BURNS COOLEY DENNIS, INC.

GEOTECHNICAL AND MATERIALS ENGINEERING CONSULTANTS

Aggregate Absorption in HMA Mixtures

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Prepared by
L. Allen Cooley, Jr., Ph.D.
Kevin Williams, P.E.

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16. Abstract:

Designing hot mix asphalt (HMA) that will perform for many years is a complex balancing act of selecting an appropriate design asphalt binder content that is sufficiently high to provide durability but not so high as to lead to rutting problems. One of the factors that has to be considered during the design of HMA is the absorption of asphalt by aggregates. Most all aggregates used in the production of HMA have some absorptive characteristics. The objective of this project was to evaluate asphalt absorption through the production and construction process. In order to accomplish this objective, six on-going HMA construction projects were visited and HMA sampled. The HMA was sampled from four locations through the production and construction process, including: the slat conveyor prior to the mix being placed in the silo, trucks prior to transportation, the paver, and the compacted HMA layer (cores). Laboratory testing was conducted on these samples to evaluate the amount of asphalt that was absorbed by the aggregates throughout the production and construction process.

Based upon the results of testing, it was concluded that asphalt absorption continues from the production process through the construction process. Sample obtained from the slat conveyor and the truck had similar average asphalt absorption values, while the paver and core samples also had similar average asphalt absorption values. However, the asphalt absorption at the paver and core locations were significantly higher than the other two. This suggested that most of the absorption took place during mix transportation to the job site. It was attempted to compare the amount of asphalt absorption that took place during mix design (based upon the job mix formula) to the amount of asphalt absorption that took place during the production and construction process; however, this attempt was not successful. Generally, the amount of asphalt absorption in the field was much higher than that shown on the job mix formulas.

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CHAPTER 1 - INTRODUCTION

1.1 Introduction and Objectives

Designing hot mix asphalt (HMA) that will perform for many years is a complex balancing act of selecting an appropriate design asphalt binder content that is sufficiently high to provide durability but not so high as to lead to rutting problems. There are a number of items that can affect the selection of an appropriate design asphalt binder content, including: design compactive effort, gradation shape, nominal maximum aggregate size, aggregate shape characteristics and aggregate absorption. Most of these issues have been evaluated within Mississippi; however, the influence of aggregate absorption has not.

When asphalt binder is heated during the production process, the viscosity of the binder is greatly reduced, becoming fluid. Absorptive aggregates will pull the fluid asphalt into the pores of the aggregate, which is called asphalt absorption. Asphalt binder that is absorbed into the aggregates does not contribute to the durability characteristics of the produced HMA. Therefore, properly accounting for the absorption characteristics of the aggregates is vital to preventing premature cracking of HMA pavements.

Figures 1 through 3 illustrate the impact that asphalt absorption has on the volumetric properties of HMA. These three figures present the difference in material and volumetric properties between split samples of plant-produced material that have been oven aged for one hour and four hours. A total of five samples are presented within each of the figures. Four of the five samples were obtained from a single project, just different days. For this project, gravels were predominately utilized within the mixture. However, there was 20 percent limestone (#89's) within this mixture. For Sample 5, only gravel (and coarse sand) was utilized except for 15 percent RAP. For all five samples, a neat PG 67-22 asphalt binder was used in the mix.

Figure 1 presents the difference in theoretical maximum density between the split samples after one and four hours oven aging. As can be seen in the figure, the theoretical maximum density increased in each instance when the split sample was aged for four hours. The only explanation for this consistent increase in TMD is that asphalt was absorbed into the aggregates during the extra aging time.

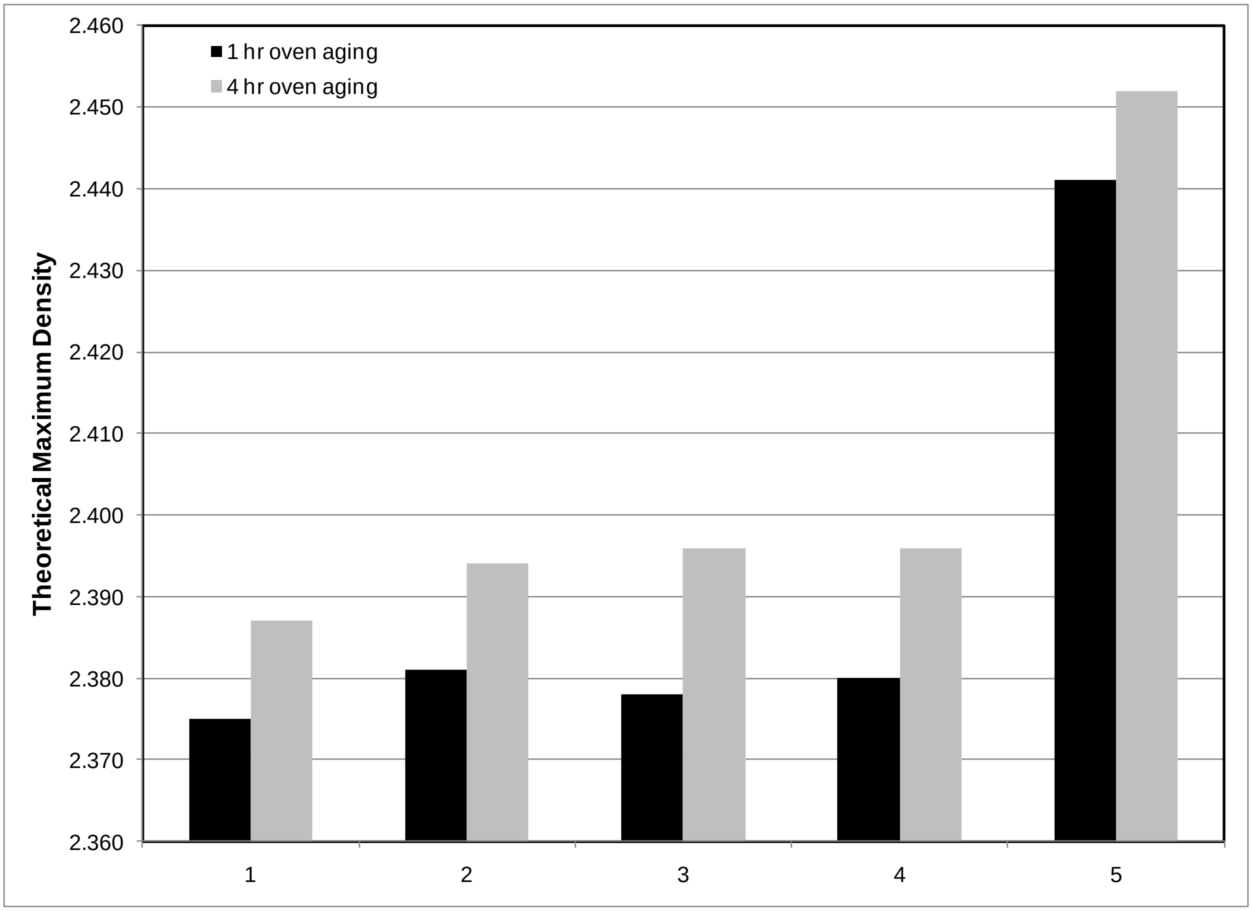

Figure 1: Effect of Aging Time on Theoretical Maximum Density

Figure 2 illustrates the effect of aging time on asphalt absorption. The trend of the data is that the amount of asphalt absorbed by the aggregates increases as the aging time increases. Figure 2 seems to verify the differences in TMD values shown within Figure 1.

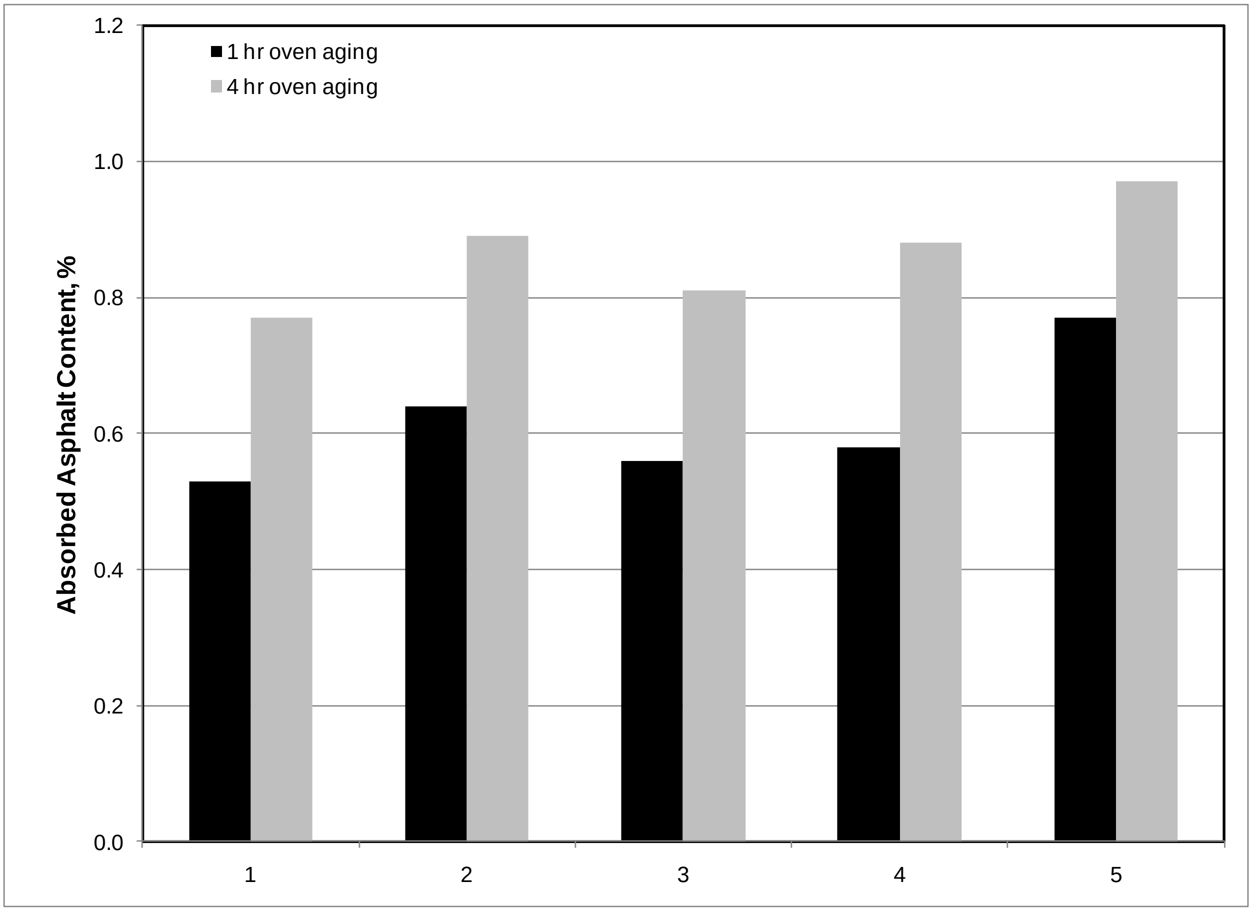

Figure 2: Influence of Aging Time on Absorbed Asphalt Content

Figure 3 illustrates the influence of aging time on air void contents of laboratory compacted samples. It should be stated here that the two data points do reflect true split samples in that samples were compacted for both aging times. Similar to Figures 1 and 2, the trend in the data is increasing air void contents as oven aging time increased. In some instances, the difference between the two split samples was more than 1 percent air voids.

The significance of Figures 1 through 3 is that asphalt binder within plant produced mixture absorbs for extended periods of time. The question that must be asked is how long the absorption takes place in the field. If the amount of absorbed asphalt is not accurately taken into account during mix design or QC/QA operations, MDOT may be getting under asphalted mixtures. Under asphalted mixtures will lead to premature cracking.

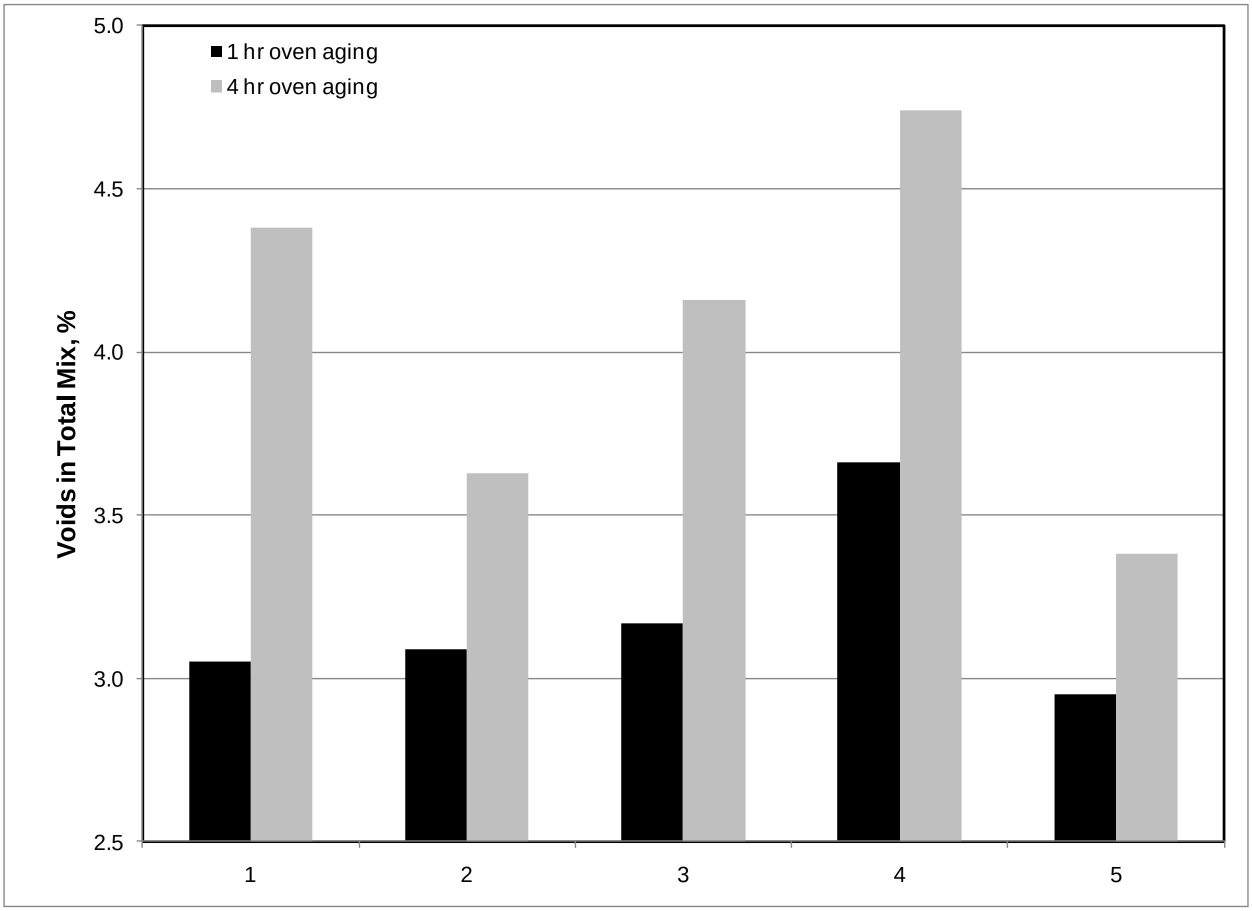

Figure 3: Influence of Oven Aging Time on Air Void Content

Driving around the state, one can visually see cracking that has prematurely formed in HMA pavements. In many cases, these localized areas of premature cracking are located where local gravel sources have high absorptive characteristics. Figures 4 and 5 illustrate two pavements that have prematurely cracked within 7 to 8 years of construction possibly due to absorption issues. Figure 4 is from the northern part of the state while Figure 5 is from the southern. Properly accounting for the absorption characteristics during selection of the design asphalt binder content and/or QC/QA procedures could potentially add years to the life of the pavement layer and greatly increase the performance life. Therefore, the objective of this project was to evaluate asphalt absorption through the production and construction process.

Figure 4: Premature Cracking Likely Caused by Absorption Issues (North)

Figure 5: Premature Cracking Potentially Caused by Absorption Issues (South)

CHAPTER 2 – RESEARCH APPROACH

In order to accomplish the project objective, four tasks were required. The research approach was designed to determine the amount of asphalt absorption that takes place in field produced mix through the production and construction process. This information is needed to set a threshold on the true amount of absorption that takes place and for how long absorption takes place. This research is vital to identify the extent of potential performance problems and to set a benchmark for future research (if problems are found) to accurately account for the amount of absorbed asphalt. The following describes the work to be conducted in each task.

2.1 Task 1 – Collection of Aggregate Data

This task entailed collecting information on the aggregates used within HMA produced in Mississippi. Primarily, the information collected was specific gravity and absorption data for many aggregate sources. Also of importance was obtaining a representative sample of approved job mix formulas to determine the relative proportion of HMA mixes that are 100 percent gravel, are a blend of gravel and stone, or 100 percent stone.

2.2 Task 2 – Literature Review

Task 2 was a literature review on the influence of aggregate absorption on HMA performance. The last major synthesis and research on aggregate absorption was done during the Strategic Highway Research Program (SHRP) in the late1980's and early 1990's, or almost 30 years ago.

2.3 Task 3 – Field Sampling of Plant Produced Mix

Task 3 involved sampling on-going projects. It was anticipated that a total of 8 projects would be included and a total of 4 sampling times would be used (total of 32 sampling times). Unfortunately, only six of the eight projects were tested because of time constraints.

At each project, HMA samples were obtained at various times for testing during Task 4. Loose HMA samples were obtained at the exit point of the mixing drum, in the truck at the plant (to take into account for silo storage time) and at the paver. Two types of loose mix samples were obtained. First, bulk loose mix samples were obtained for subsequent testing. Secondly, a portion of each sample was immediately spread onto a "cookie sheet" and immediately cooled using ice.

Cores were also obtained after compaction and prior to traffic control being removed in order to determine if absorption takes place post-construction.

2.4 Task 4 – Laboratory Testing of Field Produced Mix

For each of the samples obtained during Task 3, a series of tests were conducted. On the loose mix samples that were immediately cooled, theoretical maximum density (Rice) tests were conducted. MDOT's dry-back procedures were used for this testing.

For each of the bulk loose mix samples obtained, the mix was heated to compaction temperature and immediately compacted to the appropriate compactive effort. This methodology will identify how the sampling point affects voids in total mix. This data can then be compared to the QC data obtained from the different projects to determine the point in time that current MDOT procedures represent. A portion of each bulk loose mix sample will also be used to determine asphalt content and gradation. A theoretical maximum density test will also be conducted to validate whether any additional absorption took place during the reheating process.

Testing of the cores entailed determining the theoretical maximum density, asphalt content and gradation.

CHAPTER 3 – LITERATURE REVIEW

Most aggregates used in the production of HMA have both external and internal voids. These voids explain the differences between different specific gravity measures or aggregates. The term porosity is used to describe these voids. Because most aggregates have some level of porosity, most aggregates used within the production of HMA will absorb asphalt binder. Lee et. al. (1990) provided five potential issues that may be caused within HMA because of the absorption of asphalt binder by aggregates, including:

1. Incorrect calculation of HMA volumetric properties;
2. Insufficient effective asphalt binder within the HMA mix;
3. Thinner films of asphalt binder coating aggregates leading to premature age-hardening;
4. Thinner films of asphalt binder coating the aggregates leading to an increased potential for low temperature cracking; and
5. Construction problems such as segregation and tender mixes.

Incorrect calculation of HMA volumetric properties can result because of the time dependency of asphalt absorption. Many researchers have shown that asphalt absorption within an HMA increases with time. The time dependency of asphalt absorption within HMA mixes has been documented for many, many years. Nevitt and Krchma (1942) showed that the rate of asphalt absorption progressed at a high initial rate after which the rate of absorption slowed. Kandhal and Khatri (1991) described this phenomenon as a hyperbolic relationship. Nevitt and Krchma (1942) indicated that asphalt absorption can take place for up to 6 months.

The time dependency of asphalt absorption affects the amount of free asphalt available within the mix. Here, the term “free asphalt” refers to the asphalt binder that has not been absorbed by the aggregates. The term effective asphalt binder content is used to describe the amount of free asphalt. As the amount of free asphalt available within the HMA mix decreases, the amount of asphalt binder available to bind and lubricate the aggregate particles decreases.

Kandhal and Koehler (1985) showed that the time dependency of asphalt absorption affects the theoretical maximum specific gravity of the mix. As asphalt binder is absorbed by aggregates, the volume of the sample associated with the theoretical maximum specific gravity is reduced. This reduction in volume leads to increases in the measured theoretical maximum specific gravity with time. Hence, as asphalt absorption occurs within the mix, the volumetric properties are changing. This means that incorrect volumetric properties can be calculated for compacted HMA samples.

To combat the time dependency of asphalt absorption, many researchers have recommended that HMA mixture should be held at an elevated temperature prior to testing. Kandhal and Koehler (1985) stated that in Pennsylvania HMA mix was held in an oven for six hours at 290°F prior to determining the theoretical maximum specific gravity using the Rice method. This time period was used to allow most of the asphalt absorption to take place. In 1994, McGennis et. al. (1994) recommended within the Superpave mix design system that HMA be held at an elevated temperature for four hours at 275°F. In 2011, Advanced Asphalt

Technologies, LLC (2011) recommended that HMA mixes incorporating aggregates with a combined water absorption less than 2 percent be held in a forced draft oven set at the mixture's compaction temperature for 2 hours prior to any testing. For HMA mixes incorporating aggregates with more than 2 percent water absorption, the HMA mix should be held for 4 hours at the compaction temperature. Each of these conditioning procedures prior to testing were recommended in an effort to account for the amount of asphalt absorption that takes place during the production and construction of HMA.

Several volumetric properties can be affected because of the time dependency of asphalt absorption. First, air void content within a compacted HMA can be affected. The two test methods required for determining the air void content of HMA are the bulk specific gravity of the compacted HMA and the theoretical maximum specific gravity. The amount of free asphalt available within the HMA can affect the results from both of these tests. During compaction of an HMA mix, the volume of free asphalt within the mix lubricates the aggregate particles. If more free asphalt is available within a sample, then the mix can be compacted to a higher density. Likewise, if less volume of free asphalt is available, a lower compacted density can result. As stated above, the absorption of asphalt binder by aggregates causes the volume associated with the theoretical maximum specific gravity to decrease, leading to a higher theoretical maximum specific gravity. Therefore, the time dependency of asphalt absorption by aggregates can lead to changing air void contents.

Another important volumetric property affected by the time dependency of asphalt absorption is voids in mineral aggregate (VMA). Roberts et al (1996) define VMA as the "volume of intergranular void space between the aggregate particles of a compacted paving mixture that includes the air voids and volume of the asphalt not absorbed into the aggregates." As shown in this definition, the time dependency of asphalt absorption will affect the determination of VMA. Inaccurate calculation of VMA can have a detrimental effect on the performance of an HMA pavement. Voids in mineral aggregate has long been considered an important volumetric property related to the durability of an HMA. Mixtures with low VMA values are considered to be susceptible to durability problems such as cracking, raveling and stripping. Depending upon whether all asphalt absorption has taken place or not, an artificially high VMA value may result.

Raveling was defined by the Strategic Highway Research Program (1993) as the wearing away of the pavement surface. This wearing away is generally caused by the dislodging of aggregate particles. Roberts et al (1996) state that one of the potential causes of raveling within an HMA layer is an insufficient asphalt binder content. Asphalt absorption can affect the asphalt binder content of the HMA layer. If asphalt absorption is not taken into account during the design of the HMA mixture, the selected optimum asphalt binder content for the mix may be incorrectly selected as lower than optimal. Said another way, if more asphalt absorption takes place during production and construction than took place during mix design, the effective asphalt binder within the HMA layer will be less. Less effective asphalt binder means thinner asphalt binder films which can lead to an increased potential for raveling.

The same premise is why the potential for cracking can be increased because of the time dependency of asphalt absorption. Less effective asphalt binder to bind the aggregate particles make an HMA layer more susceptible to environmental conditions. This can result in age-hardening of the asphalt binder film coating the aggregates which increases the potential for cracking (Lee et.al., 1990).

One aspect of asphalt absorption generally not considered is the affect on construction. Buchanan and Cooley (2003) documented a study investigating the possible causes of the tender zone within coarse-graded Superpave design HMA. The tender zone relates to a condition during the field compaction of HMA. Buchanan and Cooley (2003) defined the tender zone as a range of mix compaction temperatures in which the mix exhibited instability under rollers during the compaction process. For the projects they visited, one observation common to a number of the projects exhibiting the tender zone was that the aggregates used within the HMA had relatively high absorptive characteristics. Also, these projects generally had very short haul distances and very short silo storage times. They surmised that because of the short silo storage and haul times, the mix exhibited the tenderness because the mix acted as if it was over-asphalted from the lack of asphalt being absorbed by the aggregates..

In summary, most all aggregates used within the production of HMA have some absorptive characteristics. Absorption of asphalt binder by the aggregates is time dependent. Initially, the rate of asphalt absorption is high. After some period of time the rate diminishes. Depending upon the characteristics of the asphalt binder and aggregates, absorption can take place for an extended period of time. The time dependency of asphalt absorption by the aggregates within HMA can lead to the calculation of volumetric properties that are not representative of true properties of the HMA. These non-representative volumetric properties can increase the potential for durability problems in the field. Also, there is evidence that the time dependency of asphalt absorption can affect the construction of HMA layers.

Though not part of this study, there is some concern whether the amount of asphalt absorption and/or time dependency of asphalt absorption changes within Warm Mix Asphalt (WMA) when compared to HMA. If there are differences in the absorption characteristics between WMA and HMA, it could affect how WMA mixes should be designed compared to HMA mixes.

CHAPTER 4 – METHODS AND MATERIALS

4.1 Test Methods

Test methods used within this project included determining the theoretical maximum specific gravity of asphalt mixtures (G_{mm}), asphalt content (P_b) using the ignition oven, and compaction of samples using the Superpave gyratory compactor (SGC). The theoretical maximum specific gravity was conducted in accordance with AASHTO T209. This test method entails placing loose HMA mixture into a pycnometer and placing the mix under a specified vacuum for a given amount of time under agitation. The vacuum removes air bubbles trapped within the loose mix contained within the pycnometer. Comparing the submerged mass of the pycnometer filled with water and then the pycnometer filled with the loose de-aired mixture provides a volume for the mixture. This test results in the theoretical maximum specific gravity of the HMA material. A dryback procedure was utilized for all samples.

The asphalt content of the different samples was determined in accordance with Method A of AASHTO T308. Loose HMA mix was placed into an ignition furnace and heated to a temperature that ignites the asphalt binder. The asphalt binder content was calculated by determining the difference in mass between the initial HMA sample and the mass of remaining aggregates. An asphalt binder correction factor was determined for each of the projects using stockpiled materials sampled at each respective field project. The asphalt binder correction factors were determined in accordance with Annex A2 of AASHTO T308 except three laboratory samples were prepared at the appropriate job mix formula design asphalt content and the differences averaged.

Loose mixture sampled from each of the field projects was reheated and compacted in a SGC in accordance with AASHTO T312. The loose mix was reheated in a forced draft oven until the mix reached a temperature of approximately 280°F. This lower temperature was used in an effort to minimize asphalt absorption during the reheating process. After reaching this temperature, the loose mix was placed into an SGC mold and compacted to the appropriate design number of gyrations for the respective projects. After allowing the compacted samples to cool to room temperature, the bulk specific gravity of the compacted mixture (G_{mb}) was determined in accordance with AASHTO T166. Using the theoretical maximum specific gravity and bulk specific gravity of the compacted sample allowed the calculation of air void contents (V_a) for the compacted samples.

The theoretical maximum specific gravity and asphalt content results were used to calculate the effective specific gravity of the aggregates (G_{se}). The effective specific gravity of the aggregate is an aggregate property that takes into account the volume of asphalt binder that is absorbed by an aggregate within an HMA mix. The following equation was used to calculate the effective specific gravity.

$$G_{se} = \frac{100 - P_b}{\frac{100}{G_{mm}} - \frac{P_b}{G_b}}$$

Where:

G_{se} = Effective Specific Gravity of Aggregate
P_b = Asphalt Content (%)
G_{mm} = Theoretical maximum specific gravity
G_b = Specific gravity of the asphalt binder.

4.2 Materials

Materials used during this project were plant produced HMA. A total of six field projects were tested. These projects were from the Northeast, Central, and Southern parts of the state. Hot mix asphalt produced for projects ranging from Interstates to low volume highways were included. Table 1 presents a summary of the HMA mixes produced for the six projects while Table 2 presents the types and proportion of aggregates used within the HMA.

Table 1: HMA Properties of the Six Field Projects

	Project 1	Project 2	Project 3	Project 4	Project 5	Project 6
Mix Type	HT 9.5 mm	HT 9.5 mm	ST 9.5 mm	MT 9.5 mm	HT 19 mm	MT 12.5 mm
			Gradation Information			
1 in.	100	100	100	100	100	100
¾ in.	100	100	100	100	99	100
½ in.	100	100	100	100	87	97
⅜ in.	91	93	96	95	76	86
No. 4	55	69	68	65	50	57
No. 8	37	41	43	46	34	35
No. 16	27	28	29	31	26	28
No. 30	20	20	20	22	20	22
No. 50	13	12	11	13	11	13
No. 100	9	9	7	8	7	8
No. 200	6.2	6.6	5.2	5.9	5.5	5.4
Property			Mix Information			
Pb	4.90	6.2	5.5	6.1	4.5	5.4
VMA	15.0	15.4	15.6	15.4	13.4	14.5
VFA	73.3	74	73.9	74	70.1	72.4
Gmm	2.407	2.315	2.466	2.326	2.372	2.37
Gsb	2.586	2.472	2.65	2.479	2.511	2.522
Pba	0.02	0.77	0.42	0.79	0.23	0.56
Pbe	4.88	5.43	5.08	5.31	4.27	4.84
D/B	1.27	1.22	1.02	1.10	1.29	1.13
Gse	2.587	2.522	2.680	2.530	2.526	2.559
Gb	1.026	1.032	1.04	1.039	1.034	1.033
PG Grade	PG 76-22	PG 67-22	PG 67-22	PG 67-22	PG 67-22	PG 67-22
% RAP	15	15	15	15	30	12

Three of the six projects used High-Type (HT) HMA mixes while two utilized Medium-Type (MT) HMA mixes and the sixth project used a Standard-Type (ST). Four of the six projects had a 9.5 mm nominal maximum aggregate size (NMAS) gradation while one was a 12.5 mm NMAS and one a 19.0 mm NMAS. One of the six projects included a polymer-modified PG 76-22 asphalt binder and the other five had an unmodified PG 67-22 asphalt binder.

Table 2: Aggregate Blends Used for Six Field Projects

	Percent of Aggregate Blend					
Stockpile Name	Project 1	Project 2	Project 3	Project 4	Project 5	Project 6
-1" Cr. Gravel					43	
-3/4" Cr. Gravel					19	5
-1/2" Cr. Gravel	72	26	24	44		67
-1/2" Cr. Concrete	12					
-3/8" Cr. Gravel		50				
#89 LMS			27	15		
#821 LMS			23			
#901 LMS				15		
RAP	15	15	15	15	30	12
Coarse Sand		7	10	10	7	10
Mineral Filler		1				5
Hydrated Lime	1	1	1	1	1	1
Avg. Water Abs.	1.83	2.26	0.73	2.75	2.16	1.72

Of particular interest within Table 1 is the mix information for Project 1. For this mix, the job-mix-formula data showed a bulk specific gravity of aggregate (G_{sb}) of 2.586. The aggregate effective specific gravity (G_{se}) was 2.587. Though the aggregate effective specific gravity should be higher than the bulk specific gravity, the two values are much closer than typical. Because of the closeness of the effective and bulk specific gravities, Table 1 shows that the percentage of absorbed asphalt (P_{ba}) was much lower than typically encountered. As such, the researchers conducted testing to determine the specific gravity and absorption of the -½ in. crushed gravel stockpile sampled from this project. This stockpile was chosen because it represented 72 percent of the aggregate blend (Table 2). Results of this testing indicated that the bulk specific gravities obtained from the two laboratories (contactor's and Burns Cooley Dennis) were outside the allowable reproducibility limit. Using the value determined in the Burns Cooley Dennis, Inc. laboratory resulted in a combined aggregate bulk specific gravity of 2.520 for Project 1. This value was used during the analysis part of this report.

CHAPTER 5 - COLLECTION OF AGGREGATE DATA

5.1 Collection of Aggregate Data

After the notification to proceed was received from MDOT, the researchers contacted the Materials Division about collecting information on aggregate properties typically used within Mississippi HMA. Based upon these conversations, MDOT Materials Division provided the researchers information from four recent years of job mix formulas (JMFs) used on Mississippi projects. Approximately 680 JMFs were provided with detailed information on the aggregate sources and pertinent specific gravity and water absorption data. On average, these JMFs had specific gravity and absorption data for approximately four stockpiles per JMF. Because the database of JMFs contained four recent years of HMA mixes designed within Mississippi for MDOT projects, it was assumed that aggregate specific gravity and absorption data within the database would provide typical values.

The database of JMFs was evaluated to determine the typical aggregates used within HMA produced in Mississippi and the typical specific gravity and absorption values. Aggregates, excluding fillers, typically found within HMA included coarse sand, crushed gravel, granite, slag and limestone. For the coarse aggregate stockpiles, crushed gravel and limestone were by far the predominant aggregate types used. Some HMA mixes did include granite and slag, however. For fine aggregates, coarse sand and limestone materials were most common.

Table 3 presents various statistics about the aggregate specific gravity and absorption data obtained from the various JMFs. For the apparent specific gravity (G_{sa}) data, the maximum value encountered within the state was 3.933. This value is higher than typically encountered and was observed for a slag material. Slag materials represented only a very small percentage of aggregates encountered on the JMFs. The minimum value for G_{sa} was 2.470, while the average value was 2.668. A G_{sa} value of 2.648 was found to be the median value which means that half the values were above 2.648 and half were below. For bulk specific gravity (G_{sb}) the maximum value was 3.665 (again representing the slag materials). The minimum G_{sb} was 2.351, while the average was 2.574 and the median was 2.559. For water absorption, the maximum value was 4.37 percent, while the minimum was 0.09 percent. The average was 1.40 percent and median was 1.26 percent.

Table 3: Aggregate Specific Gravity and Water Absorption Data

Statistic	Apparent Sp. Gr.	Bulk Specific Gr.	Water Absorption, %
Maximum Value	3.933	3.665	4.37
Minimum Value	2.470	2.351	0.09
Average Value	2.668	2.574	1.40
Median Value	2.648	2.559	1.26

For the purposes of this study, the property of interest is the amount of water absorption exhibited by the aggregates. As the percentage of water absorption increases, the potential for asphalt absorption is believed to increase. Figure 6 illustrates a histogram of the percent water absorption encountered for the aggregates contained within the JMFs (again, fillers were omitted). This figure shows that most aggregates used within HMA in Mississippi have percent water absorption values between approximately 0.5 and 1.75. This range in water absorption represents approximately 60 percent of the aggregates encountered within the JMFs. Approximately 25 percent of the aggregates used in Mississippi have a water absorption above 1.75 percent.

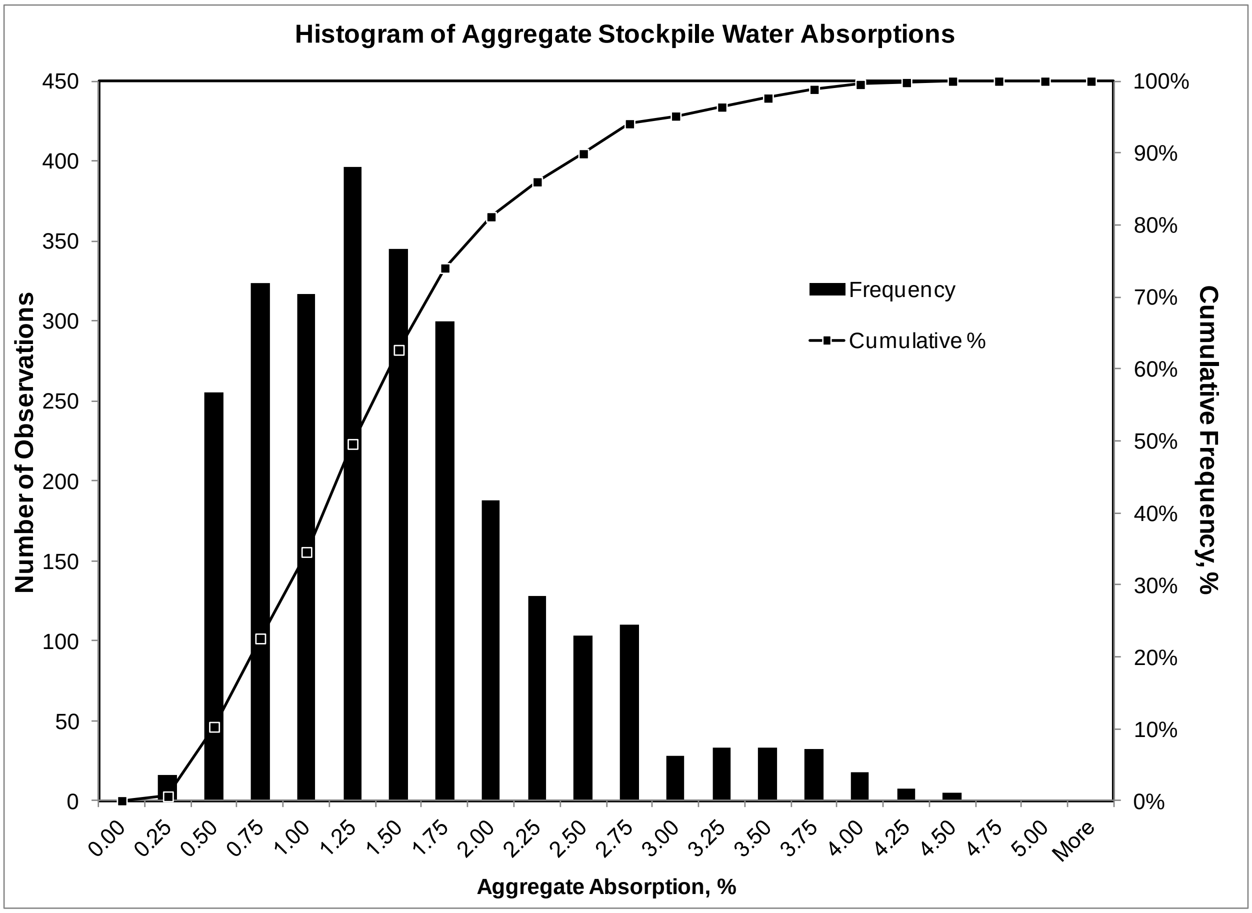

Figure 6: Histogram of Water Absorptions Encountered

The objective of this study was to evaluate the influence of aggregate absorption on HMA mixes. Generally, water absorption as determined during specific gravity and absorption testing, is used as a gage to determine the potential for asphalt being absorbed within HMA mixtures. As such, this task within the study was important to determine the types of aggregates typically used in Mississippi as well as typical water absorption values. Figure 6 showed that the majority of aggregate stockpiles used within HMA in Mississippi have water absorption between 0.5 and 1.75 percent. About one-quarter of the aggregate stockpiles used for HMA in Mississippi have a percent water absorption above 1.75.

CHAPTER 6 – TEST RESULTS AND ANALYSIS

6.1 Test Results and Analysis

Samples of HMA were obtained at various points during the production and construction process. Two general categories of samples were obtained. The first category will be referred to as "Field Sample." Immediately after these samples were obtained, ice was placed onto the samples in order to cool the mixture and stop asphalt absorption. Figure 7 illustrates a Field Sample in which ice had been placed on the sample.

Figure 7: Example of Ice Placed on Field Sample

The second category of sample will be referred to as a "Reheat Sample." These samples were loose mixture sampled at the same time as the Field Samples but placed into 5-gallon metal buckets (Figure 8). Because these were bulk samples placed into a 5-gallon metal bucket, it is probable that the mix stayed at an elevated temperature longer than the Field Samples. Therefore, there was the potential that the Reheat Samples would have higher percentages of absorbed asphalt than the Field Samples. The Reheat samples were later reheated in the laboratory for further testing.

Figure 8: Reheat Samples within Metal Buckets

6.2 Analysis of Field Sample Data

The primary HMA property evaluated in this project was the percentage of asphalt binder absorbed by the aggregates. The experimental approach and test methods were utilized to determine the amount of asphalt binder absorbed by the aggregate throughout the production and construction process. In order to calculate the absorbed asphalt binder content for a specific sample, four properties were needed, including: asphalt binder content, effective specific gravity of the aggregate, combined bulk specific gravity of the aggregates and the specific gravity of the asphalt binder. The combined bulk specific gravity of the aggregates and the specific gravity of the asphalt binder were constants for a given project and were provided within Table 1. Table 4 presents the average asphalt binder content for the various Field Samples and Table 5 provides the average effective specific gravities. Table 6 presents the average percent absorbed asphalt binder from each of the sample locations. It should be noted that data is not available for the core samples from Project 3. After arriving at the project, the HMA produced for this project was placed on shoulders. Traffic control was removed before cores could be obtained. All data being obtained for the Field Samples is presented in Appendix A.

Table 4: Average Asphalt Binder Contents for Field Samples

	Average Asphalt Binder Content				
Project	JMF	Plant	Truck	Paver	Cores
1	4.9	5.16	5.25	5.27	5.24
2	6.2	5.98	5.86	5.92	6.20
3	5.5	5.44	5.16	5.23	N/A
4	6.1	6.07	6.05	6.08	6.32
5	4.5	4.43	4.52	4.60	4.73
6	5.4	5.66	5.74	5.74	5.89

Asphalt binder contents encountered at the different projects are shown in Table 4. Generally, the measured asphalt binder contents were slightly above the JMF optimum asphalt binder content except for projects 2 and 3. This is not uncommon as some contractors prefer to produce HMA slightly above the JMF optimum asphalt content to aid in field compaction.

The average aggregate effective specific gravities at each test location are shown within Table 5. Generally, the aggregate effective specific gravities were similar to the JMF aggregate effective specific gravities. However, in two instances, the aggregate effective specific gravities obtained from testing the plant produced mix was much higher than that shown on the JMF. For Project 2, the JMF effective specific gravity was 2.522 while all of the test results from the field produced samples were 2.553 or above. For Project 5, the JMF effective specific gravity was 2.526 while the test results from the field produced samples were above 2.558. The aggregate effective specific gravity is generally a consistent material property and it is unclear why these large differences were encountered between JMF and field production for these two projects.

Table 5: Average Effective Specific Gravity for Field Samples

	Average Effective Specific Gravity				
Project	JMF	Plant	Truck	Paver	Cores
1	2.587	2.583	2.588	2.598	2.598
2	2.522	2.553	2.560	2.566	2.564
3	2.680	2.672	2.700	2.685	N/A
4	2.530	2.535	2.537	2.538	2.539
5	2.526	2.559	2.561	2.558	2.563
6	2.559	2.564	2.567	2.573	2.568

Also from Table 5, there does appear to be a general trend that the effective specific gravity increases from the Plant samples to the Core samples. Plant samples were obtained immediately after production from the slat conveyor going from the plant to the storage silo. Truck samples were obtained from trucks after any silo storage time took place. These Truck samples were obtained similar to typical quality control/quality assurance samples here in Mississippi. As the name infers, the Paver samples were obtained from the paver. Generally these samples were obtained from the wings of the paver. Core samples were obtained from the roadway after the completion of rolling. For a given set of HMA materials, the average aggregate effective specific gravity should only change due to the amount of asphalt absorbed by the aggregates.

Figure 9 illustrates the definition of aggregate effective specific gravity. Effective specific gravity is defined as the dry mass of aggregate divided by the effective volume of aggregate. The effective volume of aggregate includes the solid volume of aggregate plus the volume of water permeable voids filled with asphalt binder. As can be seen from Figure 9, as the amount of asphalt binder absorbed by the aggregate increases, the effective volume of the aggregate decreases; hence, an increase in effective specific gravity. Therefore, any trend toward higher aggregate effective specific gravity values through the production and construction process indicates an increase in absorbed asphalt.

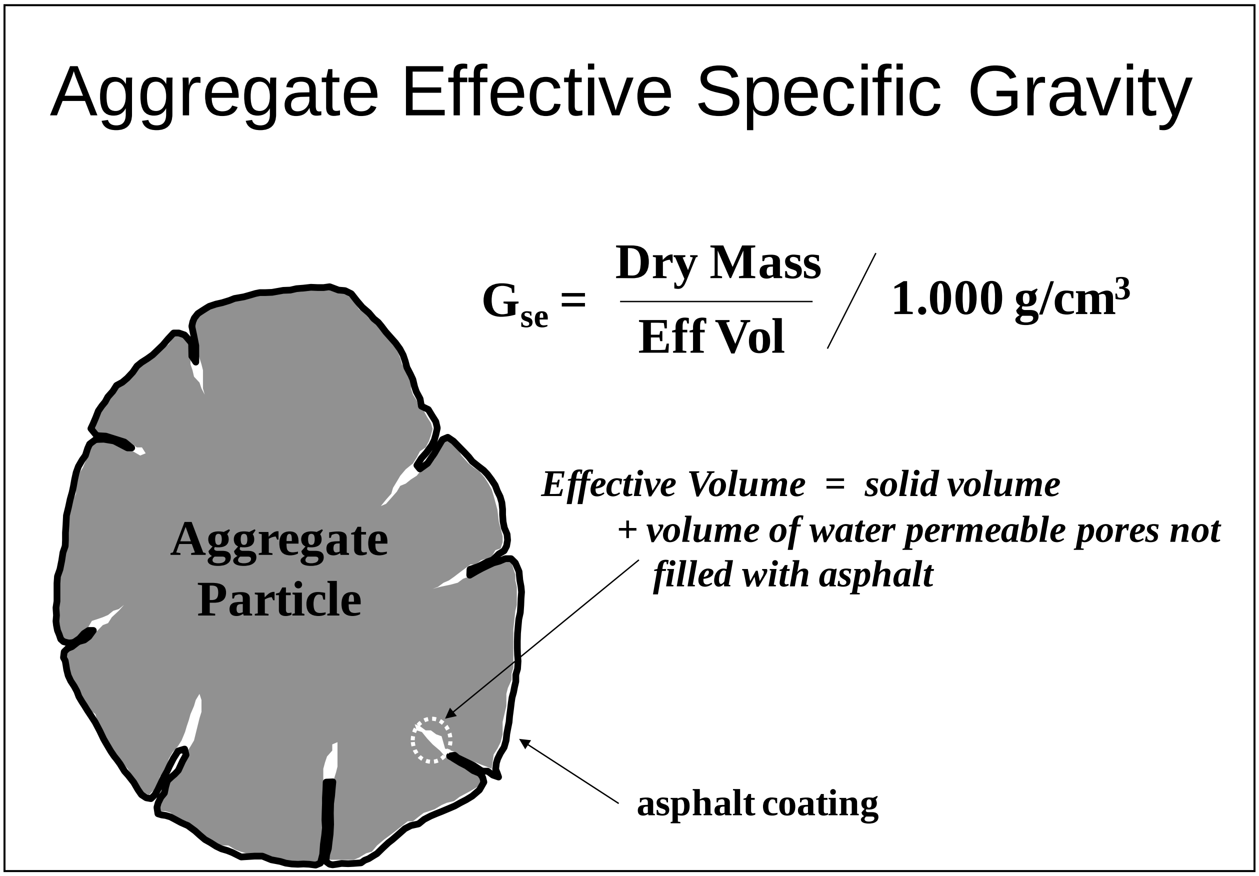

Figure 9: Definition of Aggregate Effective Specific Gravity

The average values of absorbed asphalt binder for each sample location are shown within Table 6. The percentages of absorbed asphalt binder (P_{ba}) for the plant produced samples range from 0.32 to 1.52. In most cases, the P_{ba} was greater for the plant produced samples than those presented on the JMFs. In some cases, the P_{ba} values for the plant produced HMA were twice those presented on the JMFs. To understand the potential causes for these differences, the following volumetric equation for calculating P_{ba} is provided:

$$P_{ba} = 100\ x\ \frac{G_{se} - G_{sb}}{G_{se}\ x\ G_{sb}}\ x\ G_b$$

Where:

P_{ba} = Percent absorbed asphalt
G_{se} = Effective specific gravity of the aggregates
G_{sb} = Combined aggregate bulk specific gravity of the aggregates
G_b = Specific gravity of the asphalt binder

Table 6: Average Percent Absorbed Asphalt Binder

	Average Percent Absorbed Asphalt				
Project	JMF	Plant	Truck	Paver	Cores
1	0.72*	1.00	1.08	1.22	1.22
2	0.77	1.32	1.42	1.52	1.48
3	0.42	0.32	0.29	0.51	N/A
4	0.79	0.91	0.94	0.96	0.98
5	0.23	0.76	0.79	0.75	0.83
6	0.67	0.66	0.71	0.80	0.73

* Value calculated using BCD determined combined G_{sb} as described previously.

As shown in the above equation for percent absorbed asphalt, there are three properties required to volumetrically calculate the P_{ba}, including, effective specific gravity of the aggregates, combined bulk specific gravity of the aggregates, and the specific gravity of the asphalt binder. Of these three properties, the specific gravity of the asphalt binder is a constant value as long as the asphalt binder is not changed. As stated above, the effective specific gravity of the aggregates is generally a consistent property that is related to the properties of the aggregate and the amount of asphalt binder that is absorbed by the aggregate. From a material testing standpoint, the bulk specific gravity of an aggregate is probably the most difficult and variable property to determine of the three. Combining the variability of determining the bulk specific gravity of several aggregate stockpiles can potentially lead to a combined bulk specific gravity that is not as precise as aggregate effective specific gravity or asphalt binder specific gravity. Therefore, the large difference in P_{ba} between the JMF and plant produced mix observed for some projects is likely caused by the combined bulk specific gravity of the aggregates determined during development of the JMF. Based upon the trend that the P_{ba} from the plant produced mix is generally higher than the JMF P_{ba}, the actual combined bulk specific gravity of the aggregates appears to be smaller than the value depicted on the JMF. Referring back to the equation for calculating P_{ba} above, a smaller combined bulk specific gravity for the aggregates would result in a higher P_{ba} for a given aggregate effective specific gravity and asphalt binder specific gravity. This observation is somewhat troubling because the combined bulk specific gravity of the aggregates is an important property in calculating voids in mineral aggregate (VMA). The VMA is the volumetric property MDOT uses as an indicator of mix durability in designed and produced HMA. For a given set of materials and a constant compactive effort, a decrease in the combined bulk specific gravity for the aggregates would result in a lower VMA which suggests less durability.

Table 6 shows that generally the P_{ba} increases as the HMA stays at an elevated temperature (goes from the Plant samples to the Core samples). These general trends are illustrated for the six projects within Figures 10 through 15. Also included on these figures are the P_{ba} values provided on the JMFs. Generally, these figures show that the P_{ba} between the location of the Plant samples to the Core samples was about 0.2 percent difference with the Core sample location being highest. Using the "rule-of-thumb" that 0.4 percent asphalt binder is equal to 1.0 percent air voids, the average difference in air voids for HMA aged from the Plant location to the Core location would be approximately 0.5 percent air voids. For Projects 4 and 5, the difference in P_{ba} values was about 0.1 percent.

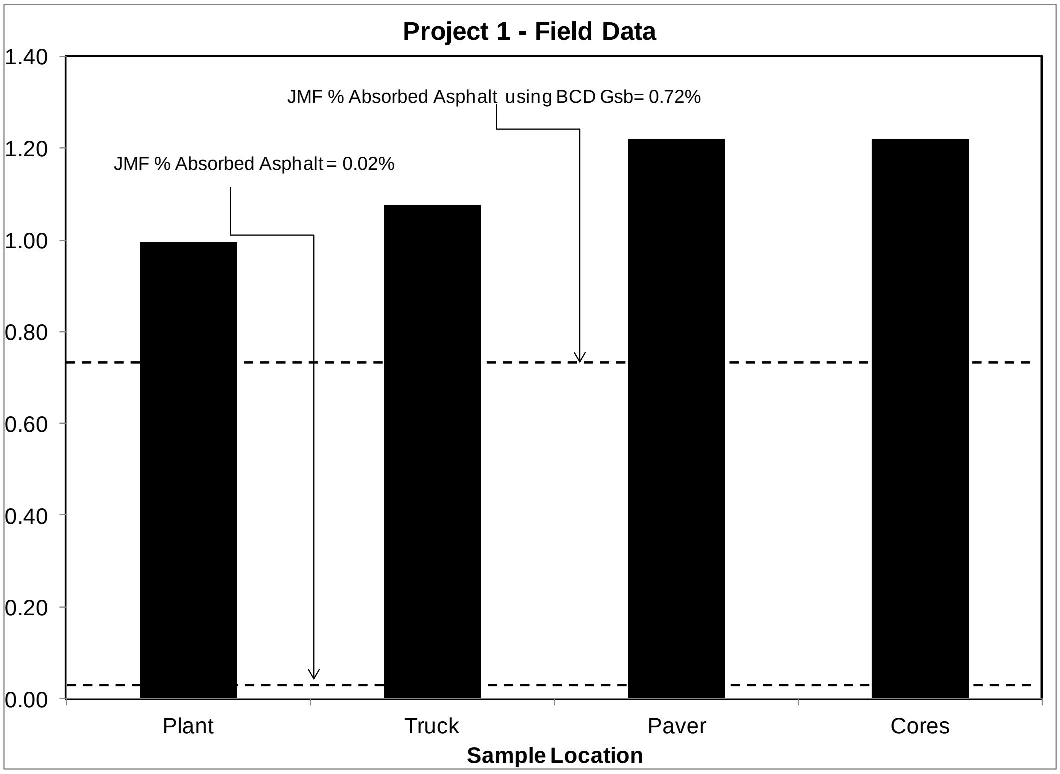

Figure 10: Average Percent Absorbed Asphalt at Each Sample Location – Project 1

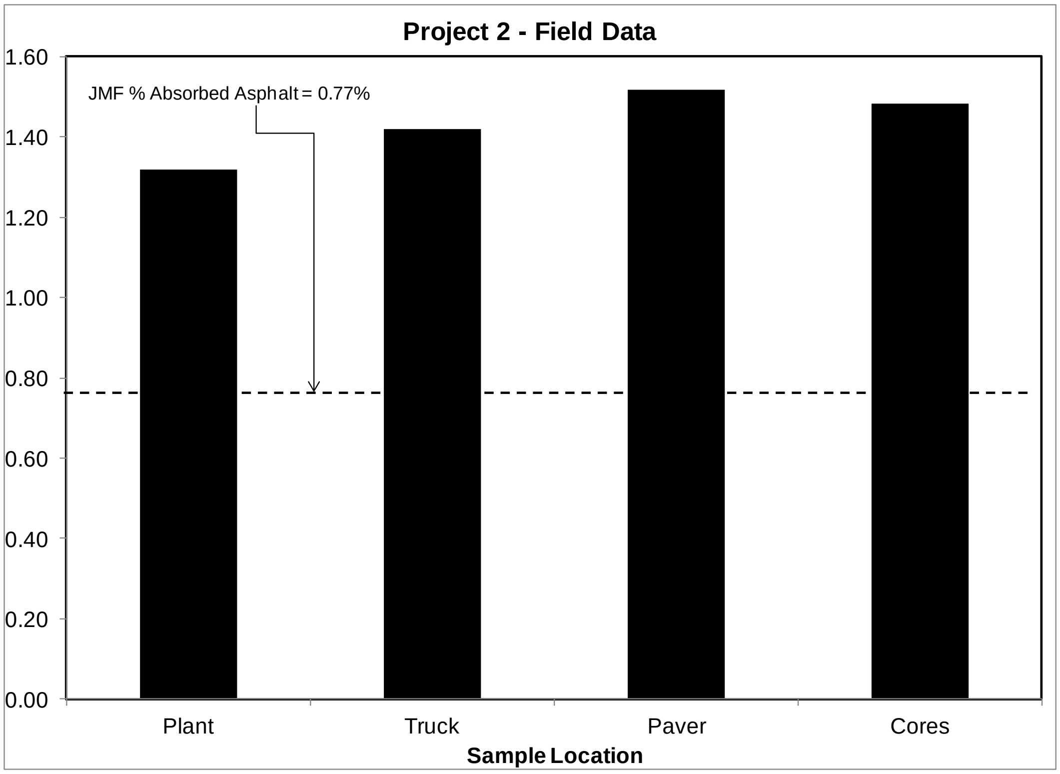

Figure 11: Average Percent Absorbed Asphalt at Each Sample Location - Project 2

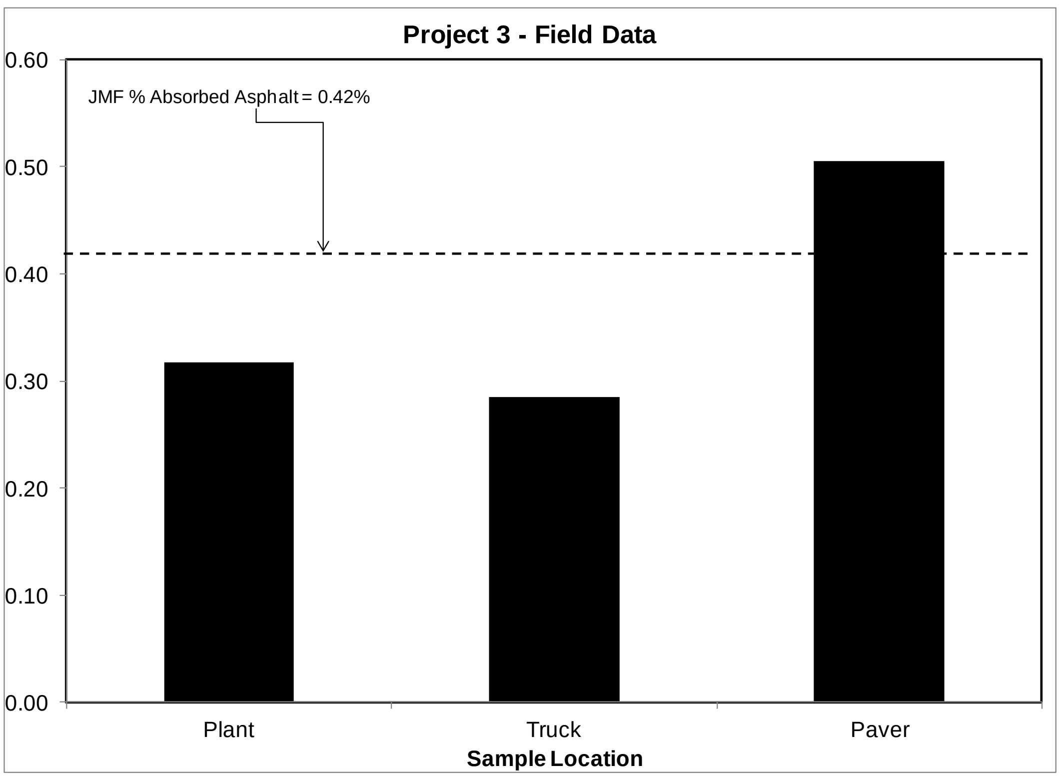

Figure 12: Average Percent Absorbed Asphalt at Each Sample Location - Project 3

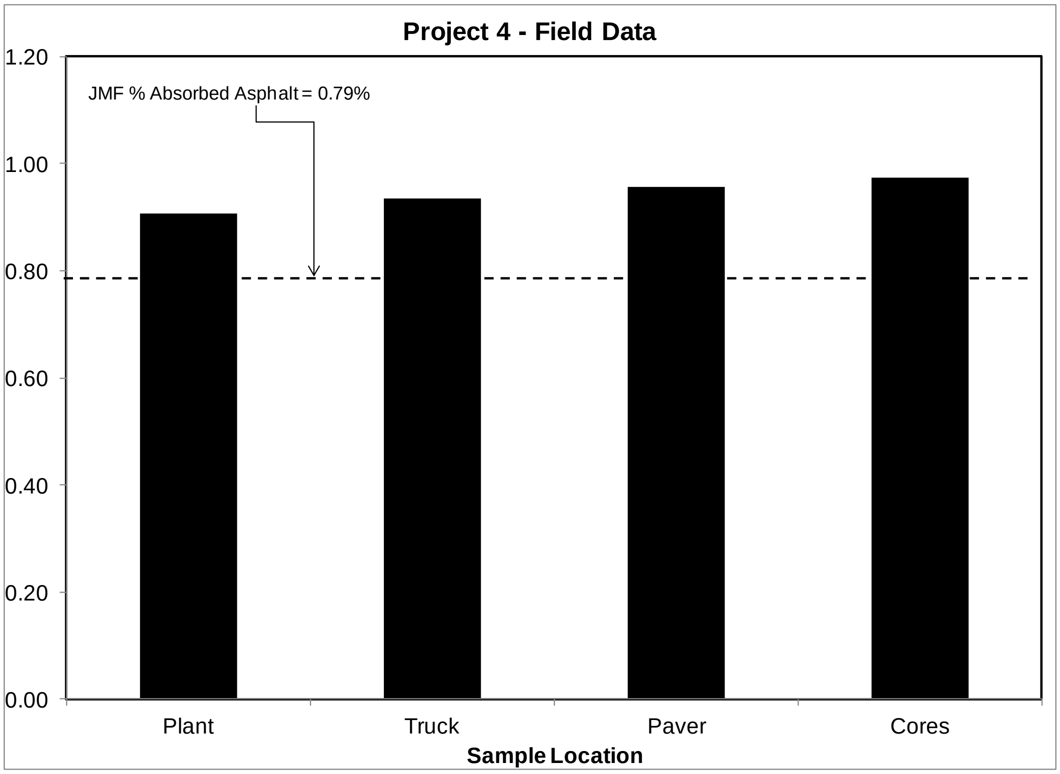

Figure 13: Average Percent Absorbed Asphalt at Each Sample Location - Project 4

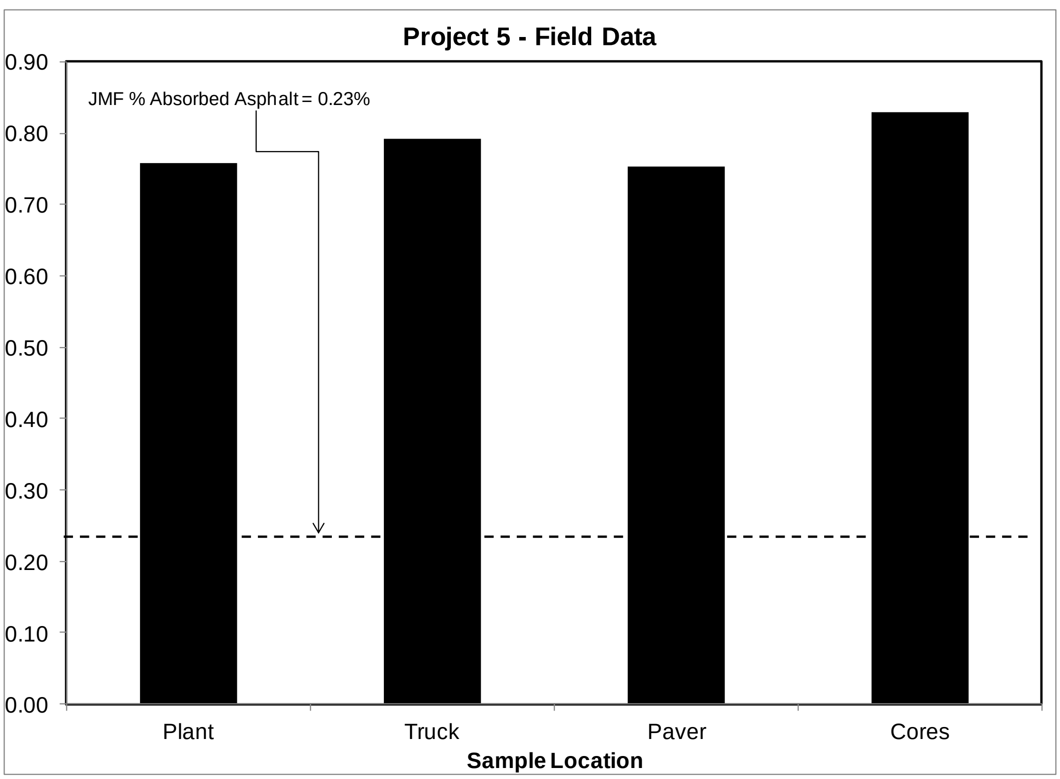

Figure 14: Average Percent Absorbed Asphalt at Each Sample Location - Project 5

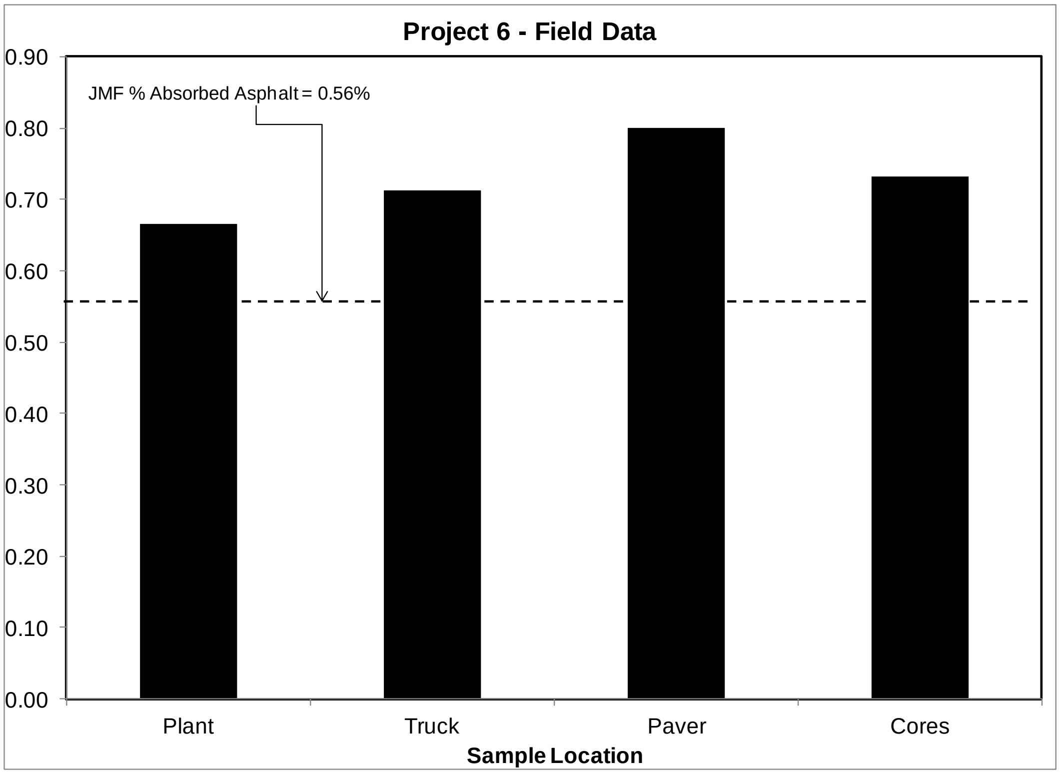

Figure 15: Average Percent Absorbed Asphalt at Each Sample Location - Project 6

An Analysis of Variance (ANOVA) was conducted on the P_{ba} data obtained at the field projects to determine whether significant differences occurred in the P_{ba} values obtained at the different sample locations. Table 7 presents the results of the ANOVA. Based upon Table 7, results of the ANOVA showed that both the Project and Sample location had a significant effect on the measured P_{ba} values. Both Project and Sample location had p-values less than 0.05 which indicates that both were significant at a level of significance of 95 percent. Because of the significance of Sample location, a Tukey's multiple comparison test was conducted to evaluate which of the sample locations were significantly different. Results of Tukey's multiple comparison test are presented within Table 8.

Table 7: Results of ANOVA for Percent Absorbed Asphalt Data - Field Samples

Source of Variation	df	Sum of Squares	Mean Squares	F-statistic	p-value	Significant?
Project	5	10.071	2.014	179.93	0.000	Yes
Sample Location	3	0.312	0.104	9.28	0.000	Yes
Interaction	15	0.162	0.011	0.96	0.501	No
Error	72	0.806	0.011			
Total	95	11.351				

Table 8 presents the results of the Tukey's multiple comparison test in the form of letters. Average P_{ba} values with the same letter ranking are considered statistically similar. Averages with different letters are considered significantly different. Based upon the rankings, the Plant and Truck samples were similar. Also, the average P_{ba} values for the Paver and Core samples were similar. However, the Plant and Truck samples were significantly different than the Paver and Core samples. These ranking suggest that most of the asphalt absorption takes place during

HMA mix transportation. This is logical as the mix is generally held at an elevated temperature for the greatest length of time within the truck during transportation. There are exceptions where a very short haul time is required to get to the project; however, many projects require a 30 minute haul or longer.

Table 8: Results of Tukey's Multiple Comparison Test for Percent Absorbed Asphalt Data - Field Samples

Sample Location	Average P_{ba}	Tukey's Ranking*
Plant	0.83	A
Truck	0.87	A
Paver	0.96	B
Cores	0.96	B

* Sample Locations with different Tukey's rankings are significantly difference at level of significance of 0.05.

One of the objectives of this analysis was to determine the point within the production and construction process the P_{ba} was equal to the JMF P_{ba}. As discussed above, there is a concern about the combined bulk specific gravity of the aggregates provided on a number of the JMFs. Another method to determine the point at which the P_{ba} of the plant produced mix equals the P_{ba} provided on the JMF is to evaluate the aggregate effective specific gravity. As stated above, the aggregate effective specific gravity should be a relatively consistent property as long as the aggregate materials and proportions are relatively consistent. Figure 16 illustrates the aggregate effective specific gravity at each sample location for Project 1. Also included on this figure is the JMF value for effective specific gravity. Based upon Figure 16, the P_{ba} on the JMF was approximately equal to amount of absorption that took place through the Truck sample.

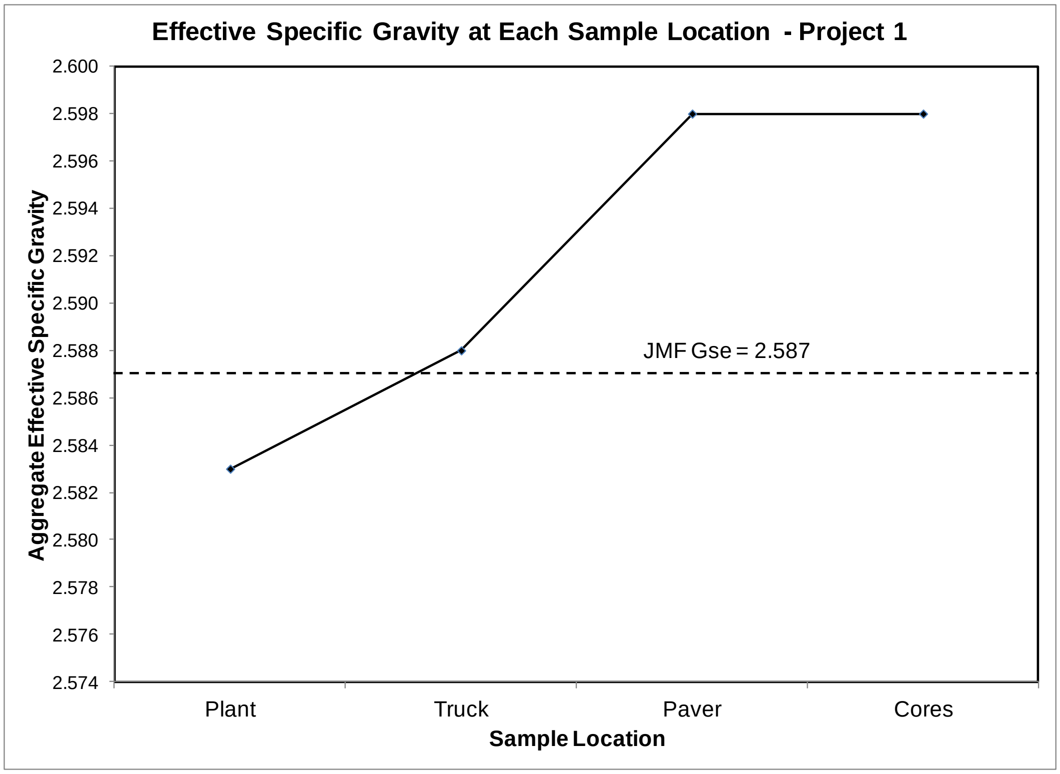

Figure 16: Effective Specific Gravity at Each Sample Location - Project 1

Figure 17 illustrates the aggregate effective specific gravity at each sample location for Project 2. As can be seen on this figure, the aggregate effective specific gravity provided on the JMF and the aggregate effective specific gravity on the plant produced material were never equal. There are two possibilities for these values not being close to equal. First, the aggregate effective specific gravity provided on the JMF was not representative of the materials. Secondly, the aggregate properties and/or proportions of materials were slightly different during production than those used to develop the JMF. Unfortunately, the aggregate effective specific gravity data comparing JMF to plant produced materials at the different sample locations were similar to Figure 17 for Projects 4, 5 and 6. Project 3 did indicate that the aggregate effective specific gravity provided on the JMF and the aggregate effective specific gravities determined on the plant produced mix were equal (Figure 18). Figure 18 shows that the aggregate effective specific gravities were approximately equal between the Truck and paver sampling points. This again suggests that the amount of asphalt absorption during development of the JMF was approximately representative of the amount of absorption through production and silo storage time.

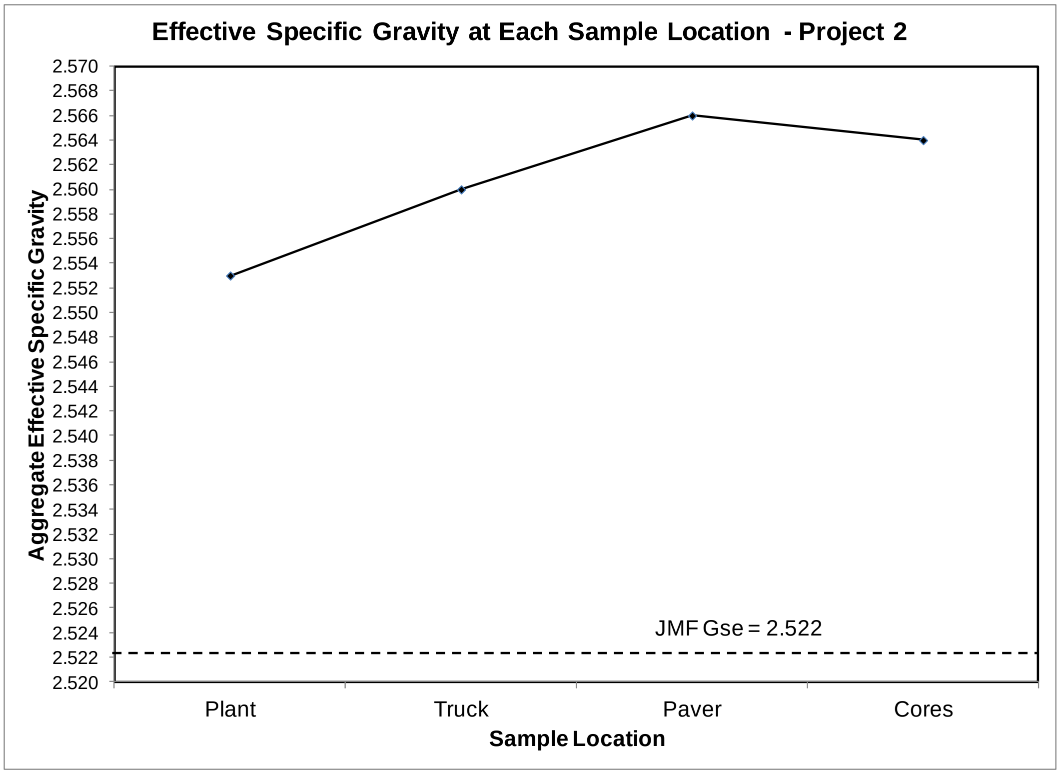

Figure 17: Effective Specific Gravity at Each Sample Location - Project 2

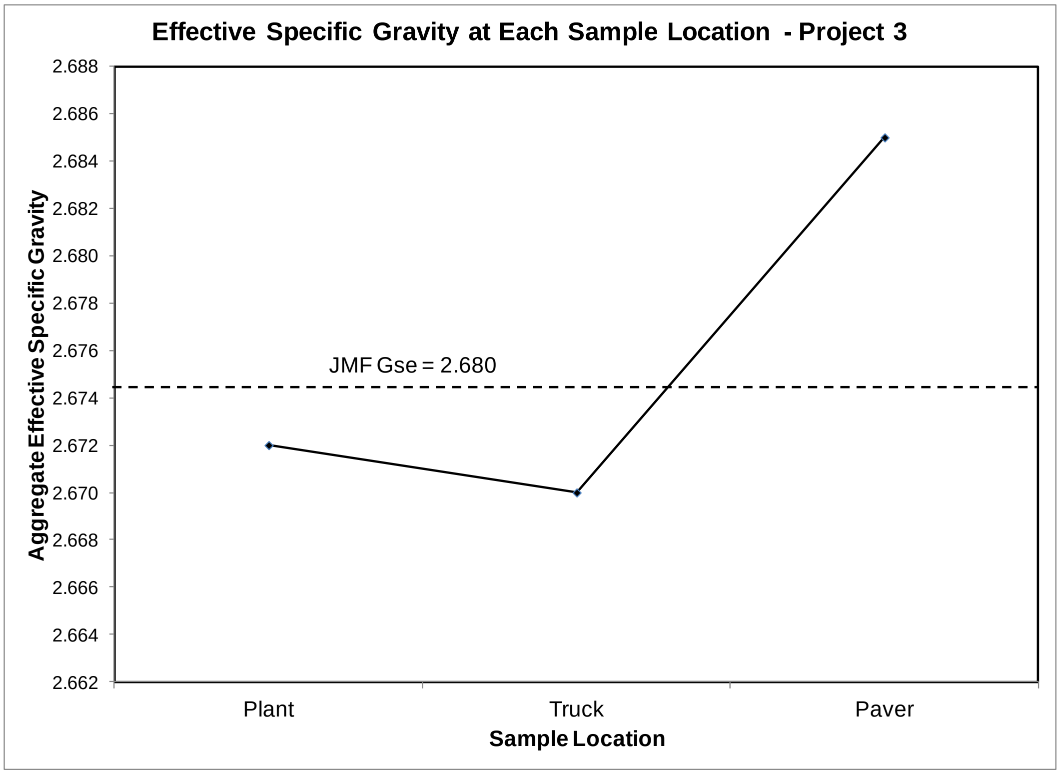

Figure 18: Effective Specific Gravity at Each Sample Location - Project 3

Though evaluating pavement density was not part of this study, a total of 60 cores were obtained during the field work. Three cores were obtained at each of the four test locations at a project in order to provide sufficient material to conduct a theoretical maximum specific gravity test and to determine asphalt binder content. Recall that cores were not obtained at Project 3. Prior to running these two tests, the bulk specific gravity of the cores was determined. Using the bulk specific gravity of each core and the theoretical maximum specific gravity determined on the cores allowed the percent density of each core to be calculated. Figure 19 presents a histogram illustrating the frequency of core densities. Data is presented as the percent theoretical maximum specific gravity. Following is an excerpt from the 2004 Edition of the Mississippi Standard Specification for Road and Bridge Construction:

> *"The density requirement for each completed lift on a lot to lot basis from density tests performed by the Department shall be as follows:*
>
> 1 *For all single lift overlays, with or without leveling and/or milling, the required lot density shll be 92.0 percent of maximum density.*
> 2 *For all multiple lift overlays of two(2) or more lifts excluding leveling lifts, the required lot density of the bottom lift shall be 92.0 percent of maximum density. The required lot density for all subsequent lifts shall be 93.0 percent of maximum density.*
> 3 *For all pavements on new construction, the required lot density for all lifts shall be 93.0 percent of maximum density."*

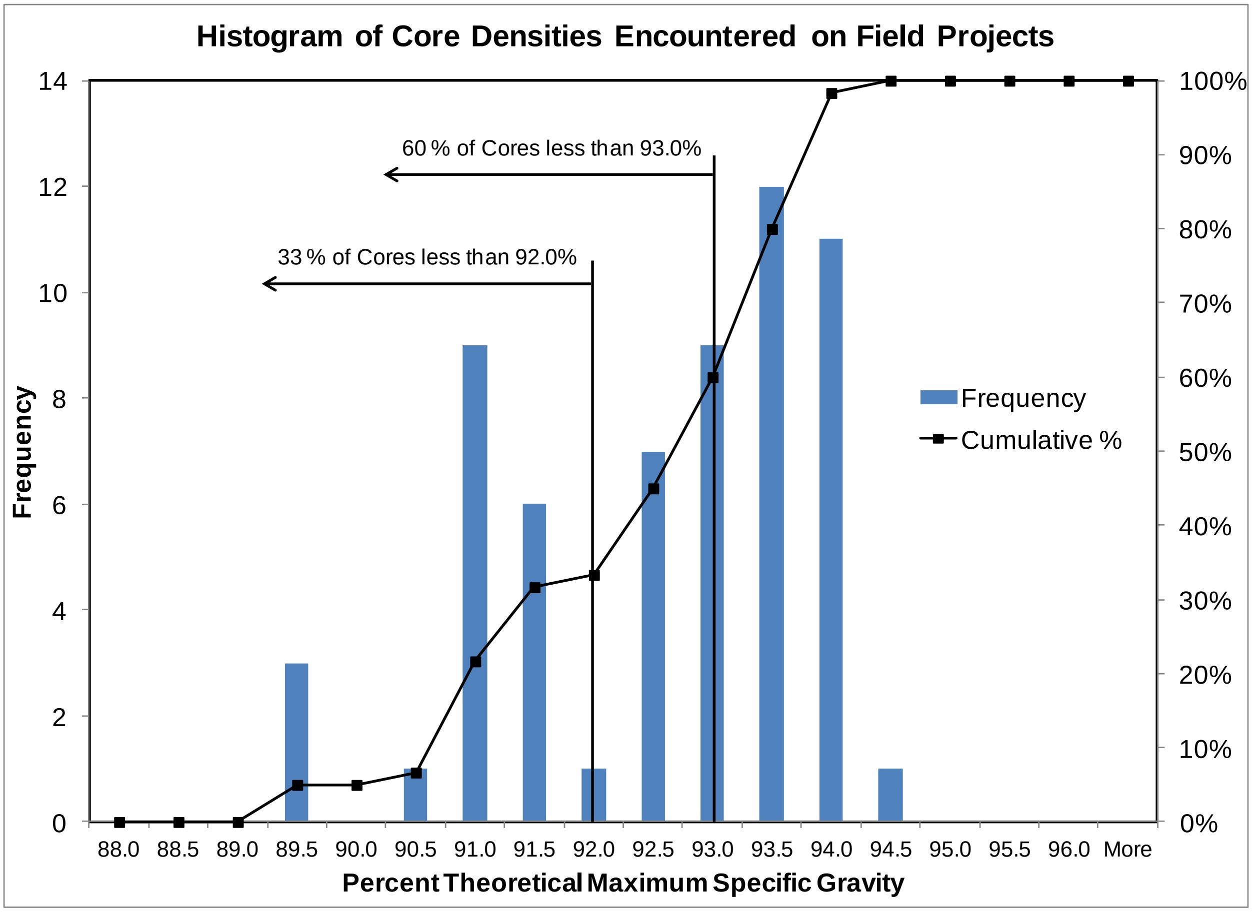

Figure 19: Histogram Showing Range of In-Place Densities Encountered

The purpose of this project was not to evaluate single or multiple lift overlays; therefore, that specific data was not obtained for each project. However, both types were encountered during the field work. The purpose of Figure 19 is solely to illustrate the range of densities encountered at the five projects. As shown by the histogram, 33 percent of the core samples had a density of less than 92.0 percent theoretical maximum density while 60 percent had less than 93 percent.

6.3 Analysis of Reheat Sample Data

Analysis of the Reheat Samples was similar to the analysis conducted for the Field Samples. Appendix B presents all data obtained for the Reheat Samples. Table 9 presents the average aggregate effective specific gravities obtained for the Reheat Samples. Because the Reheat Samples and Field Samples were obtained at the same time, the average asphalt binder contents for the Reheat Samples are identical to those shown in Table 4. Similar to the Field Sample data, the aggregate effective specific gravity data from the plant produced materials were similar to the JMF on four of the six projects. The JMF aggregate effective specific gravity was lower than for the plant produced materials for Project 2 and 5.

Table 9: Average Effective Specific Gravity for Reheat Samples

	Average Effective Specific Gravity			
Project	JMF	Plant	Truck	Paver
1	2.587	2.592	2.588	2.598
2	2.522	2.559	2.566	2.565
3	2.680	2.674	2.674	2.684
4	2.530	2.530	2.529	2.531
5	2.526	2.559	2.563	2.558
6	2.559	2.555	2.566	2.568

Table 10 presents the average percent absorbed asphalt at each of the sample locations. Again, similar to the Field Samples, the data suggests that the P_{ba} increases from the Plant to the Paver locations. Figures 20 through 25 illustrate the average P_{ba} at each of the sample locations. These figures do suggest a general trend of increasing P_{ba} as the mix is held at an elevated temperature (from Plant sample to Paver sample).

Table 10: Average Absorbed Asphalt Contents for Reheat Samples

	Average Percent Absorbed Asphalt			
Project	JMF	Plant	Truck	Paver
1	0.02	1.14	1.06	1.21
2	0.77	1.41	1.51	1.49
3	0.42	0.35	0.35	0.49
4	0.79	0.83	0.82	0.85
5	0.23	0.76	0.83	0.76
6	0.67	0.52	0.70	0.72

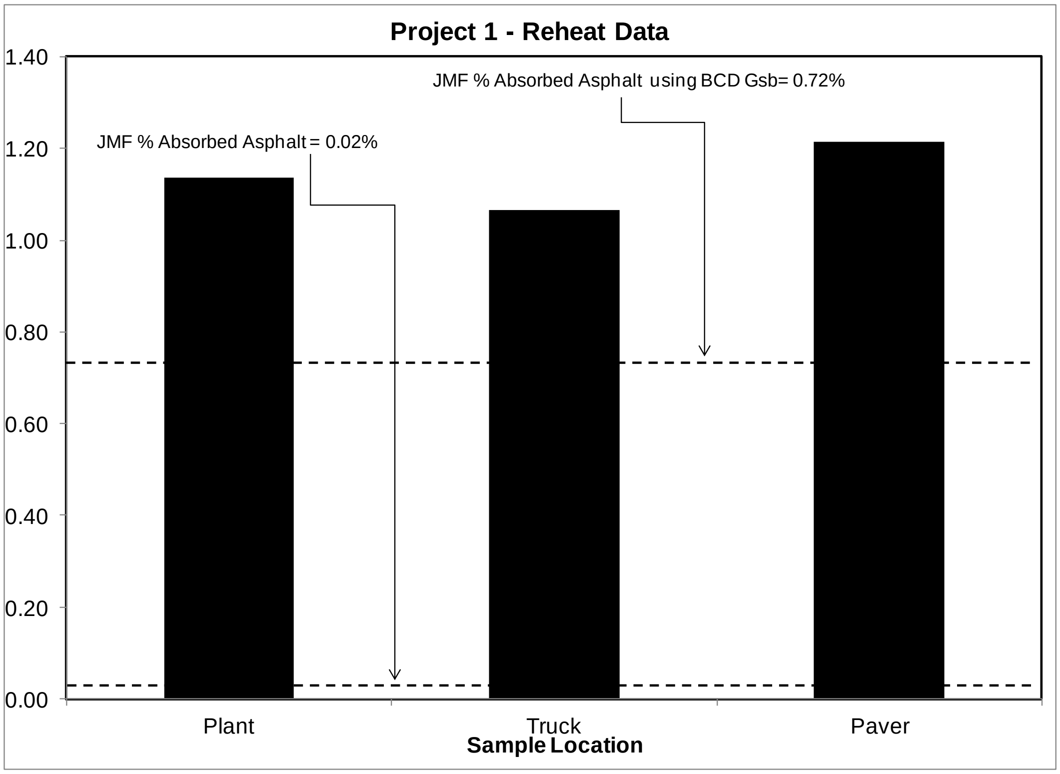

Figure 20: Average Percent Absorbed Asphalt at Each Sample Location - Project 1

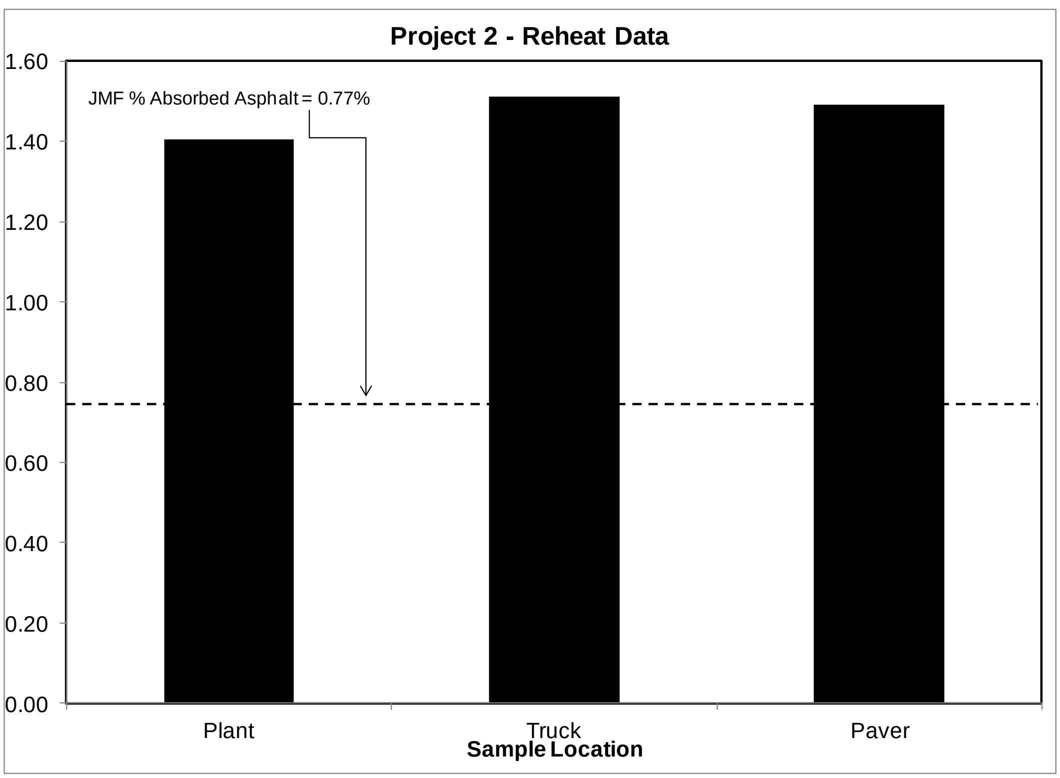

Figure 21: Average Percent Absorbed Asphalt at Each Sample Location - Project 2

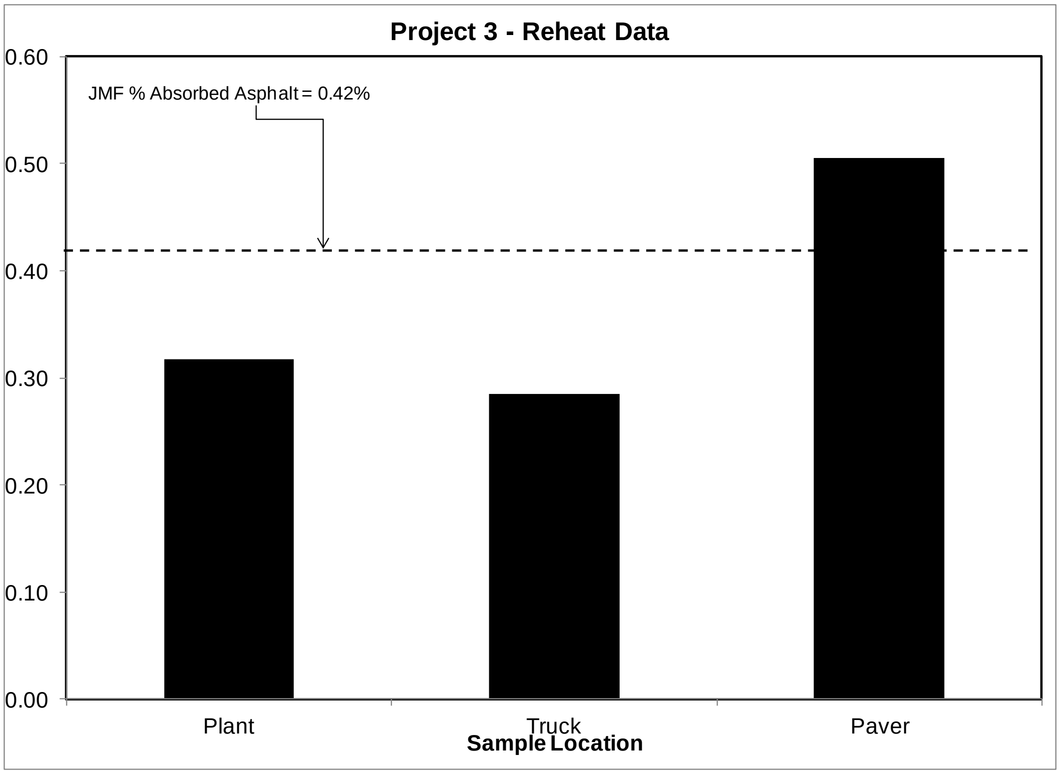

Figure 22: Average Percent Absorbed Asphalt at Each Sample Location - Project 3

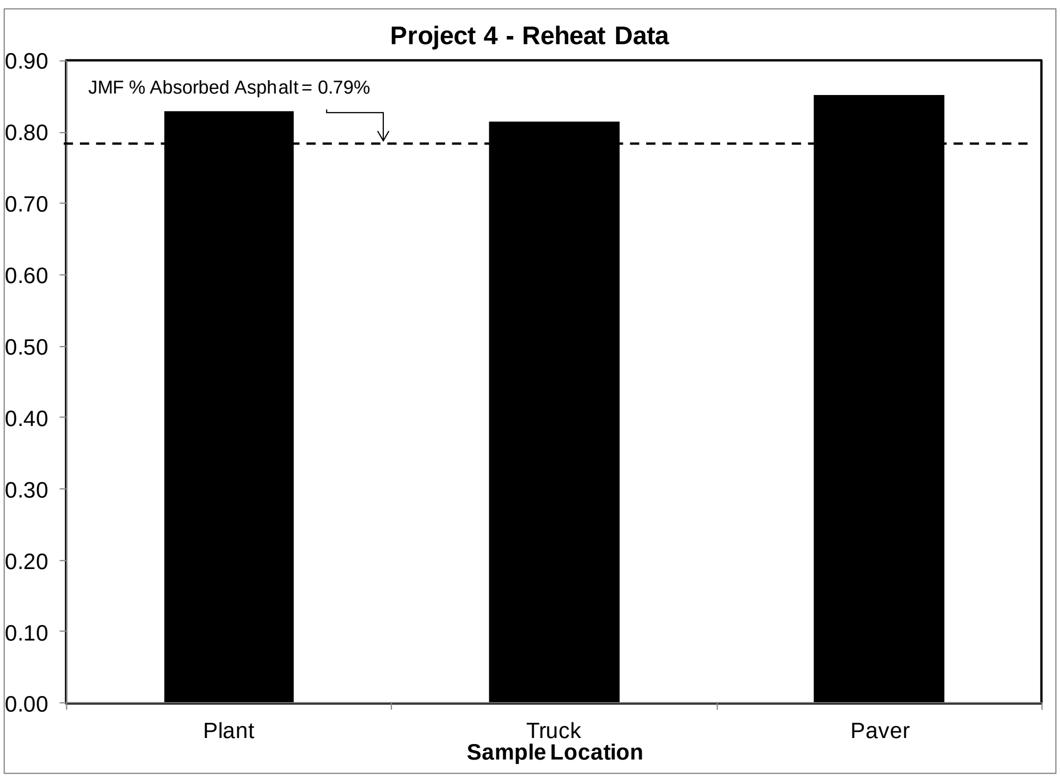

Figure 23: Average Percent Absorbed Asphalt at Each Sample Location - Project 4

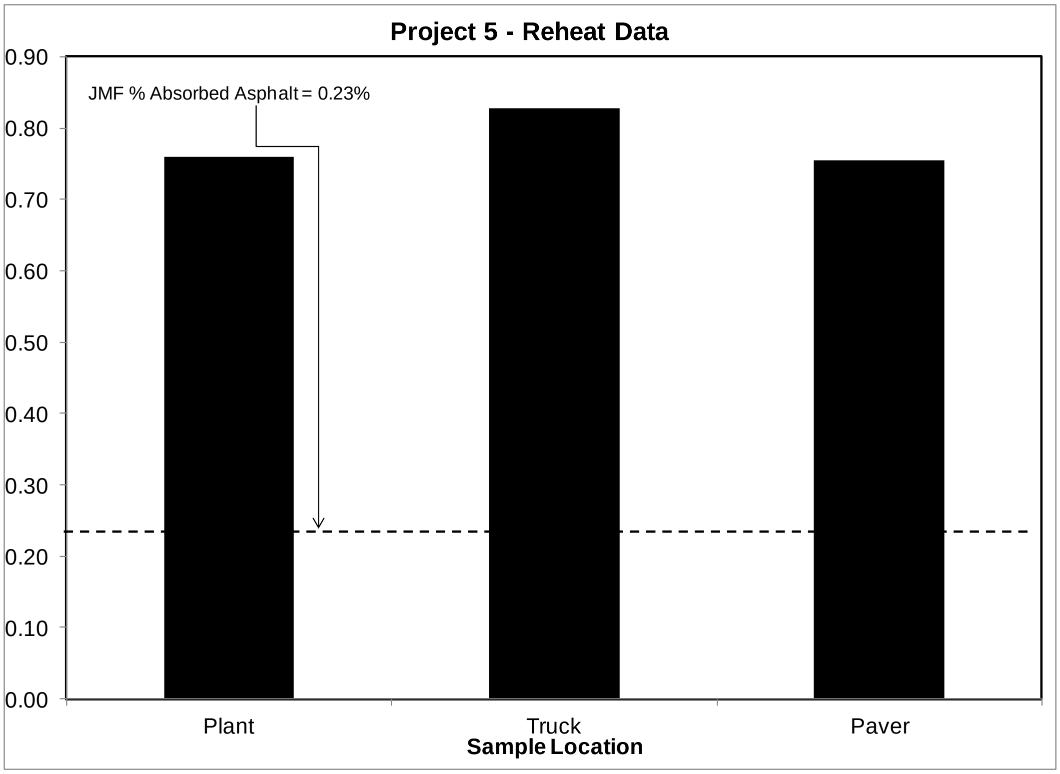

Figure 24: Average Percent Absorbed Asphalt at Each Sample Location - Project 5

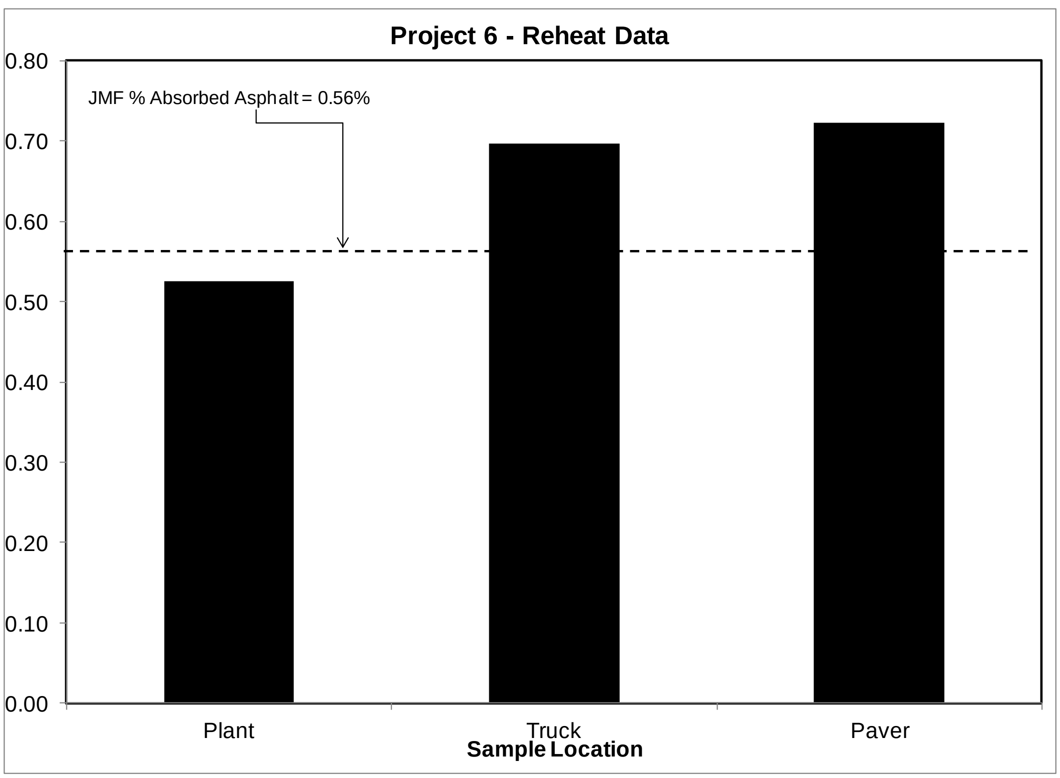

Figure 25: Average Percent Absorbed Asphalt at Each Sample Location - Project 6

An ANOVA was conducted on the Reheat Sample data to determine if the P_{ba} values were significantly different at the three sample locations. Table 11 presents the results of the ANOVA. Based upon Table 11, results of the ANOVA showed that both the Project and Sample location had a significant effect on the measured P_{ba} values (level of significance of 95 percent). Because of the significance of Sample location, a Tukey's multiple comparison test was again conducted to evaluate which of the sample locations were significantly different. Table 12 presents the results of the Tukey's multiple comparison test. The Tukey's multiple comparison test indicated that for the Reheat Sample data set, the average P_{ba} for the Plant and Truck sample locations were similar. Likewise, the average P_{ba} for the Truck and Paver sample locations were similar. However, the average P_{ba} for the Plant and Paver locations were significantly different. Similar to the Field Sample data, this analysis suggests that after the mix is produced, the longer it stays at an elevated temperature the amount of asphalt absorbed by the aggregate increases.

Table 11: Results of ANOVA on Percent Absorbed Asphalt - Reheat Samples

Source of Variation	df	Sum of Squares	Mean Squares	F-statistic	p-value	Significant?
Project	5	8.604	1.721	256.91	0.000	Yes
Sample Location	2	0.092	0.046	6.85	0.002	Yes
Interaction	10	0.142	0.014	2.13	0.037	Yes
Error	54	0.362	0.007			
Total	71	9.201				

Table 12: Results of Tukey's Multiple Comparison Test for Percent Absorbed Asphalt Data - Reheat Samples

Sample Location	Average P_{ba}	Tukey's Ranking*
Plant	0.83	A
Truck	0.88	AB
Paver	0.92	B

* Sample Locations with different Tukey's rankings are significantly difference at level of significance of 0.05.

Part of the research approach for the Reheat Samples was developed to determine the effect of asphalt absorption on the air voids of compacted samples. Recall that the Reheat samples were compacted in a Superpave gyratory compactor to the appropriate design number of gyrations for the project. The purpose of conducting this testing was to evaluate whether the air void content of the compacted samples would increase if the P_{ba} increased through the production and construction process (i.e., from the Plant samples to the Paver samples). Figure 26 illustrates the average air void content of the compacted specimens at each sample location. For some projects, the average air void content decreased from the Plant sample to the Paver sample. Conversely, for some projects the average air void content increased from the plant sample to the Paver sample. Based on Figure 26, no discernible trend was observed for the influence of sample location on air voids.

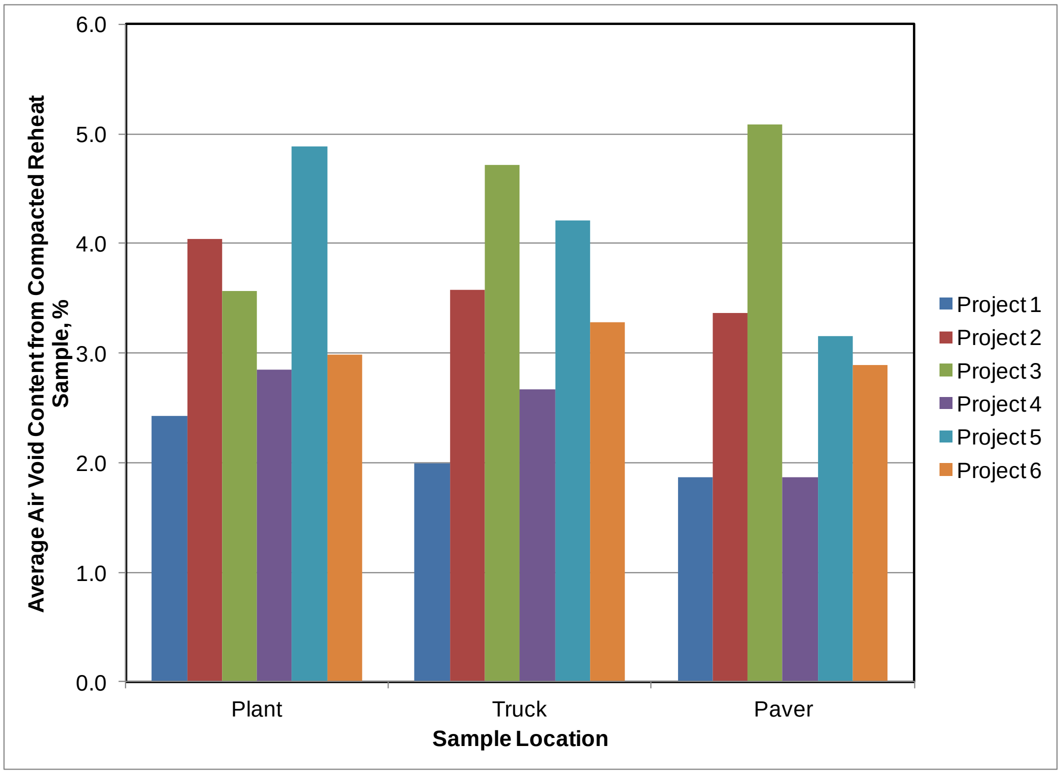

Figure 26: Average Air Void Content by Sample Location - Reheat Samples

CHAPTER 7 – CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The objective of the research was to evaluate the amount of asphalt absorption that takes place through the production and construction process. To accomplish this objective, plant produced HMA was sampled in four different locations through the production and construction process. Two types of samples were obtained which were categorized as Field Samples and Reheat Samples. For the Field Samples, ice was placed on the hot HMA mix immediately after sampling. This was done to minimize the amount of asphalt binder absorbed by the aggregates after sampling. The Reheat Samples were placed into 5-gallon metal buckets and subsequently tested in the laboratory. Predominately, laboratory testing for the Field and Reheat Samples was conducted to determine the amount of asphalt absorbed by the aggregates. Based upon the sampling and testing conducted, the following conclusions are provided:

- The predominant aggregate types used in the production of HMA in Mississippi are gravel and limestone.
- The percentage of water absorption values encountered for Mississippi HMA mixes during this project ranged from 0.09 to 4.37 percent. Approximately 60 percent of the aggregates had a water absorption value between 0.5 and 1.75 percent. Roughly 25 percent of the aggregates had a water absorption value above 1.75 percent.
- The asphalt binder content of plant produced mix was generally slightly higher than the asphalt binder content provided on the JMF.
- A trend of increasing aggregate effective specific gravity as the HMA was held at an elevated temperature after production was observed. This was true for both the Field Samples and Reheat Samples.
- The aggregate effective specific gravity obtained for the Field Samples was generally higher than the JMF. Only two projects showed aggregate effective specific gravity values that were equal to the effective specific gravity at some point in the production process.
- A trend of increasing absorbed asphalt through the production and construction process was observed for both the Field and Reheat Samples.
- The percent absorbed asphalt values presented on the JMFs were, for the most part, much less than those determined for the plant produced samples. This was true for both the Field and Reheat Samples. It is hypothesized that these differences were caused by combined bulk specific gravity values presented on the JMF being non-representative of the materials used during production when samples were obtained.
- For the Field Samples, samples obtained at the Plant and Truck sampling locations exhibited similar percentages of absorbed asphalt binder. The Paver and Core samples also had similar percentages of absorbed asphalt binder. However, significant differences were observed between the Plant/Truck samples and Paver/Core samples. Therefore, for

the HMA projects sampled during this project, most of the asphalt absorption took placed during mix transportation.

- The project was unsuccessful in determining the point in the production and construction process at which Mississippi's mix design procedure accounts for asphalt absorption. This is concluded because the percentages of absorbed asphalt binder contained on the JMF could not be consistently replicated based upon the testing of plant produced mix at varying locations through the production and construction process. The percent absorbed asphalt was higher for the plant produced HMA.
- No consistent trend could be found between the average air void contents of the Reheat Samples and sample location.

7.2 Recommendations

Based upon the above conclusions for this project, the following recommendations are provided:

- The aggregate bulk specific gravity test should be conducted on the final blend of aggregates. This research project suggested that the bulk specific gravity value presented on the respective JMFs may not have been representative. Combining the variabilities of aggregate bulk specific gravity tests on a number of stockpiles may result in a non-representative combined bulk specific gravity value. Conducting the bulk specific gravity test on the final blend may reduce some of this variability. This is especially needed because of the importance of aggregate bulk specific gravity in the calculation of voids in mineral aggregate (VMA). MDOT uses VMA as the indicator of HMA mix durability during mix design. Non-representative combined bulk specific gravity values may lead to under-asphalted HMA mixes.
- Because this project was unsuccessful in determining the point in the production and construction process at which Mississippi's mix design procedure accounts for asphalt absorption, further research is needed to define this point. In all instances during this project, the percent absorbed asphalt values obtained at the Paver and Core locations were higher than that presented on the JMF.

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APPENDIX A

TEST RESULTS FOR FIELD SAMPLES

State Study 245 - Aggregate Absorption in HMA Mixtures
Work Assignment BCD-MT 2010-07

Project No.: 1
Highway/Interstate: I-20

	Plant 1	Plant 2	Plant 3	Plant 4	Avg.
Time Sampled	9:20 AM	10:50 AM	12:45 PM	1:20 PM	
Theoretical Max. Gravity 1, Gmm1	2.389	2.393	2.397	2.388	
Theoretical Max. Gravity 2, Gmm2	2.392	2.385	2.408	2.408	2.395
Asphalt Content (Pb), %	5.19	5.15	5.07	5.24	5.16
Effective Specific Gravity, Gse	2.579	2.575	2.589	2.590	2.583
Aggregate Bulk Specific Gravity (Gsb)	2.520	2.520	2.520	2.520	
Absorbed Asphalt Content (Pba), %	0.93	0.87	1.08	1.10	1.00

	Truck 1	Truck 2	Truck 3	Truck 4	Avg.
Time Sampled	8:45 AM	10:15 AM	11:30 AM	1:00 PM	
Theoretical Max. Gravity 1, Gmm1	2.386	2.394	2.399	2.391	
Theoretical Max. Gravity 2, Gmm2	2.398	2.394	2.403	2.406	2.396
Asphalt Content (Pb), %	5.26	5.21	5.34	5.17	5.25
Effective Specific Gravity, Gse	2.584	2.584	2.598	2.588	2.588
Aggregate Bulk Specific Gravity (Gsb)	2.520	2.520	2.520	2.520	
Absorbed Asphalt Content (Pba), %	1.00	1.01	1.22	1.07	1.07

	Paver 1	Paver 2	Paver 3	Paver 4	Avg.
Time Sampled	8:55 AM	9:55 AM	11:50 AM	1:00 PM	
Theoretical Max. Gravity 1, Gmm1	2.402	2.390	2.412	2.405	
Theoretical Max. Gravity 2, Gmm2	2.393	2.406	2.411	2.408	2.403
Asphalt Content (Pb), %	5.25	5.30	5.24	5.29	5.27
Effective Specific Gravity, Gse	2.590	2.593	2.607	2.603	2.598
Aggregate Bulk Specific Gravity (Gsb)	2.520	2.520	2.520	2.520	
Absorbed Asphalt Content (Pba), %	1.10	1.14	1.35	1.29	1.22

	Core 1	Core 2	Core 3	Core 4	Avg.
Theoretical Max. Gravity 1, Gmm1	2.388	2.410	2.405	2.405	
Theoretical Max. Gravity 2, Gmm2	2.394	2.417	2.401	2.414	2.404
Asphalt Content (Pb), %	5.39	5.35	5.10	5.13	5.24
Effective Specific Gravity, Gse	2.588	2.614	2.590	2.600	2.598
Aggregate Bulk Specific Gravity (Gsb)	2.520	2.520	2.520	2.520	
Absorbed Asphalt Content (Pba), %	1.06	1.46	1.11	1.25	1.22
Bulk Specific Gravity - Core 1, Gmb	2.175	2.192	2.182	2.154	
Bulk Specific Gravity - Core 2, Gmb	2.181	2.178	2.181	2.147	
Bulk Specific Gravity - Core 3, Gmb	2.178	2.188	2.185	2.149	2.174
Air Void Content - Core 1, %	9.03	9.18	9.20	10.60	
Air Void Content - Core 2, %	8.78	9.76	9.24	10.89	
Air Void Content - Core 3, %	8.91	9.34	9.07	10.81	9.57

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Work Assignment BCD-MT 2010-07

Project No.: 2
Highway/Interstate: HWY 84

	Plant 1	Plant 2	Plant 3	Plant 4	Avg.
Time Sampled	8:15 AM	10:30AM	11:15 AM	11:20 AM	
Theoretical Max. Gravity 1, Gmm1	2.349	2.325	2.345	2.355	
Theoretical Max. Gravity 2, Gmm2	2.355	2.322	2.343	2.359	2.344
Asphalt Content (Pb), %	5.71	6.60	5.86	5.74	5.98
Effective Specific Gravity, Gse	2.552	2.552	2.548	2.560	2.553
Aggregate Bulk Specific Gravity (Gsb)	2.472	2.472	2.472	2.472	
Absorbed Asphalt Content (Pba), %	1.31	1.30	1.24	1.42	1.32

	Truck 1	Truck 2	Truck 3	Truck 4	Avg.
Time Sampled	8:45 AM	9:10AM	11:45 AM	2:00 PM	
Theoretical Max. Gravity 1, Gmm1	2.360	2.340	2.348	2.360	
Theoretical Max. Gravity 2, Gmm2	2.351	2.347	2.359	2.359	2.353
Asphalt Content (Pb), %	5.94	6.00	5.91	5.60	5.86
Effective Specific Gravity, Gse	2.566	2.554	2.562	2.557	2.560
Aggregate Bulk Specific Gravity (Gsb)	2.472	2.472	2.472	2.472	
Absorbed Asphalt Content (Pba), %	1.52	1.32	1.46	1.38	1.42

	Paver 1	Paver 2	Paver 3	Paver 4	Avg.
Time Sampled	9:10AM	10:45AM	11:45AM	12:45PM	
Theoretical Max. Gravity 1, Gmm1	2.360	2.360	2.345	2.359	
Theoretical Max. Gravity 2, Gmm2	2.362	2.364	2.349	2.348	2.356
Asphalt Content (Pb), %	5.79	5.72	6.25	5.93	5.92
Effective Specific Gravity, Gse	2.567	2.565	2.568	2.563	2.566
Aggregate Bulk Specific Gravity (Gsb)	2.472	2.472	2.472	2.472	
Absorbed Asphalt Content (Pba), %	1.53	1.51	1.55	1.48	1.52

	Core 1	Core 2	Core 3	Core 4	Avg.
Theoretical Max. Gravity 1, Gmm1	2.348	2.355	2.335	2.340	
Theoretical Max. Gravity 2, Gmm2	2.351	2.356	2.332	2.345	2.345
Asphalt Content (Pb), %	6.16	6.01	6.42	6.20	6.20
Effective Specific Gravity, Gse	2.568	2.569	2.558	2.560	2.564
Aggregate Bulk Specific Gravity (Gsb)	2.472	2.472	2.472	2.472	
Absorbed Asphalt Content (Pba), %	1.54	1.57	1.39	1.43	1.48
Bulk Specific Gravity - Core 1, Gmb	2.138	2.171	2.125	2.162	
Bulk Specific Gravity - Core 2, Gmb	2.130	2.180	2.130	2.171	
Bulk Specific Gravity - Core 3, Gmb	2.146	2.169	2.120	2.150	2.149
Air Void Content - Core 1, %	9.00	7.83	8.94	7.71	
Air Void Content - Core 2, %	9.34	7.45	8.72	7.32	
Air Void Content - Core 3, %	8.66	7.92	9.15	8.22	8.35

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Project No.: 3
Highway/Interstate: I-59

	Plant 1	Plant 2	Plant 3	Plant 4	Avg.
Time Sampled	8:35 AM	10:00 AM	12:05 PM	1:50 PM	
Theoretical Max. Gravity 1, Gmm1	2.442	2.462	2.444	2.481	
Theoretical Max. Gravity 2, Gmm2	2.431	2.463	2.453	2.479	2.457
Asphalt Content (Pb), %	5.91	5.11	5.64	5.10	5.44
Effective Specific Gravity, Gse	2.668	2.664	2.671	2.685	2.672
Aggregate Bulk Specific Gravity (Gsb)	2.650	2.650	2.650	2.650	
Absorbed Asphalt Content (Pba), %	0.26	0.20	0.30	0.51	0.32

	Truck 1	Truck 2	Truck 3	Truck 4	Avg.
Time Sampled	9:15 AM	10:55 AM	1:15 PM	2:30 PM	
Theoretical Max. Gravity 1, Gmm1	2.455	2.461	2.472	2.474	
Theoretical Max. Gravity 2, Gmm2	2.454	2.464	2.471	2.472	2.465
Asphalt Content (Pb), %	5.31	5.51	4.99	4.82	5.16
Effective Specific Gravity, Gse	2.663	2.682	2.670	2.664	2.670
Aggregate Bulk Specific Gravity (Gsb)	2.650	2.650	2.650	2.650	
Absorbed Asphalt Content (Pba), %	0.19	0.46	0.29	0.20	0.29

	Paver 1	Paver 2	Paver 3	Paver 4	Avg.
Time Sampled	11:15 AM	10:45AM			
Theoretical Max. Gravity 1, Gmm1	2.473	2.479			
Theoretical Max. Gravity 2, Gmm2	2.474	2.476			2.476
Asphalt Content (Pb), %	5.27	5.18			5.23
Effective Specific Gravity, Gse	2.685	2.686			2.685
Aggregate Bulk Specific Gravity (Gsb)	2.650	2.650			
Absorbed Asphalt Content (Pba), %	0.50	0.51			0.51

	Core 1	Core 2	Core 3	Core 4	Avg.
Theoretical Max. Gravity 1, Gmm1					
Theoretical Max. Gravity 2, Gmm2					#DIV/0!
Asphalt Content (Pb), %					#DIV/0!
Effective Specific Gravity, Gse					#DIV/0!
Aggregate Bulk Specific Gravity (Gsb)					
Absorbed Asphalt Content (Pba), %					#DIV/0!
Bulk Specific Gravity - Core 1, Gmb					
Bulk Specific Gravity - Core 2, Gmb					
Bulk Specific Gravity - Core 3, Gmb					#DIV/0!
Air Void Content - Core 1, %					
Air Void Content - Core 2, %					
Air Void Content - Core 3, %					#DIV/0!

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Work Assignment BCD-MT 2010-07

Project No.: 4
Highway/Interstate: HWY 45

	Plant 1	Plant 2	Plant 3	Plant 4	Avg.
Time Sampled	8:00AM	1:10PM	2:40PM		
Theoretical Max. Gravity 1, Gmm1	2.324	2.323	2.325	2.324	
Theoretical Max. Gravity 2, Gmm2	2.328	2.321	2.330	2.336	2.326
Asphalt Content (Pb), %	5.97	6.27	6.05	5.98	6.07
Effective Specific Gravity, Gse	2.530	2.537	2.535	2.536	2.535
Aggregate Bulk Specific Gravity (Gsb)	2.479	2.479	2.479	2.479	
Absorbed Asphalt Content (Pba), %	0.84	0.95	0.92	0.92	0.91

	Truck 1	Truck 2	Truck 3	Truck 4	Avg.
Time Sampled	8:10AM	1:15PM	2:00PM	3:00 PM	
Theoretical Max. Gravity 1, Gmm1	2.329	2.330	2.328	2.334	
Theoretical Max. Gravity 2, Gmm2	2.321	2.331	2.324	2.331	2.329
Asphalt Content (Pb), %	5.95	6.19	5.95	6.10	6.05
Effective Specific Gravity, Gse	2.528	2.545	2.529	2.544	2.537
Aggregate Bulk Specific Gravity (Gsb)	2.479	2.479	2.479	2.479	
Absorbed Asphalt Content (Pba), %	0.80	1.07	0.82	1.05	0.94

	Paver 1	Paver 2	Paver 3	Paver 4	Avg.
Time Sampled	8:45AM	1:30PM	2:15PM	3:00 PM	
Theoretical Max. Gravity 1, Gmm1	2.331	2.319	2.328	2.330	
Theoretical Max. Gravity 2, Gmm2	2.335	2.326	2.329	2.330	2.329
Asphalt Content (Pb), %	6.01	5.99	6.24	6.09	6.08
Effective Specific Gravity, Gse	2.541	2.527	2.544	2.540	2.538
Aggregate Bulk Specific Gravity (Gsb)	2.479	2.479	2.479	2.479	
Absorbed Asphalt Content (Pba), %	1.00	0.78	1.06	0.99	0.96

	Core 1	Core 2	Core 3	Core 4	Avg.
Theoretical Max. Gravity 1, Gmm1	2.323	2.323	2.319	2.326	
Theoretical Max. Gravity 2, Gmm2	2.322	2.323	2.314	2.324	2.322
Asphalt Content (Pb), %	6.22	6.32	6.40	6.35	6.32
Effective Specific Gravity, Gse	2.536	2.540	2.535	2.544	2.539
Aggregate Bulk Specific Gravity (Gsb)	2.479	2.479	2.479	2.479	
Absorbed Asphalt Content (Pba), %	0.92	1.00	0.92	1.06	0.97
Bulk Specific Gravity - Core 1, Gmb	2.143	2.165	2.145	2.188	
Bulk Specific Gravity - Core 2, Gmb	2.146	2.158	2.161	2.185	
Bulk Specific Gravity - Core 3, Gmb	2.163	2.158	2.166	2.185	2.164
Air Void Content - Core 1, %	7.73	6.80	7.40	5.89	
Air Void Content - Core 2, %	7.60	7.10	6.71	6.02	
Air Void Content - Core 3, %	6.87	7.10	6.50	6.02	6.81

State Study 245 - Aggregate Absorption in HMA Mixtures
Work Assignment BCD-MT 2010-07

Project No.:	5
Highway/Interstate:	I-55

	Plant 1	Plant 2	Plant 3	Plant 4	Avg.
Time Sampled	9:00AM	10:30AM		8:00AM	
Theoretical Max. Gravity 1, Gmm1	2.399	2.403	2.401	2.392	
Theoretical Max. Gravity 2, Gmm2	2.405	2.410	2.394	2.392	2.400
Asphalt Content (Pb), %	4.47	4.31	4.38	4.54	4.43
Effective Specific Gravity, Gse	2.563	2.562	2.554	2.554	2.559
Aggregate Bulk Specific Gravity (Gsb)	2.511	2.511	2.511	2.511	
Absorbed Asphalt Content (Pba), %	0.83	0.82	0.69	0.69	0.76

	Truck 1	Truck 2	Truck 3	Truck 4	Avg.
Time Sampled	9:45AM	11:00AM		3:20PM	
Theoretical Max. Gravity 1, Gmm1	2.401	2.391	2.402	2.402	
Theoretical Max. Gravity 2, Gmm2	2.395	2.389	2.406	2.400	2.398
Asphalt Content (Pb), %	4.72	4.52	4.54	4.29	4.52
Effective Specific Gravity, Gse	2.569	2.551	2.569	2.555	2.561
Aggregate Bulk Specific Gravity (Gsb)	2.511	2.511	2.511	2.511	
Absorbed Asphalt Content (Pba), %	0.92	0.64	0.91	0.70	0.79

	Paver 1	Paver 2	Paver 3	Paver 4	Avg.
Time Sampled					
Theoretical Max. Gravity 1, Gmm1	2.382	2.384	2.401	2.407	
Theoretical Max. Gravity 2, Gmm2	2.378	2.389	2.406	2.401	2.394
Asphalt Content (Pb), %	4.95	4.64	4.49	4.31	4.60
Effective Specific Gravity, Gse	2.556	2.552	2.566	2.559	2.558
Aggregate Bulk Specific Gravity (Gsb)	2.511	2.511	2.511	2.511	
Absorbed Asphalt Content (Pba), %	0.72	0.65	0.87	0.77	0.75

	Core 1	Core 2	Core 3	Core 4	Avg.
Theoretical Max. Gravity 1, Gmm1	2.383	2.393	2.397	2.394	
Theoretical Max. Gravity 2, Gmm2	2.384	2.396	2.394	2.402	2.393
Asphalt Content (Pb), %	4.80	4.60	4.70	4.83	4.73
Effective Specific Gravity, Gse	2.554	2.560	2.565	2.573	2.563
Aggregate Bulk Specific Gravity (Gsb)	2.511	2.511	2.511	2.511	
Absorbed Asphalt Content (Pba), %	0.69	0.78	0.86	0.99	0.83
Bulk Specific Gravity - Core 1, Gmb	2.225	2.238	2.206	2.232	
Bulk Specific Gravity - Core 2, Gmb	2.232	2.239	2.208	2.227	
Bulk Specific Gravity - Core 3, Gmb	2.231	2.239	2.180	2.234	2.224
Air Void Content - Core 1, %	6.65	6.54	7.91	6.92	
Air Void Content - Core 2, %	6.36	6.49	7.83	7.13	
Air Void Content - Core 3, %	6.40	6.49	9.00	6.84	7.05

State Study 245 - Aggregate Absorption in HMA Mixtures
Work Assignment BCD-MT 2010-07

Project No.:	6
Highway/Interstate:	HWY 43

	Plant 1	Plant 2	Plant 3	Plant 4	Avg.
Time Sampled					
Theoretical Max. Gravity 1, Gmm1	2.354	2.353	2.370	2.368	
Theoretical Max. Gravity 2, Gmm2	2.369	2.355	2.373	2.361	2.363
Asphalt Content (Pb), %	5.71	5.72	5.65	5.55	5.66
Effective Specific Gravity, Gse	2.564	2.555	2.574	2.562	2.564
Aggregate Bulk Specific Gravity (Gsb)	2.522	2.522	2.522	2.522	
Absorbed Asphalt Content (Pba), %	0.67	0.53	0.83	0.63	0.66

	Truck 1	Truck 2	Truck 3	Truck 4	Avg.
Time Sampled					
Theoretical Max. Gravity 1, Gmm1	2.369	2.354	2.365	2.371	
Theoretical Max. Gravity 2, Gmm2	2.361	2.351	2.362	2.369	2.363
Asphalt Content (Pb), %	5.58	5.75	5.81	5.81	5.74
Effective Specific Gravity, Gse	2.563	2.555	2.571	2.579	2.567
Aggregate Bulk Specific Gravity (Gsb)	2.522	2.522	2.522	2.522	
Absorbed Asphalt Content (Pba), %	0.66	0.52	0.77	0.90	0.71

	Paver 1	Paver 2	Paver 3	Paver 4	Avg.
Time Sampled					
Theoretical Max. Gravity 1, Gmm1	2.371	2.367	2.367	2.365	
Theoretical Max. Gravity 2, Gmm2	2.373	2.370	2.362	2.363	2.367
Asphalt Content (Pb), %	5.77	5.66	5.72	5.80	5.74
Effective Specific Gravity, Gse	2.580	2.571	2.568	2.571	2.573
Aggregate Bulk Specific Gravity (Gsb)	2.522	2.522	2.522	2.522	
Absorbed Asphalt Content (Pba), %	0.91	0.77	0.74	0.78	0.80

	Core 1	Core 2	Core 3	Core 4	Avg.
Theoretical Max. Gravity 1, Gmm1	2.369	2.358	2.360	2.352	
Theoretical Max. Gravity 2, Gmm2	2.361	2.355	2.355	2.361	2.359
Asphalt Content (Pb), %	5.81	5.95	5.86	5.92	5.89
Effective Specific Gravity, Gse	2.573	2.568	2.565	2.567	2.568
Aggregate Bulk Specific Gravity (Gsb)	2.522	2.522	2.522	2.522	
Absorbed Asphalt Content (Pba), %	0.80	0.73	0.69	0.71	0.73
Bulk Specific Gravity - Core 1, Gmb	2.214	2.203	2.207	2.191	
Bulk Specific Gravity - Core 2, Gmb	2.210	2.196	2.204	2.192	
Bulk Specific Gravity - Core 3, Gmb	2.215	2.185	2.211	2.187	2.201
Air Void Content - Core 1, %	6.38	6.51	6.38	7.02	
Air Void Content - Core 2, %	6.55	6.81	6.51	6.98	
Air Void Content - Core 3, %	6.34	7.28	6.21	7.19	6.68

APPENDIX B
TEST RESULTS FROM REHEAT SAMPLES

State Study 245 - Aggregate Absorption in HMA Mixtures
Work Assignment BCD-MT 2010-07

Project No.: 1
Highway/Interstate: I-20

	Plant 1	Plant 2	Plant 3	Plant 4	Avg.
Time Sampled	9:20 AM	10:50 AM	12:45 PM	1:20 PM	
Theoretical Max. Gravity 1, Gmm1	2.399	2.404	2.405	2.403	
Theoretical Max. Gravity 2, Gmm2	2.409	2.400	2.402	2.398	2.403
Asphalt Content (Pb), %	5.19	5.15	5.07	5.24	5.16
Effective Specific Gravity, Gse	2.595	2.591	2.590	2.593	2.592
Aggregate Bulk Specific Gravity (Gsb)	2.52	2.52	2.52	2.52	
Absorbed Asphalt Content (Pba), %	1.18	1.12	1.10	1.15	1.14
Bulk Specific Gravity - Reheat, Gmb1	2.353	2.346	2.348	2.335	
Bulk Specific Gravity - Reheat, Gmb2	2.350	2.345	2.347	2.329	2.344
Air Void Content 2- Reheat, %	2.12	2.33	2.31	2.73	
Air Void Content 1- Reheat, %	2.25	2.37	2.35	2.98	2.43

	Truck 1	Truck 2	Truck 3	Truck 4	Avg.
Time Sampled	8:45 AM	10:15 AM	11:30 AM	1:00 PM	
Theoretical Max. Gravity 1, Gmm1	2.390	2.405	2.388	2.397	
Theoretical Max. Gravity 2, Gmm2	2.396	2.398	2.394	2.399	2.396
Asphalt Content (Pb), %	5.26	5.21	5.34	5.17	5.25
Effective Specific Gravity, Gse	2.585	2.593	2.586	2.587	2.588
Aggregate Bulk Specific Gravity (Gsb)	2.52	2.52	2.52	2.52	
Absorbed Asphalt Content (Pba), %	1.02	1.15	1.03	1.06	1.06
Bulk Specific Gravity - Reheat, Gmb1	2.358	2.337	2.357	2.357	
Bulk Specific Gravity - Reheat, Gmb2	2.364	2.341	2.350	2.357	2.353
Air Void Content 2- Reheat, %	1.46	2.69	1.42	1.71	
Air Void Content 1- Reheat, %	1.21	2.52	1.71	1.71	1.80

	Paver 1	Paver 2	Paver 3	Paver 4	Avg.
Time Sampled	8:55 AM	9:55 AM	11:50 AM	1:00 PM	
Theoretical Max. Gravity 1, Gmm1	2.398	2.389	2.409	2.405	
Theoretical Max. Gravity 2, Gmm2	2.401	2.403	2.409	2.410	2.403
Asphalt Content (Pb), %	5.25	5.30	5.24	5.29	5.27
Effective Specific Gravity, Gse	2.592	2.590	2.604	2.604	2.598
Aggregate Bulk Specific Gravity (Gsb)	2.52	2.52	2.52	2.52	
Absorbed Asphalt Content (Pba), %	1.14	1.10	1.31	1.31	1.21
Bulk Specific Gravity - Reheat, Gmb1	2.373	2.355	2.337	2.355	
Bulk Specific Gravity - Reheat, Gmb2	2.369	2.361	2.346	2.369	2.358
Air Void Content 2- Reheat, %	1.10	1.71	2.99	2.18	
Air Void Content 1- Reheat, %	1.27	1.46	2.62	1.60	1.87

State Study 245 - Aggregate Absorption in HMA Mixtures
Work Assignment BCD-MT 2010-07

Project No.:	2
Highway/Interstate:	HWY 84

	Plant 1	Plant 2	Plant 3	Plant 4	Avg.
Time Sampled	8:15 AM	10:30 AM	11:15 AM	11:20	
Theoretical Max. Gravity 1, Gmm1	2.355	2.325	2.351	2.361	
Theoretical Max. Gravity 2, Gmm2	2.358	2.323	2.356	2.360	2.349
Asphalt Content (Pb), %	5.71	6.60	5.86	5.74	5.98
Effective Specific Gravity, Gse	2.558	2.553	2.560	2.564	2.559
Aggregate Bulk Specific Gravity (Gsb)	2.472	2.472	2.472	2.472	
Absorbed Asphalt Content (Pba), %	1.39	1.31	1.43	1.49	1.41
Bulk Specific Gravity - Reheat, Gmb1	2.258	2.221	2.258	2.281	
Bulk Specific Gravity - Reheat, Gmb2	2.262	2.223	2.259	2.269	2.254
Air Void Content 2- Reheat, %	4.18	4.43	4.06	3.37	
Air Void Content 1- Reheat, %	4.01	4.35	4.02	3.88	4.04

	Truck 1	Truck 2	Truck 3	Truck 4	Avg.
Time Sampled	8:45 AM	9:00 AM	11:45 AM	2:00 PM	
Theoretical Max. Gravity 1, Gmm1	2.359	2.357	2.349	2.365	
Theoretical Max. Gravity 2, Gmm2	2.354	2.357	2.356	2.364	2.358
Asphalt Content (Pb), %	5.94	6.00	5.91	5.60	5.86
Effective Specific Gravity, Gse	2.567	2.571	2.561	2.564	2.566
Aggregate Bulk Specific Gravity (Gsb)	2.472	2.472	2.472	2.472	
Absorbed Asphalt Content (Pba), %	1.54	1.59	1.44	1.48	1.51
Bulk Specific Gravity - Reheat, Gmb1	2.264	2.282	2.270	2.276	
Bulk Specific Gravity - Reheat, Gmb2	2.261	2.281	2.274	2.278	2.273
Air Void Content 2- Reheat, %	3.93	3.18	3.51	3.74	
Air Void Content 1- Reheat, %	4.05	3.22	3.34	3.66	3.58

	Paver 1	Paver 2	Paver 3	Paver 4	Avg.
Time Sampled	8:55 AM	9:55 AM	11:50 AM	1:00 PM	
Theoretical Max. Gravity 1, Gmm1	2.355	2.358	2.341	2.356	
Theoretical Max. Gravity 2, Gmm2	2.361	2.365	2.345	2.357	2.355
Asphalt Content (Pb), %	5.79	5.72	6.25	5.93	5.92
Effective Specific Gravity, Gse	2.563	2.565	2.563	2.567	2.565
Aggregate Bulk Specific Gravity (Gsb)	2.472	2.472	2.472	2.472	
Absorbed Asphalt Content (Pba), %	1.47	1.50	1.47	1.53	1.49
Bulk Specific Gravity - Reheat, Gmb1	2.265	2.273	2.279	2.286	
Bulk Specific Gravity - Reheat, Gmb2	2.264	2.274	2.276	2.287	2.276
Air Void Content 2- Reheat, %	3.94	3.75	2.73	2.99	
Air Void Content 1- Reheat, %	3.99	3.71	2.86	2.95	3.36

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Project No.:	3
Highway/Interstate:	I-59

	Plant 1	Plant 2	Plant 3	Plant 4	Avg.
Time Sampled	8:15 AM	10:00 AM	11:15 AM	11:20	
Theoretical Max. Gravity 1, Gmm1	2.441	2.466	2.444	2.474	
Theoretical Max. Gravity 2, Gmm2	2.446	2.465	2.457	2.475	2.459
Asphalt Content (Pb), %	5.91	5.11	5.64	5.10	5.44
Effective Specific Gravity, Gse	2.677	2.668	2.673	2.678	2.674
Aggregate Bulk Specific Gravity (Gsb)	2.650	2.650	2.650	2.650	
Absorbed Asphalt Content (Pba), %	0.38	0.26	0.33	0.41	0.35
Bulk Specific Gravity - Reheat, Gmb1	2.366	2.352	2.366	2.366	
Bulk Specific Gravity - Reheat, Gmb2	2.375	2.358	2.369	2.365	2.365
Air Void Content 2- Reheat, %	3.17	4.60	3.45	4.38	
Air Void Content 1- Reheat, %	2.80	4.36	3.33	4.43	3.82

	Truck 1	Truck 2	Truck 3	Truck 4	Avg.
Time Sampled			1:15 PM	2:30 PM	
Theoretical Max. Gravity 1, Gmm1	2.460	2.464	2.480	2.474	
Theoretical Max. Gravity 2, Gmm2	2.456	2.467	2.478	2.472	2.469
Asphalt Content (Pb), %	5.31	5.51	4.99	4.82	5.16
Effective Specific Gravity, Gse	2.667	2.686	2.679	2.664	2.674
Aggregate Bulk Specific Gravity (Gsb)	2.650	2.650	2.650	2.650	
Absorbed Asphalt Content (Pba), %	0.25	0.52	0.42	0.20	0.35
Bulk Specific Gravity - Reheat, Gmb1	2.352	2.348	2.358	2.357	
Bulk Specific Gravity - Reheat, Gmb2	N/A	2.345	2.350	2.357	2.352
Air Void Content 2- Reheat, %	4.31	4.77	4.88	4.69	
Air Void Content 1- Reheat, %	N/A	4.89	5.20	4.69	4.78

	Paver 1	Paver 2	Paver 3	Paver 4	Avg.
Time Sampled					
Theoretical Max. Gravity 1, Gmm1	2.475	2.476			
Theoretical Max. Gravity 2, Gmm2	2.467	2.480			2.475
Asphalt Content (Pb), %	5.27	5.18			5.23
Effective Specific Gravity, Gse	2.682	2.686			2.684
Aggregate Bulk Specific Gravity (Gsb)	2.650	2.650			
Absorbed Asphalt Content (Pba), %	0.46	0.52			0.49
Bulk Specific Gravity - Reheat, Gmb1	2.345	2.350			
Bulk Specific Gravity - Reheat, Gmb2	2.361	2.339			2.349
Air Void Content 2- Reheat, %	5.10	5.17			
Air Void Content 1- Reheat, %	4.45	5.61			5.08

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Project No.: 4
Highway/Interstate: HWY 45

	Plant 1	Plant 2	Plant 3	Plant 4	Avg.
Time Sampled	8:00AM	1:10PM	2:40PM		
Theoretical Max. Gravity 1, Gmm1	2.319	2.314	2.325	2.332	
Theoretical Max. Gravity 2, Gmm2	2.320	2.319	2.324	2.328	2.323
Asphalt Content (Pb), %	5.97	6.27	6.05	5.98	6.07
Effective Specific Gravity, Gse	2.522	2.530	2.532	2.536	2.530
Aggregate Bulk Specific Gravity (Gsb)	2.479	2.479	2.479	2.479	
Absorbed Asphalt Content (Pba), %	0.71	0.83	0.86	0.92	0.83
Bulk Specific Gravity - Reheat, Gmb1	2.257	2.261	2.261	2.244	
Bulk Specific Gravity - Reheat, Gmb2	2.257	2.265	2.266	2.241	2.257
Air Void Content 2- Reheat, %	2.69	2.40	2.73	3.69	
Air Void Content 1- Reheat, %	2.69	2.22	2.52	3.82	2.85

	Truck 1	Truck 2	Truck 3	Truck 4	Avg.
Time Sampled	8:10AM	1:15PM	2:00PM	3:00 PM	
Theoretical Max. Gravity 1, Gmm1	2.319	2.319	2.323	2.330	
Theoretical Max. Gravity 2, Gmm2	2.324	2.311	2.329	2.326	2.323
Asphalt Content (Pb), %	5.95	6.19	5.95	6.10	6.05
Effective Specific Gravity, Gse	2.524	2.525	2.529	2.538	2.529
Aggregate Bulk Specific Gravity (Gsb)	2.479	2.479	2.479	2.479	
Absorbed Asphalt Content (Pba), %	0.73	0.75	0.82	0.96	0.82
Bulk Specific Gravity - Reheat, Gmb1	2.264	2.269	2.265	2.247	
Bulk Specific Gravity - Reheat, Gmb2	2.260	2.266	2.265	2.25	2.261
Air Void Content 2- Reheat, %	2.48	1.99	2.62	3.48	
Air Void Content 1- Reheat, %	2.65	2.12	2.62	3.35	2.66

	Paver 1	Paver 2	Paver 3	Paver 4	Avg.
Time Sampled	8:45AM	1:30PM	2:15PM	3:00 PM	
Theoretical Max. Gravity 1, Gmm1	2.326	2.325	2.320	2.320	
Theoretical Max. Gravity 2, Gmm2	2.324	2.324	2.323	2.324	2.323
Asphalt Content (Pb), %	6.01	5.99	6.24	6.09	6.08
Effective Specific Gravity, Gse	2.531	2.529	2.535	2.530	2.531
Aggregate Bulk Specific Gravity (Gsb)	2.479	2.479	2.479	2.479	
Absorbed Asphalt Content (Pba), %	0.84	0.82	0.92	0.83	0.85
Bulk Specific Gravity - Reheat, Gmb1	2.287	2.278	2.277	2.279	
Bulk Specific Gravity - Reheat, Gmb2	2.284	2.279	2.277	2.278	2.280
Air Void Content 2- Reheat, %	1.63	2.00	1.92	1.85	
Air Void Content 1- Reheat, %	1.76	1.96	1.92	1.89	1.87

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Project No.: 5
Highway/Interstate: I-55

	Plant 1	Plant 2	Plant 3	Plant 4	Avg.
Time Sampled					
Theoretical Max. Gravity 1, Gmm1	2.383	2.407	2.400	2.393	
Theoretical Max. Gravity 2, Gmm2	2.396	2.405	2.407	2.405	2.400
Asphalt Content (Pb), %	4.47	4.31	4.38	4.54	4.43
Effective Specific Gravity, Gse	2.549	2.562	2.562	2.563	2.559
Aggregate Bulk Specific Gravity (Gsb)	2.511	2.511	2.511	2.511	
Absorbed Asphalt Content (Pba), %	0.60	0.81	0.81	0.82	0.76
Bulk Specific Gravity - Reheat, Gmb1	2.279	2.294	2.276	2.280	
Bulk Specific Gravity - Reheat, Gmb2	2.283	2.286	2.281	2.279	2.282
Air Void Content 2- Reheat, %	4.62	4.66	5.30	4.96	
Air Void Content 1- Reheat, %	4.46	4.99	5.10	5.00	4.89

	Truck 1	Truck 2	Truck 3	Truck 4	Avg.
Time Sampled					
Theoretical Max. Gravity 1, Gmm1	2.398	2.398	2.405	2.407	
Theoretical Max. Gravity 2, Gmm2	2.396	2.390	2.407	2.402	2.400
Asphalt Content (Pb), %	4.72	4.52	4.49	4.29	4.51
Effective Specific Gravity, Gse	2.568	2.556	2.569	2.559	2.563
Aggregate Bulk Specific Gravity (Gsb)	2.511	2.511	2.511	2.511	
Absorbed Asphalt Content (Pba), %	0.90	0.72	0.92	0.77	0.83
Bulk Specific Gravity - Reheat, Gmb1	2.304	2.307	2.305	2.275	
Bulk Specific Gravity - Reheat, Gmb2	2.311	2.312	2.301	2.279	2.299
Air Void Content 2- Reheat, %	3.88	3.63	4.20	5.39	
Air Void Content 1- Reheat, %	3.59	3.43	4.36	5.22	4.21

	Paver 1	Paver 2	Paver 3	Paver 4	Avg.
Time Sampled					
Theoretical Max. Gravity 1, Gmm1	2.385	2.383	2.397	2.409	
Theoretical Max. Gravity 2, Gmm2	2.384	2.388	2.401	2.395	2.393
Asphalt Content (Pb), %	5.02	4.64	4.52	4.31	4.62
Effective Specific Gravity, Gse	2.565	2.551	2.562	2.557	2.558
Aggregate Bulk Specific Gravity (Gsb)	2.511	2.511	2.511	2.511	
Absorbed Asphalt Content (Pba), %	0.85	0.63	0.81	0.73	0.76
Bulk Specific Gravity - Reheat, Gmb1	2.321	2.321	2.314	2.314	
Bulk Specific Gravity - Reheat, Gmb2	2.324	2.324	2.313	2.307	2.317
Air Void Content 2- Reheat, %	2.66	2.70	3.54	3.66	
Air Void Content 1- Reheat, %	2.54	2.58	3.58	3.96	3.15

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Project No.:	6
Highway/Interstate:	HWY 43

	Plant 1	Plant 2	Plant 3	Plant 4	Avg.
Time Sampled					
Theoretical Max. Gravity 1, Gmm1	2.353	2.354	2.354	2.360	
Theoretical Max. Gravity 2, Gmm2	2.361	2.350	2.354	2.360	2.356
Asphalt Content (Pb), %	5.71	5.72	5.65	5.55	5.66
Effective Specific Gravity, Gse	2.559	2.553	2.553	2.556	2.555
Aggregate Bulk Specific Gravity (Gsb)	2.522	2.522	2.522	2.522	
Absorbed Asphalt Content (Pba), %	0.58	0.49	0.49	0.54	0.52
Bulk Specific Gravity - Reheat, Gmb1	2.300	2.298	2.274	2.281	
Bulk Specific Gravity - Reheat, Gmb2	2.290	2.286	2.269	2.285	2.285
Air Void Content 2- Reheat, %	2.42	2.30	3.40	3.35	
Air Void Content 1- Reheat, %	2.84	2.81	3.61	3.18	2.99

	Truck 1	Truck 2	Truck 3	Truck 4	Avg.
Time Sampled					
Theoretical Max. Gravity 1, Gmm1	2.364	2.359	2.357	2.362	
Theoretical Max. Gravity 2, Gmm2	2.369	2.367	2.360	2.359	2.362
Asphalt Content (Pb), %	5.58	5.75	5.81	5.81	5.74
Effective Specific Gravity, Gse	2.565	2.568	2.565	2.567	2.566
Aggregate Bulk Specific Gravity (Gsb)	2.522	2.522	2.522	2.522	
Absorbed Asphalt Content (Pba), %	0.68	0.72	0.68	0.71	0.70
Bulk Specific Gravity - Reheat, Gmb1	2.302	2.256	2.290	2.299	
Bulk Specific Gravity - Reheat, Gmb2	2.293	2.248	2.293	2.296	2.285
Air Void Content 2- Reheat, %	2.73	4.53	2.90	2.61	
Air Void Content 1- Reheat, %	3.11	4.87	2.78	2.73	3.28

	Paver 1	Paver 2	Paver 3	Paver 4	Avg.
Time Sampled					
Theoretical Max. Gravity 1, Gmm1	2.368	2.363	2.362	2.358	
Theoretical Max. Gravity 2, Gmm2	2.373	2.366	2.360	2.356	2.363
Asphalt Content (Pb), %	5.77	5.66	5.72	5.80	5.74
Effective Specific Gravity, Gse	2.578	2.566	2.564	2.562	2.568
Aggregate Bulk Specific Gravity (Gsb)	2.522	2.522	2.522	2.522	
Absorbed Asphalt Content (Pba), %	0.88	0.70	0.67	0.64	0.72
Bulk Specific Gravity - Reheat, Gmb1	2.299	2.278	2.289	2.3	
Bulk Specific Gravity - Reheat, Gmb2	2.301	2.280	2.293	2.309	2.295
Air Void Content 2- Reheat, %	3.02	3.66	3.05	1.99	
Air Void Content 1- Reheat, %	2.93	3.57	2.88	2.04	2.89