	
#30	16-29	22.0		12.0	38.0	65.0	6.0	22	
#50		10.0		7.0	28.0	16.0	5.0	10.2	
#100		5.4		3.0	23.0	4.7	4.0	5.4	
#200	2-6.5	3.6		2.0	16.4	2.1	3.0	3.6	

Requested _____

Contractor

Approved _____

Region Materials Engineer

Approved _____

Region Construction Engineer

Approved _____

Engineer of Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Date: 05/16/00

Project Ref. No. SP County Sumner Region III
 Proj. No. 83002-4252-04 Contract No. 1198
 Type ACS-HM Sec. No. 411-S 12.5mm w/PG 76-22 Article 411.03.10
 Contractor Rogers Group Inc. Subcontractor: _____
 State Rt. 6 (U.S. 31) **TOTAL MIX INCLUDING BITUMEN** Date of Letting 05/16/00

MATERIAL	Screen	% Passing	PRODUCER AND ADDRESS	% USED
				0.00
1/2"	3/4"-Pan		RGI, Cross Plains, TN	42.66
Screenings	3/8"-Pan		RGI, Cross Plains, TN	23.70
Washed Scrms	3/8"-Pan		RGI, Cross Plains, Gallatin, TN	18.96
Sand	3/8"-Pan		Hunter Marine, Nashville, TN	9.48
Asphalt Cement	PG 64-22		Ergon Nashville, TN	5.20
Anti-Strip	Ad-Here 65-00		DOSAGE RATE: 0.5	
FAA : 44.09			Eff. Gravity of Aggregate : 2.659	N/A 100 %

100 PERCENT MINERAL AGGREGATE				AGGREGATE ANALYSIS TOTAL PERCENT PASSING					
SCREEN	Til Passing	Requested Percent		C A. Percent	1/2" Percent	Screenings Percent	Wash Scr Percent	Sand Percent	Calculated Mix
Temp				0	47	23.0	20.0	10	100.0
% A.C.	5.3- 7.0	5.20							
	Compaction Temp:	285-325			(Washed Gradations)				
	Mixing Temp:	295-335			LOI:	25.2			
					Theo:	2.456			
					NCAT Furnace Corr. Factor	0.7			
2"	100				100.0	100.0	100.0	100.0	100.0
1 1/2"	100				100.0	100.0	100.0	100.0	100.0
1"	100				100.0	100.0	100.0	100.0	100.0
3/4"	100				100.0	100.0	100.0	100.0	100.0
1/2"	90-100				88.0	100.0	100.0	100.0	94.4
3/8"	76-91				67.0	100.0	100.0	100.0	84.5
#4	50-71				6.5	94.0	94.0	98.0	53.3
#8	33-58				5.0	60.0	62.0	94.0	38.0
#16	-				3.5	40.0	37.0	89.0	27.1
#30	16-29				3.0	34.0	24.0	76.0	21.6
#50	-				2.0	20.0	14.0	19.0	10.2
#100	-				1.5	16.0	6.5	1.0	5.8
#200	2-6.5				0.5	13.5	4.5	0.5	4.3

Requested _____ Approved _____
 Contractor _____ Region Materials Engineer _____
 Approved _____ Approved _____
 Region Construction Engineer _____ Engineer of Materials and Tests _____

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Date: 5/22/00

Project Ref. No. IME-75-3(131)121 County Campbell Region 1
 Proj. No. 07100-8105-44 Contract No. 1010
 Type ACS-HM Sec. No. 411S 12.5mm w/PG 76-22 Article 01.01-01.02
 Contractor Tennessee Asphalt Subcontractor: _____
 State Rt. 25 **TOTAL MIX INCLUDING BITUMEN** Date of Letting Jan-00
 Design Number: _____ Mix No: _____

MATERIAL	Screen	% Passing	PRODUCER AND ADDRESS	% USED
TN 7's	3/4" -Pan		Vulcan Materials Enka N.C.	46.80
#10's	#10 3/8" -Pan		Key Limestone Div. Lafollette, TN	23.40
White Sand	3/8" -Pan		Nolichucky Sand & Gravel Greenville, TN	23.40
Asphalt Cement	PG 76-22		SHELL OIL CO. Knoxville TN.	6.40
Anti-Strip	TYPE: <u>Pave Bond Lite</u>		DOSAGE RATE: <u>0.50%</u>	
Angularity	<u>51%</u>	% Fracture Face on CA : <u>100/100</u> % Glassy Particles on CA: <u>N/A</u>		Total 100

100 PERCENT MINERAL AGGREGATE				AGGREGATE ANALYSIS TOTAL PERCENT PASSING				
SCREEN	Ttl Passing	Requested Percent	Mixing Temperature		TN #7's	# 10's	White Sand	Calculated Mix
Temp	290-330	310.0	310-350	0	50	25.0	25.0	100.0
% A.C.		6.40%			(Washed Gradations)			
					DAR:	0.55		
					Theo:	2.468		
					TSR:	81.3		
					LOI:	10.9		
2"	100							
1.5"	100							
1"	100							
3/4"	100	100.0			100.0	100.0	100.0	100.00
1/2"	90-100	96.2			92.3	100.0	100.0	96.15
3/8"	76-91	84.2			68.4	100.0	100.0	84.20
#4	50-71	61.3			27.2	90.6	100.0	61.25
#8	33-58	44.0			5.1	67.2	98.7	44.03
#16		37.1			2.8	46.6	96.3	37.13
#30	16-29	26.5			2.1	31.7	70.0	26.48
#50		9.4			1.6	21.8	12.5	9.38
#100		5.2			1.1	15.5	3.2	5.23
#200	2-6.5	3.5			0.5	11.5	1.6	3.53

Requested _____

Contractor

Approved _____

Region Materials Engineer

Approved _____

Region Construction Engineer

Approved _____

Engineer of Materials and Tests

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Plant # _____ Date: 2/8/00
 L-R Job # _____
 Project Ref. No. _____ S.P. _____ County Coffee/Grundy Region II
 Proj. No. _____ Contract No. 1014
 Type 411-S Sec. No. 411-S Article _____
 Contractor Rogers Group Inc. Subcontractor: _____
 State Rt. I-24 **TOTAL MIX INCLUDING BITUMEN** Date of Letting _____

MATERIAL	Size Range of Type	PRODUCER AND ADDRESS	% USED
Med. Coarse Aggregate	5/8" - #200	Rogers Group Inc., Lawrenceburg	42.70
Screenings	3/8" - #200	Rogers Group Inc., Hillsboro, TN	23.73
Sand	3/8" - #200	Cumb. Mtn. Sand-Hillsboro, TN	18.98
Hard Screenings	3/8" - #200	Rogers Group Inc., Lawrenceburg	9.49
Anti-Strip	Pave Bond Lite	Southern States-Nash., TN	5.10
Asphalt Cement	PG 76-22	Ergon Oil-Nash. TN	0.50
Anti-Strip	TYPE:	DOSAGE RATE:	
% Fractured Faces on +4 Material:		100 % Glassy Particles on +4 Material	N/A
			100 %

100 PERCENT MINERAL AGGREGATE				AGGREGATE ANALYSIS TOTAL PERCENT PASSING					
SCREEN	Ttl Passing Design Range	Requested Percent		Percent	Medium C.A. % Percent	Screenin % Percent	Sand Percent	Hrd. Screenings Percent	Calculated Mix
Temp	300-340			0	45	25	20	10	100.0
% A.C.		5.45			(Washed Gradations)				
	Compaction Temp:	335			Latex Brand	None			
	Mixing Temp:	350			% Latex Used	N/A			
2"					LOI:	22.1			
1 1/2"					Theo:	2.461			
1"									
3/4"	100	100.00			100.0	100.0	100.0	100.0	100.0
5/8"		100.00			100.0	100.0	100.0	100.0	100.0
1/2"	90-100	98.47			96.6	100.0	100.0	100.0	98.5
3/8"	76-91	86.10			69.1	100.0	100.0	100.0	86.1
#4	50-71	53.20			6.1	86.4	98.6	91.0	53.2
#8	33-58	38.30			1.4	53.1	90.0	62.0	38.1
#16		28.60			0.8	33.7	80.6	37.0	28.6
#30	16-29	23.50			0.6	28.6	67.0	27.0	23.5
#50		11.30			0.5	19.5	21.4	19.0	11.3
#100		6.10			0.4	14.1	4.5	15.0	6.1
#200	2-6.5	4.30			0.3	10.2	2.0	12.5	4.3

Requested _____ Approved _____
 Contractor _____ Region Materials Engineer _____
 Approved _____ Approved _____
 Region Construction Engineer _____ Engineer of Materials and Tests _____

Appendix B

Bulk and Theoretical Maximum Specific Gravity Data

Theoretical Maximum Specific Gravity (Rice)

County:	Sullivan
Mix Type:	411-S
Project Number:	5800
Contractor:	Summers -Taylor, Materials
Date Sampled:	11/9/99
Rice Gravity Date:	12/21/99

	Sample Number		
	1	2	3
Dry Bowl mass, g	2004.3	2004.7	2005.0
(A) Dry mass of Asphalt, g	1987.1	2579	2554.3
(B) Wet mass; Asphalt, Bowl, & water, g	2447.2	2798.3	2784.8
(D) Wet mass; Bowl & water, g	1265.2	1265.2	1265.2
Bouyant Force (C=B-D), g	1182.0	1533.1	1519.6
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.468	2.466	2.469
Average of Three Test	2.468		

Bulk Specific Gravity

	Sample Number		
	1	2	3
(W_D) Dry Weight, g	1308.1	1159	1337.8
(W_{SSD}) Saturated Surface Dry Weight, g	1324.3	1167.3	1366.8
(W_{SUB}) Weight Submerged in Water, g	735.5	654.5	757.3
(G_{MB}) Bulk Specific Gravity	2.222	2.260	2.195

Theoretical Maximum Specific Gravity (Rice)

County:	Sullivan
Mix Type:	411-D
Project Number:	5405
Contractor:	Summers-Taylor, Materials
Date Sampled:	11/1/99
Rice Gravity Date:	12/20/99

	Sample Number		
	1	2	3
Dry Bowl mass, g	2004.2	2004.8	2004.9
(A) Dry mass of Asphalt, g	2211	2646.6	2089.9
(B) Wet mass; Asphalt, Bowl, & water, g	2579.9	2841.4	2509.1
(D) Wet mass; Bowl & water, g	1265.1	1265.1	1265.1
Bouyant Force (C=B-D), g	1314.8	1576.3	1244.0
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.467	2.473	2.471
Average of Three Test	2.470		

Bulk Specific Gravity

	Sample Number		
	1	2	3
(W _D) Dry Weight, g	931.6	812.4	959.5
(W _{SSD}) Saturated Surface Dry Weight, g	950	831.8	984.9
(W _{SUB}) Weight Submerged in Water, g	516.1	452.3	535
(G _{MB}) Bulk Specific Gravity	2.147	2.141	2.133

Theoretical Maximum Specific Gravity (Rice)

County:	Hamilton
Mix Type:	411-S
Project Number:	5822
Contractor:	Vulcan Materials
Date Sampled:	11/4/99
Rice Gravity Date:	12/17/99

	Sample Number		
	1	2	3
Dry Bowl mass, g	2005.3	2004.8	2004.6
(A) Dry mass of Asphalt, g	3249.3	3073.0	2507.8
(B) Wet mass; Asphalt, Bowl, & water, g	3127.6	3030.0	2704.4
(D) Wet mass; Bowl & water, g	1265.1	1265.1	1265.1
Bouyant Force (C=B-D), g	1862.5	1764.9	1439.3
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.343	2.349	2.347
Average of Three Test	2.346		

Bulk Specific Gravity

	Sample Number		
	1	2	3
(W _D) Dry Weight, g	863.3	964.8	910.8
(W _{SSD}) Saturated Surface Dry Weight, g	874.3	987	938.4
(W _{SUB}) Weight Submerged in Water, g	459.7	505.9	479.5
(G _{MB}) Bulk Specific Gravity	2.082	2.005	1.985

Theoretical Maximum Specific Gravity (Rice)

County:	Hamilton
Mix Type:	411-D
Project Number:	5621
Contractor:	Hillis Group
Date Sampled:	11/8/99
Rice Gravity Date:	12/17/99

	Sample Number		
	1	2	3
Dry Bowl mass, g	2004.5	2005.0	2005.0
(A) Dry mass of Asphalt, g	2362.1	2261.8	2883.0
(B) Wet mass; Asphalt, Bowl, & water, g	2672.1	2607.7	2984.0
(D) Wet mass; Bowl & water, g	1265.1	1265.1	1265.1
Bouyant Force (C=B-D), g	1407.0	1342.6	1718.9
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.473	2.461	2.477
Average of Three Test	2.470		

Bulk Specific Gravity

	Sample Number		
	1	2	3
(W _D) Dry Weight, g	1064.5	1175.1	1305.1
(W _{SSD}) Saturated Surface Dry Weight, g	1074.3	1180.1	1307.4
(W _{SUB}) Weight Submerged in Water, g	596.6	656.7	737.4
(G _{MB}) Bulk Specific Gravity	2.228	2.245	2.290

Theoretical Maximum Specific Gravity (Rice)

County:	Smith
Mix Type:	411-S
Project Number:	5706
Contractor:	Rogers Group
Date Sampled:	9/10/99
Rice Gravity Date:	12/21/99

	Sample Number		
	1	2	3
Dry Bowl mass, g	2004.7	2004.8	2004.6
(A) Dry mass of Asphalt, g	1778.3	1784.3	1964.8
(B) Wet mass; Asphalt, Bowl, & water, g	2326.4	2330.4	2438.0
(D) Wet mass; Bowl & water, g	1265.2	1265.2	1265.2
Bouyant Force (C=B-D), g	1061.2	1065.2	1172.8
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.480	2.481	2.481
Average of Three Test	2.481		

Bulk Specific Gravity

	Sample Number		
	1	2	3
(W _D) Dry Weight, g	1397.9	1370.5	1330
(W _{SSD}) Saturated Surface Dry Weight, g	1409.3	1386.1	1345.2
(W _{SUB}) Weight Submerged in Water, g	792.1	781.9	757.1
(G _{MB}) Bulk Specific Gravity	2.265	2.268	2.262

Theoretical Maximum Specific Gravity (Rice)

County:	Davidson
Mix Type:	411-D
Project Number:	5114
Contractor:	Rogers Group
Date Sampled:	10/16/99
Rice Gravity Date:	12/21/99

	Sample Number		
	1	2	3
Dry Bowl mass, g	2004.7	2004.6	2004.7
(A) Dry mass of Asphalt, g	2098.1	2014.1	1962.8
(B) Wet mass; Asphalt, Bowl, & water, g	2498.9	2450.6	2420.4
(D) Wet mass; Bowl & water, g	1265.2	1265.2	1265.2
Bouyant Force (C=B-D), g	1233.7	1185.4	1155.2
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.427	2.430	2.430
Average of Three Test	2.429		

Bulk Specific Gravity

	Sample Number		
	1	2	3
(W_D) Dry Weight, g	1145.5	1054.5	1122.9
(W_{SSD}) Saturated Surface Dry Weight, g	1148.7	1059.6	1128.5
(W_{SUB}) Weight Submerged in Water, g	641.6	598.8	631.1
(G_{MB}) Bulk Specific Gravity	2.259	2.288	2.258

Theoretical Maximum Specific Gravity (Rice)

County:	Fayette
Mix Type:	411-S
Project Number:	5616
Contractor:	Lehman - Roberts
Date Sampled:	8/25/99
Rice Gravity Date:	12/20/99

	Sample Number		
	1	2	3
Dry Bowl mass, g	2004.7	2005.2	2004.7
(A) Dry mass of Asphalt, g	2764.1	2670.4	2395.4
(B) Wet mass; Asphalt, Bowl, & water, g	2885.3	2832.7	2669.5
(D) Wet mass; Bowl & water, g	1265.1	1265.1	1265.1
Bouyant Force (C=B-D), g	1620.2	1567.6	1404.4
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.416	2.421	2.417
Average of Three Test	2.418		

Bulk Specific Gravity

	Sample Number		
	1	2	3
(W _D) Dry Weight, g	1159.6	1502.8	1350
(W _{SSD}) Saturated Surface Dry Weight, g	1163.3	1505.4	1355.7
(W _{SUB}) Weight Submerged in Water, g	638.9	840.7	747.6
(G _{MB}) Bulk Specific Gravity	2.211	2.261	2.220

Theoretical Maximum Specific Gravity (Rice)

County:	Fayette
Mix Type:	411-D
Project Number:	5616
Contractor:	Lehman - Roberts
Date Sampled:	8/25/99
Rice Gravity Date:	12/20/99

	Sample Number		
	1	2	3
Dry Bowl mass, g	2004.8	2004.8	2004.8
(A) Dry mass of Asphalt, g	2495	2139.4	2267.1
(B) Wet mass; Asphalt, Bowl, & water, g	2707.8	2501.4	2576.0
(D) Wet mass; Bowl & water, g	1265.1	1265.1	1265.1
Bouyant Force (C=B-D), g	1442.7	1236.3	1310.9
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.371	2.369	2.371
Average of Three Test	2.370		

Bulk Specific Gravity

	Sample Number		
	1	2	3
(W _D) Dry Weight, g	1270.8	1498.6	1353.9
(W _{SSD}) Saturated Surface Dry Weight, g	1272.6	1500.3	1355.5
(W _{SUB}) Weight Submerged in Water, g	710.3	837.2	759.5
(G _{MB}) Bulk Specific Gravity	2.260	2.260	2.272

Theoretical Maximum Specific Gravity (Rice)

County:	Madison
Mix Type:	411S
Project Number:	57201-8110-44
Contractor:	Dement
Date Sampled:	7/11/00

	Sample Number		
	L	C	R
Dry Bowl mass, g	2004.5	2004.5	2004.5
(A) Dry mass of Asphalt, g	1919.8	1938.8	1914.2
(B) Wet mass; Asphalt, Bowl, & water, g	2370.8	2386.1	2370.5
(D) Wet mass; Bowl & water, g	1265	1265	1265.0
Bouyant Force (C=B-D), g	1105.8	1121.1	1105.5
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.358	2.371	2.367
Average of Three Test	2.366		

Bulk Specific Gravity

	Sample Number		
	L	C	R
(W _D) Dry Weight, g	1141.2	1050.8	901.9
(W _{SSD}) Saturated Surface Dry Weight, g	1150	1060.5	916
(W _{SUB}) Weight Submerged in Water, g	613.6	559.2	474.7
(G _{MB}) Bulk Specific Gravity	2.128	2.096	2.044

Theoretical Maximum Specific Gravity (Rice)

County:	Campbell
Mix Type:	411-S
Project Number:	07100-8105-44
Contractor:	Tennessee Asphalt
Date Sampled:	5/31/00
Rice Gravity Date:	

	Sample Number		
	1	2	3
Dry Bowl mass, g	2004.4	2004.4	2004.4
(A) Dry mass of Asphalt, g	1913.2	1609.1	1714.6
(B) Wet mass; Asphalt, Bowl, & water, g	2407.3	2224.8	2287.2
(D) Wet mass; Bowl & water, g	1264.8	1264.8	1264.8
Bouyant Force (C=B-D), g	1142.5	960.0	1022.4
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.482	2.479	2.477
Average of Three Test	2.479		

Bulk Specific Gravity

	Sample Number		
	L	C	R
(W _D) Dry Weight, g	1231.8	1216.4	1390.6
(W _{SSD}) Saturated Surface Dry Weight, g	1232.9	1217.7	1391.4
(W _{SUB}) Weight Submerged in Water, g	705.5	696.8	798.8
(G _{MB}) Bulk Specific Gravity	2.336	2.335	2.347

Theoretical Maximum Specific Gravity (Rice)

County:	Sumner
Mix Type:	411S
Project Number:	83002-4252-04
Contractor:	Dement
Date Sampled:	6/10/00
Rice Gravity Date:	

	Sample Number		
	L	C	R
Dry Bowl mass, g	2004.5	2004.5	2004.5
(A) Dry mass of Asphalt, g	2117.3	1991.3	2077.7
(B) Wet mass; Asphalt, Bowl, & water, g	2515.4	2441.7	2491.4
(D) Wet mass; Bowl & water, g	1265.3	1265.3	1265.3
Bouyant Force (C=B-D), g	1250.1	1176.4	1226.1
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.442	2.444	2.440
Average of Three Test	2.442		

Bulk Specific Gravity

	Sample Number		
	L	C	R
(W _D) Dry Weight, g	1017.4	854.6	1125.7
(W _{SSD}) Saturated Surface Dry Weight, g	1040.6	868	1133.8
(W _{SUB}) Weight Submerged in Water, g	568.3	479.7	634.1
(G _{MB}) Bulk Specific Gravity	2.154	2.201	2.253

Theoretical Maximum Specific Gravity (Rice)

County:	Coffee/Grundy
Mix Type:	411s
Contract Number:	1014
Contractor:	Rogers Group
Date Sampled:	5/15/00
Rice Gravity Date:	

	Sample Number		
	1	2	3
Dry Bowl mass, g	2004.5	2004.5	2004.5
(A) Dry mass of Asphalt, g	1729.0	1837.8	1777.9
(B) Wet mass; Asphalt, Bowl, & water, g	2293.6	2358.7	2323.3
(D) Wet mass; Bowl & water, g	1265.4	1265.4	1265.4
Bouyant Force (C=B-D), g	1028.2	1093.3	1057.9
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.467	2.469	2.469
Average of Three Test	2.468		

Bulk Specific Gravity

	Sample Number		
	L	C	R
(W _D) Dry Weight, g	956.5	971.6	1003.2
(W _{SSD}) Saturated Surface Dry Weight, g	987.2	1009	1040.6
(W _{SUB}) Weight Submerged in Water, g	539.4	546.4	569.4
(G _{MB}) Bulk Specific Gravity	2.136	2.100	2.129

Theoretical Maximum Specific Gravity (Rice)

County:	Dickson
Mix Type:	411D
Project Number:	22004-4239-04
Contractor:	Eubank
Date Sampled:	6/9/00
Rice Gravity Date:	

	Sample Number		
	1	2	3
Dry Bowl mass, g	2004.4	2004.4	2004.4
(A) Dry mass of Asphalt, g	1652.0	2129.7	1852.9
(B) Wet mass; Asphalt, Bowl, & water, g	2236.9	2538.2	2353.6
(D) Wet mass; Bowl & water, g	1265.3	1265.3	1265.3
Bouyant Force (C=B-D), g	971.6	1272.9	1088.3
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.428	2.486	2.423
Average of Three Test	2.446		

Bulk Specific Gravity

	Sample Number		
	L	C	R
(W _D) Dry Weight, g	868.6	1142.8	1307.5
(W _{SSD}) Saturated Surface Dry Weight, g	878.4	1148	1318.1
(W _{SUB}) Weight Submerged in Water, g	471.8	631.3	722.6
(G _{MB}) Bulk Specific Gravity	2.136	2.212	2.196

Theoretical Maximum Specific Gravity (Rice)

County:	Madison
Mix Type:	411D
Project Number:	57201-8111-44
Contractor:	Dement
Date Sampled:	6/20/00
Rice Gravity Date:	

	Sample Number		
	L	C	R
Dry Bowl mass, g	2003.9	2003.9	2003.9
(A) Dry mass of Asphalt, g	2053.7	2365.6	1988.4
(B) Wet mass; Asphalt, Bowl, & water, g	2452.6	2632.0	2413.9
(D) Wet mass; Bowl & water, g	1265	1265	1265
Bouyant Force (C=B-D), g	1187.6	1367.0	1148.9
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.371	2.369	2.369
Average of Three Test	2.370		

Bulk Specific Gravity

	Sample Number		
	L	C	R
(W _D) Dry Weight, g	709.9	615.4	1109.5
(W _{SSD}) Saturated Surface Dry Weight, g	712.5	619	1112
(W _{SUB}) Weight Submerged in Water, g	388.3	330.4	623.1
(G _{MB}) Bulk Specific Gravity	2.190	2.132	2.269

Theoretical Maximum Specific Gravity (Rice)

County:	Hamilton
Mix Type:	411D
Project Number:	33006-8129-44 / 33003-8155-44
Contractor:	Vulcan Construction Co.
Date Sampled:	6/6/00
Rice Gravity Date:	

	Sample Number		
	L	C	R
Dry Bowl mass, g	2004.5	2004.5	2004.5
(A) Dry mass of Asphalt, g	2426.1	2553.0	2761.7
(B) Wet mass; Asphalt, Bowl, & water, g	2638.6	2714.8	2824.5
(D) Wet mass; Bowl & water, g	1265.3	1265.3	1265.3
Bouyant Force (C=B-D), g	1373.3	1449.5	1559.2
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.304	2.314	2.297
Average of Three Test	2.305		

Bulk Specific Gravity

	Sample Number		
	L	C	R
(W _D) Dry Weight, g	952.6	1159.5	1085.9
(W _{SSD}) Saturated Surface Dry Weight, g	957.2	1163.2	1088.6
(W _{SUB}) Weight Submerged in Water, g	496.1	613.1	583.1
(G _{MB}) Bulk Specific Gravity	2.066	2.108	2.148

Theoretical Maximum Specific Gravity (Rice)

County:	Hamblen
Mix Type:	411-D
Project Number:	07100-8105-44
Contractor:	Renfro Construction
Date Sampled:	
Rice Gravity Date:	

	Sample Number		
	1	2	3
Dry Bowl mass, g	2003.8	2003.8	2003.8
(A) Dry mass of Asphalt, g	1412.9	1794.8	2128.1
(B) Wet mass; Asphalt, Bowl, & water, g	2093.7	2318.8	2513.0
(D) Wet mass; Bowl & water, g	1263.7	1236.7	1263.7
Bouyant Force (C=B-D), g	830.0	1082.1	1249.3
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.424	2.518	2.422
Average of Three Test	2.455		

Bulk Specific Gravity

	Sample Number		
	L	C	R
(W _D) Dry Weight, g	1326.1	1134	914.2
(W _{SSD}) Saturated Surface Dry Weight, g	1331.1	1138.7	920.5
(W _{SUB}) Weight Submerged in Water, g	736.5	622.6	502.9
(G _{MB}) Bulk Specific Gravity	2.230	2.197	2.189

Theoretical Maximum Specific Gravity (Rice)

County:	Haywood
Mix Type:	411D
Project Number:	38001-8174-44
Contractor:	Standard
Date Sampled:	5/18/00
Rice Gravity Date:	

	Sample Number		
	L	C	R
Dry Bowl mass, g	2004.4	2004.4	2004.4
(A) Dry mass of Asphalt, g	1192.6	1199.8	1170.4
(B) Wet mass; Asphalt, Bowl, & water, g	1948.4	1952.9	1936.5
(D) Wet mass; Bowl & water, g	1265.1	1265.1	1265.1
Bouyant Force (C=B-D), g	683.3	687.8	671.4
Theoretical Max. (Rice) $G_{MM} = A/A-C$	2.342	2.343	2.345
Average of Three Test	2.343		

Bulk Specific Gravity

	Sample Number		
	L	C	R
(W _D) Dry Weight, g	1106.4	1028.2	832.3
(W _{SSD}) Saturated Surface Dry Weight, g	1115.1	1036.4	842
(W _{SUB}) Weight Submerged in Water, g	579.9	531.5	424.1
(G _{MB}) Bulk Specific Gravity	2.067	2.036	1.992

Appendix C

Laboratory Permeability Test Protocol

1. Saturation of Test Specimens

- 1.1 Determine the bulk specific gravity of the sample in accordance with T166.
- 1.2 Place the specimen in a horizontal position in the vacuum container supported above the container bottom by the spacer. Fill the vacuum container with distilled water so that the specimen is covered by at least 25mm (1 inch) of water.
- 1.3 Remove trapped air and saturate the specimen by applying a gradually increased vacuum until the residual pressure manometer reads 28 ± 2 mm of Hg. Maintain the residual pressure for 15 ± 2 minutes. Manually agitate the container holding the specimen during the vacuum period by applying 12 taps of a rubber mallet (3 taps at each of 4 different location around the perimeter of the container) at 2 minute intervals.
- 1.4 At the end of the vacuum period, release the vacuum by slowly increasing the pressure.
- 1.5 Allow the specimen to stand within the vacuum container, still covered with water, for 5 to 10 minutes.
- 1.6 Determine and record the saturated surface dry (SSD) mass of the specimen according to T166.
- 1.7 After determining the SSD mass, return the specimen to the vacuum container similar to that described in 6.2.
- 1.8 Calculate the degree of saturation for the specimen as follows:

$$\% \text{Saturation} = \left[\frac{SSD - M}{M \left(\frac{1}{G_{mb}} - \frac{1}{G_{mm}} \right)} \right] * 100$$

Where: SSD= SSD mass of sample after vacuum conditioning, grams
M= dry mass of sample, grams
 G_{mb} = bulk specific gravity of compacted specimens
 G_{mm} = maximum theoretical specific gravity of specimen (T209).

- 1.9 If the degree of saturation is not greater than or equal to 95 percent, repeat 6.2 through 6.8 except maintain the residual pressure for 7 ± 2 minutes. Repeat these steps until 95 percent saturation is achieved.

Note: Because of potential problems with measuring the SSD mass of coarse graded mixtures, step 6.9 should only be performed a maximum of two times.

2. Permeameter Calibration/Verification

- 2.1 With the permeameter completely assembled as shown in Figure 1, use the meterstick to measure a distance of 10 cm from the bottom of the outlet pipe and place a mark onto the stand pipe. This mark will be designated as the lower timing mark.
- 2.2 Establish an upper timing mark by using the meterstick to measure a distance of 30 cm from the bottom of the outlet pipe. Place a mark at 30 cm on the standpipe.

3. Testing Procedure

- 3.1 Disassemble the permeameter by removing the clamp assembly and cap assembly.
- 3.2 Connect the pressure line on the permeameter to the vacuum quick connect. Using the pressure/vacuum pump, apply a vacuum to the sealing tube to remove entrapped air and collapse the membrane to the inside diameter of the cylinder.
- 3.3 Remove the specimen to be tested from the vacuum container filled with water and quickly apply a light coating of sealant to the perimeter of the specimen. Care should be exercised so that no sealant gets onto the top or bottom of the specimen.
- 3.4 Place the specimen onto the pedestal at the bottom of the permeameter.
- 3.5 Expediently reassemble the permeameter making sure all connections are tight.
- 3.6 Disconnect the pressure line from the vacuum quick-connector and connect to the pressure quick connect.
- 3.7 Apply a confining pressure of 117 ± 13.8 kPa (17 ± 2 psi).
- 3.8 Place a tared pan or measure having a minimum capacity of 1000ml underneath the outlet pipe in order to catch the water exiting the outlet pipe.
- 3.9 Fill the permeameter standpipe to the upper timing mark with distilled water. Exercise care when filling to minimize the incorporation of air bubbles. Use of rubber tubing and a clamp will facilitate the filling operation.
- 3.10 Carefully lead the permeameter from side to side to allow the escape of any entrapped air from underneath the cap assembly. Continue this operation until all entrapped air has been removed.
- 3.11 Commence the water flow by opening the valve on the base of the outlet pipe. Allow water to flow until it begins to exit the outlet pipe. Once the water begins to exit the outlet pipe, close the valve on the base of the outlet pipe.
- 3.12 Refill the standpipe to the upper timing mark. Remove water from tared pan or measure and replace.
- 3.13 Commence the flow of water by opening the valve on the base of the outlet pipe. Simultaneously start the timing.
- 3.14 Observe the water flow through the standpipe and record the time needed for the water level to fall from the upper timing mark to the lower timing mark. Once the water reaches the lower timing mark immediately close the valve at the base of the outlet pipe.
- 3.15 Determine the mass of water captured in the tared pan or measure. Determine the volume of water flowing through the sample as follows:

$$\text{Volume of water} = \left(\frac{d^2}{4} \right) * D$$

Where: d = diameter of standpipe, cm

D = distance between upper and lower timing mark, cm

- 3.16 Determine the beta factor by determining the percent of water flowing through the sample that was captured in the tared pan or measure as follows:

$$\beta = \frac{W_t}{W_f} * 100$$

Where:

W_t = water captured in the tared pan or measure, gram

W_f = water flowing through sample, cm³

- 3.17 If the beta factor is below 95 percent, the specimen is not saturated sufficiently. If below 95 percent repeat 8.12 through 8.16. If the beta factor is below 95 percent again, go back to section 1 and repeat through 3.16.
- 3.18 If the beta factor is 95 percent or above, repeat 3.12 through 3.14 three additional times. Use the average time of three consecutive tests to compute permeability.

4. Calculation

- 4.1 The water coefficient of permeability, k , is determined using the following equation:

$$k = \left(\frac{al}{At} \right) \ln \left(\frac{h_1}{h_2} \right)$$

Where: k = coefficient of permeability, cm/s

a = inside cross-sectional area of standpipe, cm²

l = thickness of test specimen, cm

A = cross-sectioned area of test specimen, cm²

t = average elapsed time water flowed between timing marks, s

h_1 = initial head at upper timing mark, cm

h_2 = final head at lower timing mark, cm

5. Report

- 5.1 For each sample, the coefficient of permeability is reported in whole units $\times 10^{-5}$ cm/s.

Appendix D

Field Permeability Test Data

Madison County

County:	<u>Madison</u>	Test Date:	<u>6/20/00</u>
Project Number:	<u>57201-811-44</u>	Contractor:	<u>Dement</u>
Mix Type:	<u>411-D</u>	Design Pvmnt Thickness (cm):	<u>2.888</u>
Pvmnt Temp. (°F)	<u>150</u>	Water Temp. (°C)	<u>31.1</u>
Project location:	<u>I 40 westbound side, left lane, Jackson TN</u>		
Test #	L1	L2	L3
Head at Beginning, cm	49.02256	49.02256	49.02256
Head at End, cm	48.18	48.06	48.51456
Tier	top	top	top
Test Time, sec	60	60	60
Permeability*E-05, cm/sec	1.613253364	1.845310231	0.969318
			Avg. Radius:
			Avg. Perm: 1.475960532

County:	<u>Madison</u>	Test Date:	<u>6/20/00</u>
Project Number:	<u>57201-811-44</u>	Contractor:	<u>Dement</u>
Mix Type:	<u>411-D</u>	Design Pvmnt Thickness (cm):	<u>2.788</u>
Pvmnt Temp. (°F)	<u>150</u>	Water Temp. (°C)	<u>31.1</u>
Project location:	<u>I 40 westbound side, left lane, Jackson TN</u>		
Test #	C1	C2	C3
Head at Beginning, cm	49.02256	49.02256	49.02256
Head at End, cm	45.38	44.36	45.97456
Tier	top	top	top
Test Time, sec	60	60	60
Permeability*E-05, cm/sec	6.935899	8.978092821	5.7665726
Avg. Radius:			
Avg. Perm: 7.226854823			

County:	<u>Madison</u>	Test Date:	<u>6/20/00</u>
Project Number:	<u>57201-811-44</u>	Contractor:	<u>Dement</u>
Mix Type:	<u>411-D</u>	Design Pvmnt Thickness (cm):	<u>4.252</u>
Pvmnt Temp. (°F)	<u>150</u>	Water Temp. (°C)	<u>31.1</u>
Project location:	<u>I 40 westbound side, left lane, Jackson TN</u>		
Test #	R1	R2	R3
Head at Beginning, cm	49.02256	49.02256	49.02256
Head at End, cm	49.02256	49.02256	49.02256
Tier	top	top	top
Test Time, sec	60	60	60
Permeability*E-05, cm/sec	0	0	0
Avg. Radius:			
Avg. Perm:			

Average Permeability for Madison Co 411-D:

2.900938 cm/sec x10⁻⁵

Haywood County

County: <u>Haywood</u>	Test Date: <u>5/15/00</u>			
Project Number: <u>1027</u>	Contractor: <u>Standard</u>			
Mix Type: <u>411D</u>	Design Pvm Thickness (cm): <u>4.213</u>			
Pvmt Temp. (°F) <u>168</u>	Water Temp. (°C) <u>32</u>			
Project location: <u>1544 ft from sign 82A & 82B to L1, (I-40), sign is in the west bound lane</u>				
Test #	L1	L2	L3	Avg. Radius: Avg. Perm: 248.0035257
Head at Beginning, cm	49.02256	49.02256	49.02256	
Head at End, cm	38.87272	38.87272	38.87272	
Tier	top	top	top	
Test Time, sec	9.04	7.91	6.12	
Permeability*E-05, cm/sec	205.528844	234.8901074	303.5916	

County: <u>Haywood</u>	Test Date: <u>5/15/00</u>			
Project Number: <u>1027</u>	Contractor: <u>Standard</u>			
Mix Type: <u>411D</u>	Design Pvm Thickness (cm): <u>3.909</u>			
Pvmt Temp. (°F) <u>168</u>	Water Temp. (°C) <u>32</u>			
Project location: <u>1544 ft from sign 82A & 82B to L1, (I-40), sign is in the west bound lane</u>				
Test #	C1	C2	C3	Avg. Radius: Avg. Perm: 274.9924752
Head at Beginning, cm	49.02256	49.02256	49.02256	
Head at End, cm	38.87272	38.87272	38.87272	
Tier	top	top	top	
Test Time, sec	7.33	6.4	5.38	
Permeability*E-05, cm/sec	235.1859897	269.3614538	320.43	

County: <u>Haywood</u>	Test Date: <u>5/15/00</u>			
Project Number: <u>1027</u>	Contractor: <u>Standard</u>			
Mix Type: <u>411D</u>	Design Pvm Thickness (cm): <u>3.449</u>			
Pvmt Temp. (°F) <u>168</u>	Water Temp. (°C) <u>32</u>			
Project location: <u>1544 ft from sign 82A & 82B to L1, (I-40), sign is in the west bound lane</u>				
Test #	R1	R2	R3	Avg. Radius: Avg. Perm: 468.4434106
Head at Beginning, cm	49.02256	49.02256	49.02256	
Head at End, cm	38.87272	38.87272	38.87272	
Tier	top	top	top	
Test Time, sec	3.17	3.39	3.19	
Permeability*E-05, cm/sec	479.8258961	448.6867524	476.8176	

Average Perm. For Haywood: 330.48 cm/sec x10⁻⁵

Madison County

County: <u>Madison</u>	Test Date: <u>7/11/00</u>	
Project Number <u>57201-8110-44</u>	Contractor: <u>Dement</u>	
Mix Type: <u>411-S</u>	Design Pavt Thickness (cm): <u>4.297</u>	
Pavt Temp. (<u>147</u>	Water Temp. (°C) <u>28.5</u>	
Project location <u>I-40 East, Exit 82B, 100 ft past the end of the bridge</u>		

Test #	L1	L2
Head at Beginning, cm	49.02256	49.02256
Head at End, cm	38.87272	38.87272
Tier	top	top
Test Time, sec	6.38	3.31
Permeability*E-05, cm/s	318.8877	614.65364
		vg. Radius:
		Avg. Perm: 487.78666

County: <u>Madison</u>	Test Date: <u>7/11/00</u>	
Project Number <u>57201-8110-44</u>	Contractor: <u>Dement</u>	
Mix Type: <u>411-S</u>	Design Pavt Thickness (cm): <u>3.857</u>	
Pavt Temp. (<u>147</u>	Water Temp. (°C) <u>28.5</u>	
Project location <u>I-40 East, Exit 82B, 100 ft past the end of the bridge</u>		

Test #	C1	C2
Head at Beginning, cm	49.02256	49.02256
Head at End, cm	38.87272	38.87272
Tier	top	top
Test Time, sec	4.03	3.22
Permeability*E-05, cm/s	453.14552	567.13554
		vg. Radius:
		Avg. Perm: 518.60556

County: <u>Madison</u>	Test Date: <u>7/11/00</u>	
Project Number <u>57201-8110-44</u>	Contractor: <u>Dement</u>	
Mix Type: <u>411-S</u>	Design Pavt Thickness (cm): <u>3.554</u>	
Pavt Temp. (<u>147</u>	Water Temp. (°C) <u>28.5</u>	
Project location <u>I-40 East, Exit 82B, 100 ft past the end of the bridge</u>		

Test #	R1	R2
Head at Beginning, cm	49.02256	49.02256
Head at End, cm	38.87272	38.87272
Tier	middle	middle
Test Time, sec	12.3	8.1
Permeability*E-05, cm/s	553.69791	840.80053
		vg. Radius:
		Avg. Perm: 785.47708

Average Permeability for Madison Co 411-S: 597.29 cm/sec x10⁻⁵

Dickson County

County:	<u>Dickson</u>	Test Date:	<u>6/9/00</u>
Project Number:	<u>22004-4239-04</u>	Contractor:	<u>Eubanks</u>
Mix Type:	<u>411D</u>	Design Pvmnt Thickness (cm):	<u>3.883</u>
Pvmnt Temp. (°F)	<u>130</u>	Water Temp. (°C)	<u>31.1</u>
Project location:	<u>T635 Hwy 46 South, North bound slow lane</u>		
Test #	L1	L2	L3
Head at Beginning, cm	49.02256	49.02256	49.02256
Head at End, cm	46.48256	38.87272	38.87272
Tier	top	top	top
Test Time, sec	10.21	21.17	18.5
Permeability*E-05, cm/sec	39.19026913	82.41550886	94.310071
Avg. Radius:			
Avg. Perm:			72.0

County:	<u>Dickson</u>	Test Date:	<u>6/9/00</u>
Project Number:	<u>22004-4239-04</u>	Contractor:	<u>Eubanks</u>
Mix Type:	<u>411D</u>	Design Pvmnt Thickness (cm):	<u>4.024</u>
Pvmnt Temp. (°F)	<u>130</u>	Water Temp. (°C)	<u>31.1</u>
Project location:	<u>1635 Hwy 46 South, North bound slow lane</u>		
Test #	C1	C2	C3
Head at Beginning, cm	49.02256	49.02256	49.02256
Head at End, cm	46.48256	46.48256	46.48256
Tier	top	top	top
Test Time, sec	15.93	21.9	26.67
Permeability*E-05, cm/sec	26.03027724	18.93435235	15.547893
Avg. Radius:			
Avg. Perm:			20.2

County:	<u>Dickson</u>	Test Date:	<u>6/9/00</u>
Project Number:	<u>22004-4239-04</u>	Contractor:	<u>Eubanks</u>
Mix Type:	<u>411D</u>	Design Pvmnt Thickness (cm):	<u>4.18</u>
Pvmnt Temp. (°F)	<u>130</u>	Water Temp. (°C)	<u>31.1</u>
Project location:	<u>T635 Hwy 46 South, North bound slow lane</u>		
Test #	R1	R2	R3
Head at Beginning, cm	49.02256	49.02256	49.02256
Head at End, cm	46.48256	46.48256	46.48256
Tier	top	top	top
Test Time, sec	5.23	4.68	7.1
Permeability*E-05, cm/sec	82.35902382	92.03796893	60.667281
Avg. Radius:			
Avg. Perm:			78.4

Average Perm. For Dickson 411-D:

56.83 cm/sec x10⁻⁵

Sumner County

County: <u>Sumner</u>	Test Date: <u>5/16/00</u>		
Project Number: <u>83002-4252-04</u>	Contractor: <u>Rogers Group</u>		
Mix Type: <u>411-S</u>	Design Pavt Thickness (cm): <u>3.703</u>		
Pvmt Temp. (°F) <u>68</u>	Water Temp. (°C) <u>26.7</u>		
Project location <u>State Rt. 6, Gallatin, (US 31)</u>			

Test #	L1	L2	L3	
Head at Beginning, cm	49.02256	49.02256	49.02256	
Head at End, cm	38.87272	38.87272	38.87272	
Tier	top	top	top	Avg. Radius:
Test Time, sec	10.23	8.2	14.98	
Permeability*E-05, cm/sec	178.2596574	222.389792	121.7354	Avg. Perm: 174.1282832

County: <u>Sumner</u>	Test Date: <u>5/16/00</u>		
Project Number: <u>83002-4252-04</u>	Contractor: <u>Rogers Group</u>		
Mix Type: <u>411-S</u>	Design Pavt Thickness (cm): <u>3.324</u>		
Pvmt Temp. (°F) <u>68</u>	Water Temp. (°C) <u>26.7</u>		
Project location <u>State Rt. 6, Gallatin, (US 31)</u>			

Test #	C1	C2	C3	
Head at Beginning, cm	37.42746	49.02256	49.02256	
Head at End, cm	28.45872	38.87272	38.87272	
Tier	middle	top	top	Avg. Radius:
Test Time, sec	11.54	3.35	6.18	
Permeability*E-05, cm/sec	677.9594929	488.6424548	264.879	Avg. Perm: 477.1603161

County: <u>Sumner</u>	Test Date: <u>5/16/00</u>		
Project Number: <u>83002-4252-04</u>	Contractor: <u>Rogers Group</u>		
Mix Type: <u>411-S</u>	Design Pavt Thickness (cm): <u>4.177</u>		
Pvmt Temp. (°F) <u>68</u>	Water Temp. (°C) <u>26.7</u>		
Project location <u>State Rt. 6, Gallatin, (US 31)</u>			

Test #	L1	L2	L3	
Head at Beginning, cm	49.02256	49.02256	49.02256	
Head at End, cm	38.87272	38.87272	38.87272	
Tier	top	top	top	Avg. Radius:
Test Time, sec	6.39	7.17	8.82	
Permeability*E-05, cm/sec	321.9130673	286.8932357	233.22273	Avg. Perm: 280.6763451

Average Perm. For Sumner Co 411-S: 310.65 cm/sec x10⁻⁵

Grundy/Coffee County

County:	<u>Coffee/Grundy</u>	Test Date:	<u>5/15/00</u>
Project Number:	<u>1014</u>	Contractor:	<u>Rodgers Group</u>
Mix Type:	<u>411-S</u>	Design Pvmt Thickness (cm):	<u>3.375</u>
Pvmt Temp. (°F)	<u>98</u>	Water Temp. (°F)	<u>71.6</u>
Project location:	<u>I-24, Exit 127, 930 feet from exit sign 127</u>		
<u> </u>			
Test #	L1	L2	L3
Head at Beginning, cm	37.42746	37.42746	37.42746
Head at End, cm	28.45872	28.45872	28.45872
Tier	middle	middle	middle
Test Time, sec	7.63	8.573	6.183
Permeability*E-05, cm/sec	1160.510011	1032.857971	1432.1028
Avg. Radius:			
Avg. Perm: 1208.490248			

County:	<u>Coffee/Grundy</u>	Test Date:	<u>5/15/00</u>
Project Number:	<u>1014</u>	Contractor:	<u>Rodgers Group</u>
Mix Type:	<u>411-S</u>	Design Pvmt Thickness (cm):	<u>3.668</u>
Pvmt Temp. (°F)	<u>98</u>	Water Temp. (°F)	<u>71.6</u>
Project location:	<u>I-24, Exit 127, 930 feet from exit sign 127</u>		
Test #	C1	C2	C3
Head at Beginning, cm	37.42746	37.42746	37.42746
Head at End, cm	28.45872	28.45872	28.45872
Tier	middle	middle	middle
Test Time, sec	6.62	5.77	5.67
Permeability*E-05, cm/sec	1453.687277	1667.835316	1697.2504
Avg. Radius:			
Avg. Perm: 1606.257665			

County:	<u>Coffee/Grundy</u>	Test Date:	<u>5/15/00</u>
Project Number:	<u>1014</u>	Contractor:	<u>Rodgers Group</u>
Mix Type:	<u>411-S</u>	Design Pvmt Thickness (cm):	<u>3.224</u>
Pvmt Temp. (°F)	<u>98</u>	Water Temp. (°F)	<u>71.6</u>
Project location:	<u>I-24, Exit 127, 930 feet from exit sign 127</u>		
Test #	R1	R2	R3
Head at Beginning, cm	37.42746	37.42746	37.42746
Head at End, cm	28.45872	28.45872	28.45872
Tier	middle	middle	middle
Test Time, sec	6.567	7.001	5.517
Permeability*E-05, cm/sec	1288.035013	1208.188249	1533.1749
			Avg. Radius:
			Avg. Perm: 1343.132721

Average Perm. For Coffee/Grundy:

1385.96 cm/sec x10⁻⁵

Hamilton County

County: <u>Hamilton</u>	Test Date: <u>6/6/00</u>		
Project Number: <u>33006-8129-44</u>	Contractor: <u>Vulcan Construction Co</u>		
Mix Type: <u>411D</u>	Design Pvm Thickness (cm): <u>3.754</u>		
Pvmt Temp. (°F) <u>150</u>	Water Temp. (°C) <u>26.1</u>		
Project location: <u>I-24 East bound fast lane, 280 ft from mile marker 179.6 going east</u>			
Test #	L1	L2	L3
Head at Beginning, cm	49.02256	49.02256	49.02256
Head at End, cm	47.16	38.87272	38.87272
Tier	top	top	top
Test Time, sec	60	57.54	13.89
Permeability*E-05, cm/sec	5.210732663	32.54222568	134.80775
			Avg. Radius:
			Avg. Perm: 57.5

County: <u>Hamilton</u>	Test Date: <u>6/6/00</u>		
Project Number: <u>33006-8129-44</u>	Contractor: <u>Vulcan Construction Co</u>		
Mix Type: <u>411D</u>	Design Pvm Thickness (cm): <u>4.235</u>		
Pvmt Temp. (°F) <u>150</u>	Water Temp. (°C) <u>26.1</u>		
Project location: <u>I-24 East bound fast lane, 280 ft from mile marker 179.6 going east</u>			
Test #	C1	C2	C3
Head at Beginning, cm	49.02256	49.02256	49.02256
Head at End, cm	43.94256	43.94256	43.94256
Tier	top	top	top
Test Time, sec	11.67	14.49	26.12
Permeability*E-05, cm/sec	85.35846601	68.74625938	38.136803
			Avg. Radius:
			Avg. Perm: 64.1

County: <u>Hamilton</u>	Test Date: <u>6/6/00</u>		
Project Number: <u>33006-8129-44</u>	Contractor: <u>Vulcan Construction Co</u>		
Mix Type: <u>411D</u>	Design Pvm Thickness (cm): <u>4.305</u>		
Pvmt Temp. (°F) <u>150</u>	Water Temp. (°C) <u>26.1</u>		
Project location: <u>I-24 East bound fast lane, 280 ft from mile marker 179.6 going east</u>			
Test #	R1	R2	R3
Head at Beginning, cm	49.02256	49.02256	49.02256
Head at End, cm	46.89	46.8	46.4
Tier	top	top	top
Test Time, sec	60	60	60
Permeability*E-05, cm/sec	6.861306238	7.157693032	8.481901
			Avg. Radius:
			Avg. Perm: 7.5

Average Perm. For Hamilton:

43.03 cm/sec x10⁻⁵

Campbell County

County: <u>Campbell</u>	Test Date: <u>5/31/00</u>		
Project Number: <u>1010</u>	Contractor: <u>Tennessee Asphalt</u>		
Mix Type: <u>411-S</u>	Design Pvmnt Thickness (cm): <u>3.907</u>		
Pvmnt Temp. (°F) <u>140</u>	Water Temp. (°C) <u>26</u>		
Project location: <u>I-75 North bound fast lane, approximately 767ft south of mile marker 145</u>			
Test #	L1	L2	L3
Head at Beginning, cm	49.02256	49.02256	49.02256
Head at End, cm	49.02256	49.02256	48.26056
Tier	top	top	top
Test Time, sec	60	60	600
Permeability*E-05, cm/sec	0	0	0.2197981
			Avg. Radius: 0.073
			Avg. Perm: 0.073

County: <u>Campbell</u>	Test Date: <u>5/31/00</u>		
Project Number: <u>1010</u>	Contractor: <u>Tennessee Asphalt</u>		
Mix Type: <u>411-S</u>	Design Pvmnt Thickness (cm): <u>3.937</u>		
Pvmnt Temp. (°F) <u>140</u>	Water Temp. (°C) <u>26</u>		
Project location: <u>I-75 North bound fast lane, approximately 767ft south of mile marker 145</u>			
Test #	C1	C2	C3
Head at Beginning, cm	49.02256	49.02256	49.02256
Head at End, cm	44.95856	48.76856	48.26056
Tier	top	top	top
Test Time, sec	600	19.6	75.8
Permeability*E-05, cm/sec	1.223498659	2.248277669	1.7531856
			Avg. Radius: 1.742
			Avg. Perm: 1.742

County: <u>Campbell</u>	Test Date: <u>5/31/00</u>		
Project Number: <u>1010</u>	Contractor: <u>Tennessee Asphalt</u>		
Mix Type: <u>411-S</u>	Design Pvmnt Thickness (cm): <u>4.101</u>		
Pvmnt Temp. (°F) <u>140</u>	Water Temp. (°C) <u>26</u>		
Project location: <u>I-75 North bound fast lane, approximately 767ft south of mile marker 145</u>			
Test #	R1	R2	R3
Head at Beginning, cm	49.02256	49.02256	X
Head at End, cm	44.32356	38.87272	X
Tier	top	top	X
Test Time, sec	600	520.01	X
Permeability*E-05, cm/sec	1.483953426	3.755539624	X
			Avg. Radius: 2.620
			Avg. Perm: 2.620

Average Perm. For Campbell:

1.48 cm/sec x10⁻⁵

Hamblen County

County:	<u>Hamblen</u>	Test Date:	<u>8/22/00</u>
Project Number:	<u>32001-8121-44</u>	Contractor:	<u>Renfro Construction</u>
Mix Type:	<u>411-D</u>	Design Pvmnt Thickness (cm):	<u>4.18</u>
Pvmnt Temp. (°F)	<u>150</u>	Water Temp. (°C)	<u>27</u>
Project location:	<u>I-81, East bound fast lane, approximately one mile from exit 15 before bridge</u>		
Test #	L1	L2	L3
Head at Beginning, cm	48.96256	49.02256	49.02256
Head at End, cm	46.16856	45.83233	46.48256
Tier	top	top	top
Test Time, sec	60	60	60
Permeability*E-05, cm/sec	8.633615415	9.887581801	7.8176005
Avg. Radius: 2.25"			
Avg. Perm:			8.780

County:	<u>Hamblen</u>	Test Date:	<u>8/22/00</u>
Project Number:	<u>32001-8121-44</u>	Contractor:	<u>Renfro Construction</u>
Mix Type:	<u>411-D</u>	Design Pvmnt Thickness (cm):	<u>3.84</u>
Pvmnt Temp. (°F)	<u>150</u>	Water Temp. (°C)	<u>27</u>
Project location:	<u>I-81, East bound fast lane, approximately one mile from exit 15 before bridge</u>		
Test #	C1	C2	C3
Head at Beginning, cm	49.02256	49.02256	49.02256
Head at End, cm	46.42256	46.42256	46.42256
Tier	top	top	top
Test Time, sec	9.76	5.6	9.25
Permeability*E-05, cm/sec	45.2217579	78.81506376	47.715066
Avg. Radius: 2.25"			
Avg. Perm:			57.251

County:	<u>Hamblen</u>	Test Date:	<u>8/22/00</u>
Project Number:	<u>32001-8121-44</u>	Contractor:	<u>Renfro Construction</u>
Mix Type:	<u>411-D</u>	Design Pvmnt Thickness (cm):	<u>3.27</u>
Pvmnt Temp. (°F)	<u>150</u>	Water Temp. (°C)	<u>27</u>
Project location:	<u>I-81, East bound fast lane, approximately one mile from exit 15 before bridge</u>		

Test #	R1	R2	R3
Head at Beginning, cm	49.02256	49.02256	49.02256
Head at End, cm	46.42256	46.42256	38.81272
Tier	top	top	top
Test Time, sec	9.76	5.69	12.22
Permeability*E-05, cm/sec	38.50915321	66.05436473	131.80533

Avg. Radius: 2.25"

Avg. Perm: 78.790

Average Perm. For Hamblen:

48.27 cm/sec x10⁻⁵

Sullivan County

County Sullivan Test Date 11/1/99

Project Number 5405 Contractor Summers & Taylor

Mix Type 411-D Design Pvmnt Thickness 3.2

Water Temperature 66 °F

Project Location North of SR-34(11) in left most lane @ MP 5.3
2000 ft. South of Bridge

Test Location	1 R	1 L	1 C
Measured Nuclear Density	88.9 %	92 %	92 %
Head at Beginning, cm	26.78	26.78	26.78
Head at End, cm	17.68	17.68	17.68
Tier	Bottom	Bottom	Bottom
Test Time, sec	10.8	12.1	25.9
Permeability x 10 ⁻⁵ cm/sec	3301.45	2956.43	1375.53

Test Location	2 R	2 L	2 C
Measured Nuclear Density	89.9 %	89.6 %	93.3 %
Head at Beginning, cm	26.78	26.78	37.43
Head at End, cm	17.68	17.68	28.46
Tier	Bottom	Bottom	Middle
Test Time, sec	11.02	8.9	11.3
Permeability x 10 ⁻⁵ cm/sec	3235.52	4017.05	753.19

Test Location	3 R	3 L	3 C
Measured Nuclear Density	88.4 %	89 %	89 %
Head at Beginning, cm	26.78	26.78	26.78
Head at End, cm	17.68	17.68	17.68
Tier	Bottom	Bottom	Bottom
Test Time, sec	7.95	9.6	19.1
Permeability x 10 ⁻⁵ cm/sec	4481.72	3710.41	1870.45

Sullivan County

County	<u>Sullivan</u>	Test Date	<u>11/9/99</u>
Project Number	<u>5800</u>	Contractor	<u>Summers & Taylor</u>
Mix Type	<u>411-S</u>	Design Pvmt Thickness	<u>3.81</u>
Water Temperature	<u>72 °F</u>		
Project Location	<u>U.S. 19E & SR-37 @ MP 1.053 or 280 ft. North of MP 1</u>		

Test Location	1 R	1 L	1 C
Measured Nuclear Density	88.1 %	92.6 %	89.4 %
Head at Beginning, cm	37.43	49.02	49.02
Head at End, cm	28.46	43.94	38.87
Tier	Middle	Top	Top
Test Time, sec	8.19	18.6	10
Permeability x 10 ⁻⁵ cm/sec	1343.52	58.49	230.09

Test Location	2 R	2 L	2 C
Measured Nuclear Density	90.6 %	90.8 %	92.2 %
Head at Beginning, cm	37.43	49.02	49.02
Head at End, cm	28.46	38.87	38.87
Tier	Middle	Top	Top
Test Time, sec	15.24	10.4	12.3
Permeability x 10 ⁻⁵ cm/sec	722.15	222.32	187.81

Test Location	3 R	3 L	3 C
Measured Nuclear Density	88.2 %	89.9 %	89.2 %
Head at Beginning, cm	37.43	37.43	26.79
Head at End, cm	28.46	28.46	17.68
Tier	Middle	Middle	Bottom
Test Time, sec	8.13	10.3	22.3
Permeability x 10 ⁻⁵ cm/sec	1353.43	1069.77	2060.33

Hamilton County

County Hamilton Test Date 11/4/99

Project Number 5822 Contractor Vulcan Materials

Mix Type 411-S Design Pvmnt Thickness 3.2 cm

Water Temperature 62 °F

Project Location Approximately 1 mile South of SR-29 and Hwy 111 Split,
320 ft. North of SR-319 Overpass

Test Location	1 R	1 L	1 C
Measured Nuclear Density	94.1 %	91 %	91.9 %
Head at Beginning, cm	49.02	49.02	49.02
Head at End, cm	44.45	38.87	38.87
Tier	Top	Top	Top
Test Time, sec	60	21.5	9.07
Permeability x 10 ⁻⁵ cm/sec	11.86	78.42	185.93

Test Location	2 R	2 L	2 C
Measured Nuclear Density	93.7 %	92.8 %	90.3 %
Head at Beginning, cm	49.02	49.02	37.43
Head at End, cm	46.74	38.87	28.46
Tier	Top	Top	Middle
Test Time, sec	60	18.33	12.61
Permeability x 10 ⁻⁵ cm/sec	5.78	91.99	638.92

Test Location	3 R	3 L	3 C
Measured Nuclear Density	92.5 %	92.0 %	88.1 %
Head at Beginning, cm	49.02	49.02	49.02
Head at End, cm	46.48	46.1	28.48
Tier	Top	Top	Top
Test Time, sec	30	30	7.81
Permeability x 10 ⁻⁵ cm/sec	12.89	14.88	1032.04

Hamilton County

County Hamilton Test Date 11/5/99

Project Number 5621 Contractor Hillis Group

Mix Type 411-D Design Pvmnt Thickness 3.2 cm

Water Temperature 75 °F

Project Location South of SR-58 in Right Lane, 200 ft. South of Harrison Creek Almost Directly in Front of Post Office

Test Location	1 R	1 L	1 C
Measured Nuclear Density	92.6 %	87.2 %	95.7 %
Head at Beginning, cm	49.02	49.02	49.02
Head at End, cm	48.56	38.87	48.39
Tier	Top	Top	Top
Test Time, sec	60	21.5	9.07
Permeability x 10 ⁻⁵ cm/sec	1.38	93.66	12.48

Test Location	2 R	2 L	2 C
Measured Nuclear Density	91.3 %	87.2 %	94.0 %
Head at Beginning, cm	49.02	49.02	49.02
Head at End, cm	46.99	38.87	49.02
Tier	Top	Top	Top
Test Time, sec	60	9.92	60
Permeability x 10 ⁻⁵ cm/sec	6.12	202.97	0

Test Location	3 R	3 L	3 C
Measured Nuclear Density	89.5 %	84.3 %	93.4 %
Head at Beginning, cm	49.02	37.43	49.02
Head at End, cm	46.48	28.46	48.09
Tier	Top	Middle	Top
Test Time, sec	60	16.64	60
Permeability x 10 ⁻⁵ cm/sec	7.43	578.32	2.77

Davidson County

County	<u>Davidson</u>	Test Date	<u>10/16/99</u>
Project Number	<u>5114</u>	Contractor	<u>Rogers Group</u>
Mix Type	<u>411-D</u>	Design Pvmnt Thickness	<u>3.2 cm</u>
Water Temperature	<u>70 °F</u>		
Project Location	<u>South I-65 in Left Most Lane at MP 78.8</u>		

Test Location	1 R	1 L	1 C
Measured Nuclear Density	94.4 %	91.7 %	92.6 %
Head at Beginning, cm	49.02	49.02	49.02
Head at End, cm	48.13	45.69	45.02
Tier	Top	Top	Top
Test Time, sec	30	60	20.12
Permeability x 10 ⁻⁵ cm/sec	4.93	9.52	34.20

Test Location	2 R	2 L	2 C
Measured Nuclear Density	90.6 %	91.3 %	93.4 %
Head at Beginning, cm	49.02	49.02	49.02
Head at End, cm	46.44	47.50	43.94
Tier	Top	Top	Top
Test Time, sec	30	60	20.12
Permeability x 10 ⁻⁵ cm/sec	14.58	4.26	43.95

Test Location	3 R	3 L	3 C
Measured Nuclear Density	91.6 %	92.3 %	92.5 %
Head at Beginning, cm	49.02	49.02	49.02
Head at End, cm	46.69	46.40	46.27
Tier	Top	Top	Top
Test Time, sec	30	60	20.12
Permeability x 10 ⁻⁵ cm/sec	13.11	7.41	23.21

Smith County

County Smith Test Date 9/10/99

Project Number 5706 Contractor Rogers Group

Mix Type 411-S Design Pvmnt Thickness 3.81 cm

Water Temperature 82 °F

Project Location I-40 West (Smith County) at MP 262.19

Test Location	1 R	1 L	1 C
Measured Nuclear Density	91.1 %	92.5 %	92.0 %
Head at Beginning, cm	49.02	49.02	49.02
Head at End, cm	43.98	42.16	38.87
Tier	Top	Top	Top
Test Time, sec	30	60	20.12
Permeability x 10 ⁻⁵ cm/sec	40.93	28.44	130.56

Test Location	2 R	2 L	2 C
Measured Nuclear Density	95.9 %	93.1 %	91.4 %
Head at Beginning, cm	49.02	49.02	49.02
Head at End, cm	46.99	45.64	38.87
Tier	Bottom	Bottom	Middle
Test Time, sec	60	30	21.82
Permeability x 10 ⁻⁵ cm/sec	7.99	27.02	120.42

Test Location	3 R	3 L	3 C
Measured Nuclear Density	93.2 %	91.4 %	92.2 %
Head at Beginning, cm	49.02	49.02	49.02
Head at End, cm	46.48	45.59	38.87
Tier	Top	Top	Top
Test Time, sec	30	30	12.39
Permeability x 10 ⁻⁵ cm/sec	20.08	27.37	212.04

Fayette County

County Fayette Test Date 9/10/99

Project Number 5616 Contractor Lehman-Roberts

Mix Type 411-D Design Pvmt Thickness 3.2 cm

Water Temperature 80 °F

Project Location 160 ft East of First Bridge

Test Location	1 R	1 L	1 C
Measured Nuclear Density	95.9 %	93.8 %	94.9
Head at Beginning, cm	49.32	49.32	49.32
Head at End, cm	49.32	49.32	49.20
Tier	Top	Top	Top
Test Time, sec	60	60	60
Permeability x 10 ⁻⁵ cm/sec	0	0	0.39

Test Location	2 R	2 L	2 C
Measured Nuclear Density	92.9 %	94.4 %	93.7 %
Head at Beginning, cm	49.32	49.32	49.32
Head at End, cm	46.53	49.32	48.77
Tier	Top	Top	Top
Test Time, sec	30	60	60
Permeability x 10 ⁻⁵ cm/sec	17.72	0	1.70

Test Location	3 R	3 L	3 C
Measured Nuclear Density	91.8 %	94.8 %	94.6 %
Head at Beginning, cm	49.32	49.32	49.32
Head at End, cm	45.09	49.24	49.32
Tier	Top	Top	Top
Test Time, sec	60	60	60
Permeability x 10 ⁻⁵ cm/sec	13.63	0.26	0

Fayette County

County Fayette Test Date 9/10/99
 Project Number 5706 Contractor Lehman-Roberts
 Mix Type 411-S Design Pvmnt Thickness 3.2 cm
 Water Temperature 80 °F
 Project Location Station 93+74

Test Location	1 R	1 L	1 C
Measured Nuclear Density		91.0 %	
Head at Beginning, cm	49.32	49.32	49.32
Head at End, cm	39.17	47.25	39.17
Tier	Top	Top	Top
Test Time, sec	12.67	60	13
Permeability x 10 ⁻⁵ cm/sec	165.80	6.53	161.55

Test Location	2 R	2 L	2 C
Measured Nuclear Density		94.5 %	
Head at Beginning, cm	49.32	49.32	49.32
Head at End, cm	43.40	47.50	39.17
Tier	Top	Top	Top
Test Time, sec	20	60	26.67
Permeability x 10 ⁻⁵ cm/sec	58.34	5.71	78.76

Test Location	3 R	3 L	3 C
Measured Nuclear Density		91.6 %	
Head at Beginning, cm	49.32	49.32	49.32
Head at End, cm	46.19	46.02	45.51
Tier	Top	Top	Top
Test Time, sec	60	35.33	31.66
Permeability x 10 ⁻⁵ cm/sec	9.97	17.88	23.14

Appendix E

Laboratory Permeability Test Data

County	<u>Davidson</u>
Mix Type	<u>411-D</u>
Date	<u>5/26/00</u>
Lab Tech.	<u>Dexter</u>

$$\% SAT = \left(\frac{SSD * M}{M \left(\frac{1}{G_{mb}} * \frac{1}{G_{mm}} \right)} \right) * 100$$

	Core #1	Core #2	Core #3
SSD (grams)	<u>1178.5</u>	<u>1080.1</u>	<u>1154.6</u>
M (grams)	<u>1144</u>	<u>1054.1</u>	<u>1121.1</u>
G _{mb}	<u>2.259</u>	<u>2.288</u>	<u>2.258</u>
G _{mm}	<u>2.429</u>	<u>2.429</u>	<u>2.429</u>
% Saturation	<u>97.34</u>	<u>97.2</u>	<u>95.8</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>245.8</u>	<u>286.5</u>	<u>283.3</u>
W _f (cm ³)	<u>247.5</u>	<u>288.8</u>	<u>284.5</u>
β	<u>99.3</u>	<u>99.2</u>	<u>99.5</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>3.16</u>	<u>2.83</u>	<u>3.09</u>
A (cm ²)	<u>164.1</u>	<u>165.2</u>	<u>163.36</u>
t (s)	<u>265.36</u>	<u>597.5</u>	<u>273.97</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>10</u>	<u>10</u>	<u>10</u>
k (*10 ⁻⁵ (cm/s))	<u>63.6</u>	<u>25.1</u>	<u>60.5</u>

County	<u>Davidson</u>
Mix Type	<u>411-D</u>
Date	<u>5/26/00</u>
Lab Tech.	<u>Dexter</u>

$$\% SAT = \left(\frac{SSD * M}{M \left(\frac{1}{G_{mb}} * \frac{1}{G_{mm}} \right)} \right) * 100$$

	Core #1	Core #2	Core #3
SSD (grams)	<u>1178.5</u>	<u>1080.1</u>	<u>1154.6</u>
M (grams)	<u>1144</u>	<u>1054.1</u>	<u>1121.1</u>
G _{mb}	<u>2.259</u>	<u>2.288</u>	<u>2.258</u>
G _{mm}	<u>2.429</u>	<u>2.429</u>	<u>2.429</u>
% Saturation	<u>97.34</u>	<u>97.2</u>	<u>95.8</u>

$$\beta = \left(\frac{W_l}{W_f} \right) * 100$$

W _l (grams)	<u>245.8</u>	<u>286.5</u>	<u>283.3</u>
W _f (cm ³)	<u>247.5</u>	<u>288.8</u>	<u>284.5</u>
β	<u>99.3</u>	<u>99.2</u>	<u>99.5</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>3.16</u>	<u>2.83</u>	<u>3.09</u>
A (cm ²)	<u>164.1</u>	<u>165.2</u>	<u>163.36</u>
t (s)	<u>265.36</u>	<u>597.5</u>	<u>273.97</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>10</u>	<u>10</u>	<u>10</u>
k (*10 ⁻⁵ (cm/s))	<u>63.6</u>	<u>25.1</u>	<u>60.5</u>

County	<u>Fayette</u>
Mix Type	<u>411-D</u>
Date	<u>6/6/00</u>
Lab Tech.	<u>Dexter</u>

$$\% SAT = \left(\frac{SSD * M}{M \left(\frac{1}{G_{mb}} * \frac{1}{G_{mm}} \right)} \right) * 100$$

	Core #1	Core #2	Core #3
SSD (grams)	<u>1296.1</u>	<u>1521</u>	<u>1370.5</u>
M (grams)	<u>1270.9</u>	<u>1498.8</u>	<u>1353.9</u>
G _{mb}	<u>2.260</u>	<u>2.260</u>	<u>2.272</u>
G _{mm}	<u>2.370</u>	<u>2.370</u>	<u>2.370</u>
% Saturation	<u>96.5</u>	<u>72.1</u>	<u>67.4</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>N/A</u>	<u>N/A</u>	<u>N/A</u>
W _f (cm ³)	<u>N/A</u>	<u>N/A</u>	<u>N/A</u>
β	<u>N/A</u>	<u>N/A</u>	<u>N/A</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>3.489</u>	<u>4.079</u>	<u>3.68</u>
A (cm ²)	<u>163.2</u>	<u>164.6</u>	<u>163.9</u>
t (s)	<u>900</u>	<u>900</u>	<u>900</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
k (*10 ⁻⁵ (cm/s))	<u>0</u>	<u>0</u>	<u>0</u>

County	<u>Sullivan</u>
Mix Type	<u>411-D</u>
Date	<u>6/26/00</u>
Lab Tech.	<u>Dexter</u>

$$\% SAT = \left(\frac{SSD * M}{M \left(\frac{1}{G_{mb}} * \frac{1}{G_{mm}} \right)} \right) * 100$$

	Core #1	Core #2	Core #3
SSD (grams)	<u>985.3</u>	<u>859</u>	<u>1012.9</u>
M (grams)	<u>929.6</u>	<u>810.8</u>	<u>953.6</u>
G _{mb}	<u>2.147</u>	<u>2.141</u>	<u>2.133</u>
G _{mm}	<u>2.470</u>	<u>2.470</u>	<u>2.470</u>
% Saturation	<u>98.38</u>	<u>95.55</u>	<u>97.2</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>251.4</u>	<u>277.7</u>	<u>271.6</u>
W _f (cm ³)	<u>251.4</u>	<u>2785</u>	<u>276.1</u>
β	<u>100</u>	<u>99.7</u>	<u>98.3</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>2.798</u>	<u>2.595</u>	<u>3.118</u>
A (cm ²)	<u>165.13</u>	<u>156.59</u>	<u>155.7</u>
t (s)	<u>7.29</u>	<u>7.74</u>	<u>6.22</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>10</u>	<u>10</u>	<u>10</u>
k (*10 ⁻⁵ (cm/s))	<u>2037.96</u>	<u>1877.3</u>	<u>2822.92</u>

County	<u>Sullivan</u>
Mix Type	<u>411-S</u>
Date	<u>6/22/00</u>
Lab Tech.	<u>Preston</u>

$$\% SAT = \left(\frac{SSD * M}{M \left(\frac{1}{G_{mb}} * \frac{1}{G_{mm}} \right)} \right) * 100$$

	Core #1	Core #2	Core #3
SSD (grams)	<u>1363.5</u>	<u>1201.7</u>	<u>1406.8</u>
M (grams)	<u>1307.5</u>	<u>1158.5</u>	<u>1337.5</u>
G _{mb}	<u>2.222</u>	<u>2.260</u>	<u>2.195</u>
G _{mm}	<u>2.468</u>	<u>2.468</u>	<u>2.468</u>
% Saturation	<u>95.5</u>	<u>100</u>	<u>102.8</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>295.3</u>	<u>243.6</u>	<u>246.3</u>
W _f (cm ³)	<u>296.4</u>	<u>245</u>	<u>244.2</u>
β	<u>99.6</u>	<u>99.4</u>	<u>100.9</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>3.822</u>	<u>3.269</u>	<u>4.008</u>
A (cm ²)	<u>167.3</u>	<u>166.6</u>	<u>163.2</u>
t (s)	<u>18.21</u>	<u>36.98</u>	<u>7.74</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>10</u>	<u>10</u>	<u>10</u>
k (*10 ⁻⁵ (cm/s))	<u>1099.9</u>	<u>465.24</u>	<u>2782.1</u>

County	<u>Smith</u>
Mix Type	<u>411-S</u>
Date	<u>5/25/00</u>
Lab Tech.	<u>Dexter</u>

$$\% SAT = \left(\frac{SSD * M}{M \left(\frac{1}{G_{mb}} * \frac{1}{G_{mm}} \right)} \right) * 100$$

	Core #1	Core #2	Core #3
SSD (grams)	<u>1447.1</u>	<u>1419.6</u>	<u>1380.2</u>
M (grams)	<u>1398</u>	<u>1370.7</u>	<u>1330.2</u>
G _{mb}	<u>2.265</u>	<u>2.268</u>	<u>2.262</u>
G _{mm}	<u>2.481</u>	<u>2.481</u>	<u>2.481</u>
% Saturation	<u>91.4</u>	<u>94.3</u>	<u>96.32</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>266.1</u>	<u>273.6</u>	<u>221.1</u>
W _f (cm ³)	<u>266.6</u>	<u>273.7</u>	<u>221.5</u>
β	<u>99.8</u>	<u>99.9</u>	<u>99.8</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>3.985</u>	<u>3.843</u>	<u>3.712</u>
A (cm ²)	<u>162.6</u>	<u>161.5</u>	<u>161.6</u>
t (s)	<u>88.36</u>	<u>30.3</u>	<u>54.76</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>10</u>	<u>10</u>	<u>10</u>
k (*10 ⁻⁵ (cm/s))	<u>243.9</u>	<u>688.6</u>	<u>367.8</u>

County	<u>Fayette</u>
Mix Type	<u>411-S</u>
Date	<u>6/2/00</u>
Lab Tech.	<u>Dexter</u>

$$\% SAT = \left(\frac{SSD * M}{M \left(\frac{1}{G_{mb}} * \frac{1}{G_{mm}} \right)} \right) * 100$$

	Core #1	Core #2	Core #3
SSD (grams)	<u>1202.4</u>	<u>1543.7</u>	<u>1399.1</u>
M (grams)	<u>1159.5</u>	<u>1502.6</u>	<u>1349.6</u>
G _{mb}	<u>2.211</u>	<u>2.261</u>	<u>2.220</u>
G _{mm}	<u>2.418</u>	<u>2.418</u>	<u>2.418</u>
% Saturation	<u>95.6</u>	<u>95.3</u>	<u>99.3</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>309.6</u>	<u>N/A</u>	<u>298.4</u>
W _f (cm ³)	<u>320.5</u>	<u>N/A</u>	<u>299.3</u>
β	<u>96.6</u>	<u>N/A</u>	<u>99.7</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>3.294</u>	<u>4.171</u>	<u>3.687</u>
A (cm ²)	<u>163.9</u>	<u>163.7</u>	<u>164.6</u>
t (s)	<u>155.5</u>	<u>600</u>	<u>143.2</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>10</u>	<u>30</u>	<u>10</u>
k (*10 ⁻⁵ (cm/s))	<u>113.3</u>	<u>0</u>	<u>137.2</u>

County	<u>Hamilton</u>
Mix Type	<u>411-S</u>
Date	<u>6/16/00</u>
Lab Tech.	<u>Preston</u>

$$\% SAT = \left(\frac{SSD * M}{M \left(\frac{1}{G_{mb}} * \frac{1}{G_{mm}} \right)} \right) * 100$$

	Core #1	Core #2	Core #3
SSD (grams)	<u>908.3</u>	<u>1031.3</u>	<u>983.6</u>
M (grams)	<u>861.5</u>	<u>964.7</u>	<u>909.7</u>
G _{mb}	<u>2.082</u>	<u>2.005</u>	<u>1.985</u>
G _{mm}	<u>2.346</u>	<u>2.346</u>	<u>2.346</u>
% Saturation	<u>100.5</u>	<u>95.2</u>	<u>104.8</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>317.9</u>	<u>293.7</u>	<u>217.79</u>
W _f (cm ³)	<u>316.85</u>	<u>302.7</u>	<u>236.3</u>
β	<u>100.3</u>	<u>97</u>	<u>92.2</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>2.644</u>	<u>3.144</u>	<u>2.923</u>
A (cm ²)	<u>163.6</u>	<u>164.1</u>	<u>165.1</u>
t (s)	<u>32.13</u>	<u>8.52</u>	<u>6.67</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>10</u>	<u>10</u>	<u>10</u>
k (*10 ⁻⁵ (cm/s))	<u>441.3</u>	<u>1971.7</u>	<u>2301.1</u>

County Hamblen

Mix Type 411-D

Date 11/13/00

Lab Tech. Dexter

$$\% SAT = \frac{SSD * M}{M \left(\frac{1}{G_{mb}} * \frac{1}{G_{mm}} \right)} * 100$$

	Core L	Core C	Core R
SSD (grams)	<u>1374.1</u>	<u>1177.5</u>	<u>953</u>
M (grams)	<u>1325.5</u>	<u>1132</u>	<u>911.8</u>
G _{mb}	<u>2.216</u>	<u>2.177</u>	<u>2.163</u>
G _{mm}	<u>2.455</u>	<u>2.455</u>	<u>2.455</u>
% Saturation	<u>83.4</u>	<u>77.2</u>	<u>82.2</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>323.2</u>	<u>343.2</u>	<u>223.5</u>
W _f (cm ³)	<u>332.6</u>	<u>344.8</u>	<u>224</u>
β	<u>97.2</u>	<u>99.5</u>	<u>99.8</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>3.7</u>	<u>3.2</u>	<u>2.66</u>
A (cm ²)	<u>164.4</u>	<u>165.6</u>	<u>164.5</u>
t (s)	<u>381.5</u>	<u>94.06</u>	<u>35.93</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>10</u>	<u>10</u>	<u>10</u>
k (*10 ⁻⁵ (cm/s))	<u>51.7</u>	<u>180.2</u>	<u>394.6</u>

County Hamilton

Mix Type 411-D

Date 7/15/00

Lab Tech. Preston

$$\% SAT = \left(\frac{SSD * M}{M \left(\frac{1}{G_{mb}} * \frac{1}{G_{mm}} \right)} \right) * 100$$

	Core L	Core C	Core R
SSD (grams)	<u>1328.1</u>	<u>1444.2</u>	<u>1538.6</u>
M (grams)	<u>1265.5</u>	<u>1386.1</u>	<u>1486.1</u>
G _{mb}	<u>2.073</u>	<u>2.102</u>	<u>2.138</u>
G _{mm}	<u>2.305</u>	<u>2.305</u>	<u>2.305</u>
% Saturation	<u>102.37</u>	<u>96.4</u>	<u>104.3</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>303.9</u>	<u>332.8</u>	<u>327.3</u>
W _f (cm ³)	<u>304.07</u>	<u>330.4</u>	<u>318.44</u>
β	<u>99.9</u>	<u>100</u>	<u>102.8</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>3.754</u>	<u>4.235</u>	<u>4.305</u>
A (cm ²)	<u>165.67</u>	<u>165.44</u>	<u>165</u>
t (s)	<u>94.14</u>	<u>85.54</u>	<u>690.22</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>10</u>	<u>10</u>	<u>10</u>
k (*10 ⁻⁵ (cm/s))	<u>211.05</u>	<u>78.6</u>	<u>33.14</u>

County Haywood

Mix Type 411-D

Date 6/1/00

Lab Tech. Dexter

$$\% SAT = \frac{SSD * M}{M \left(\frac{1}{G_{mb}} * \frac{1}{G_{mm}} \right)} * 100$$

	Core L	Core C	Core R
SSD (grams)	<u>1469.1</u>	<u>1350.7</u>	<u>1155</u>
M (grams)	<u>1396.5</u>	<u>1275.5</u>	<u>1079.7</u>
G _{mb}	<u>2.079</u>	<u>2.055</u>	<u>2.005</u>
G _{mm}	<u>2.343</u>	<u>2.343</u>	<u>2.468</u>
% Saturation	<u>95.9</u>	<u>98.6</u>	<u>96.9</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>290.5</u>	<u>280.9</u>	<u>300.88</u>
W _f (cm ³)	<u>290.5</u>	<u>281.6</u>	<u>301.8</u>
β	<u>100</u>	<u>99.7</u>	<u>99.6</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>4.213</u>	<u>3.909</u>	<u>3.449</u>
A (cm ²)	<u>163.5</u>	<u>164.5</u>	<u>163.6</u>
t (s)	<u>267.5</u>	<u>32.72</u>	<u>11.06</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>10</u>	<u>10</u>	<u>10</u>
k (*10 ⁻⁵ (cm/s))	<u>844.6</u>	<u>636.9</u>	<u>1671.3</u>

County Madison

Mix Type 411-D

Date 7/6/00

Lab Tech. Dexter

$$\% SAT = \left(\frac{SSD * M}{M \left(\frac{1}{G_{mb}} + \frac{1}{G_{mm}} \right)} \right) * 100$$

	Core L	Core C	Core R
SSD (grams)	<u>968.1</u>	<u>970.4</u>	<u>1518.6</u>
M (grams)	<u>935.5</u>	<u>951</u>	<u>1500.3</u>
G _{mb}	<u>2.181</u>	<u>2.119</u>	<u>2.264</u>
G _{mm}	<u>2.37</u>	<u>2.37</u>	<u>2.37</u>
% Saturation	<u>95.31</u>	<u>40.82</u>	<u>61.7</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>308.8</u>	<u>224.6</u>	<u>No Flow</u>
W _f (cm ³)	<u>300.09</u>	<u>220.2</u>	<u>No Flow</u>
β	<u>102.9</u>	<u>101.96</u>	<u>No Flow</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>2.888</u>	<u>2.788</u>	<u>4.252</u>
A (cm ²)	<u>165.7</u>	<u>162.52</u>	<u>161.51</u>
t (s)	<u>2191.81</u>	<u>102.91</u>	<u>No Flow</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>10</u>	<u>10</u>	<u>10</u>
k (*10 ⁻⁵ (cm/s))	<u>5.815</u>	<u>146.16</u>	<u>No Flow</u>

County Dickson

Mix Type 411-D

Date 7/6/00

Lab Tech. Dexter

$$\% SAT = \left(\frac{SSD * M}{M \left(\frac{1}{G_{mb}} * \frac{1}{G_{mm}} \right)} \right) * 100$$

	Core L	Core C	Core R
SSD (grams)	<u>1393.5</u>	<u>1473.1</u>	<u>1527.6</u>
M (grams)	<u>1325.7</u>	<u>1417.1</u>	<u>1468.8</u>
G _{mb}	<u>2.131</u>	<u>2.193</u>	<u>2.179</u>
G _{mm}	<u>2.446</u>	<u>2.446</u>	<u>2.446</u>
% Saturation	<u>84.63</u>	<u>83.8</u>	<u>79.9</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>282.5</u>	<u>298.5</u>	<u>318.4</u>
W _t (cm ³)	<u>282.53</u>	<u>302.5</u>	<u>319</u>
β	<u>99.9</u>	<u>98.7</u>	<u>99.8</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>3.883</u>	<u>4.024</u>	<u>4.184</u>
A (cm ²)	<u>166.47</u>	<u>166.08</u>	<u>165.97</u>
t (s)	<u>25.3</u>	<u>112.93</u>	<u>57.49</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>10</u>	<u>10</u>	<u>10</u>
k (*10 ⁻⁵ (cm/s))	<u>808.37</u>	<u>188.12</u>	<u>384.48</u>

County Madison

Mix Type 411-S

Date 7/24/00

Lab Tech. Preston

$$\% SAT = \left(\frac{SSD * M}{M \left(\frac{1}{G_{mb}} + \frac{1}{G_{mm}} \right)} \right) * 100$$

	Core L	Core C	Core R
SSD (grams)	<u>1489.6</u>	<u>1344.5</u>	<u>1218.9</u>
M (grams)	<u>1424.9</u>	<u>1280.2</u>	<u>1149.2</u>
G _{mb}	<u>2.14</u>	<u>2.108</u>	<u>2.055</u>
G _{mm}	<u>2.363</u>	<u>2.363</u>	<u>2.363</u>
% Saturation	<u>102.96</u>	<u>98.11</u>	<u>95.62</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>238.7</u>	<u>247.8</u>	<u>276.5</u>
W _f (cm ³)	<u>236.24</u>	<u>246.61</u>	<u>276.14</u>
β	<u>101.04</u>	<u>100.4</u>	<u>100.1</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>4.297</u>	<u>3.857</u>	<u>3.554</u>
A (cm ²)	<u>165.175</u>	<u>166.271</u>	<u>167.225</u>
t (s)	<u>57.74</u>	<u>46.6</u>	<u>14.85</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>10</u>	<u>10</u>	<u>10</u>
k (*10 ⁻⁵ (cm/s))	<u>395</u>	<u>436.46</u>	<u>1254.62</u>

County Sumner

Mix Type 411-S

Date 7/16/00

Lab Tech. Preston

$$\% SAT = \left(\frac{SSD * M}{M \left(\frac{1}{G_{mb}} * \frac{1}{G_{mm}} \right)} \right) * 100$$

	Core L	Core C	Core R
SSD (grams)	<u>1310.3</u>	<u>1197.2</u>	<u>1557</u>
M (grams)	<u>1243.1</u>	<u>1143.9</u>	<u>1498.9</u>
G _{mb}	<u>2.175</u>	<u>2.208</u>	<u>2.252</u>
G _{mm}	<u>2.442</u>	<u>2.442</u>	<u>2.442</u>
% Saturation	<u>107.54</u>	<u>107.3</u>	<u>112.39</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>243.1</u>	<u>276.3</u>	<u>269.6</u>
W _t (cm ³)	<u>243.42</u>	<u>275.34</u>	<u>267.36</u>
β	<u>99.87</u>	<u>100.3</u>	<u>100.8</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>3.703</u>	<u>3.3235</u>	<u>4.177</u>
A (cm ²)	<u>166.82</u>	<u>166.43</u>	<u>165.29</u>
t (s)	<u>7.297</u>	<u>13.517</u>	<u>48.903</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>10</u>	<u>10</u>	<u>10</u>
k (*10 ⁻⁵ (cm/s))	<u>2667.25</u>	<u>1394.96</u>	<u>453.09</u>

County Coffee/Grundy

Mix Type 411-S

Date 7/6/00

Lab Tech. Dexter

$$\% SAT = \left(\frac{SSD * M}{M \left(\frac{1}{G_{mb}} * \frac{1}{G_{mm}} \right)} \right) * 100$$

	Core L	Core C	Core R
SSD (grams)	<u>1179.6</u>	<u>1256.3</u>	<u>1159.9</u>
M (grams)	<u>1118</u>	<u>1184.3</u>	<u>1100.5</u>
G _{mb}	<u>2.162</u>	<u>2.141</u>	<u>2.177</u>
G _{mm}	<u>2.468</u>	<u>2.468</u>	<u>2.468</u>
% Saturation	<u>96.1</u>	<u>98.2</u>	<u>99.7</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>280.7</u>	<u>363.4</u>	<u>324</u>
W _f (cm ³)	<u>280.93</u>	<u>366.32</u>	<u>324.2</u>
β	<u>99.9</u>	<u>99.200</u>	<u>99.9</u>

$$k = \left(\frac{\alpha * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>3.375</u>	<u>3.668</u>	<u>3.224</u>
A (cm ²)	<u>166.2</u>	<u>167.38</u>	<u>167.47</u>
t (s)	<u>7.68</u>	<u>4.28</u>	<u>3.09</u>
h ₁ (cm)	<u>30</u>	<u>30</u>	<u>30</u>
h ₂ (cm)	<u>10</u>	<u>10</u>	<u>10</u>
k (*10 ⁻⁵ (cm/s))	<u>2318.4</u>	<u>4489.35</u>	<u>5462.62</u>

County Campbell

Mix Type 411-S

Date 7/4/00

Lab Tech. Dexter

$$\% SAT = \left(\frac{SSD * M}{M \left(\frac{1}{G_{mb}} * \frac{1}{G_{mm}} \right)} \right) * 100$$

	Core L	Core C	Core R
SSD (grams)	<u>1520.2</u>	<u>1518.6</u>	<u>1602.2</u>
M (grams)	<u>1489.4</u>	<u>1479.8</u>	<u>1567.8</u>
G _{mb}	<u>2.327</u>	<u>2.318</u>	<u>2.333</u>
G _{mm}	<u>2.479</u>	<u>2.479</u>	<u>2.479</u>
% Saturation	<u>78.5</u>	<u>93.51</u>	<u>86.9</u>

$$\beta = \left(\frac{W_t}{W_f} \right) * 100$$

W _t (grams)	<u>No Flow</u>	<u>250.3</u>	<u>23.5</u>
W _f (cm ³)	<u>No Flow</u>	<u>259.38</u>	<u>24.74</u>
β	<u>No Flow</u>	<u>96.49</u>	<u>94.99</u>

$$k = \left(\frac{a * l}{A * t} \right) \ln \left(\frac{h_1}{h_2} \right)$$

a (cm ²)	<u>7.981</u>	<u>7.981</u>	<u>7.981</u>
l (cm)	<u>3.907</u>	<u>3.937</u>	<u>4.101</u>
A (cm ²)	<u>165.46</u>	<u>166.18</u>	<u>166.02</u>
t (s)	<u>600</u>	<u>2711.25</u>	<u>600</u>
h ₁ (cm)	<u>No Flow</u>	<u>30</u>	<u>32.9</u>
h ₂ (cm)	<u>No Flow</u>	<u>10</u>	<u>29.8</u>
k (*10 ⁻⁵ (cm/s))	<u>No Flow</u>	<u>7.66</u>	<u>3.25</u>

VITA

Thomas Dexter Justis was born in Morristown, Tennessee on November 18, 1976. He attended schools in the Hamblen County, Tennessee Public School System, where he graduated from Morristown Hamblen High School East in May, 1995.

Thomas began his college career in the fall of 1995 at the University of Tennessee, Knoxville majoring in Civil Engineering. Upon graduation with a Bachelor of Science in Civil and Environmental Engineering from the University of Tennessee, he was awarded a graduate research assistantship to pursue a Master of Science in Civil Engineering, also at the University of Tennessee, Knoxville.

After graduating in May, 2001, Thomas has taken employment with the Tennessee Department of Transportation in Greeneville, Tennessee as a construction engineer.