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EVALUATION OF HOT-MIX ASPHALT SAMPLING TECHNIQUES

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A report of the findings of

ICT R27-8
Evaluation of Hot-Mix Asphalt Sampling Techniques

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16. Abstract

Insuring the integrity and security of hot mix asphalt (HMA) samples is critical to assuring the quality of the installed product and complying with Federal requirements. Samples of HMA are often taken at the plant with limited state supervision. Further, samples are taken from a truck where obtaining a representative sample can be difficult. The concept of moving the sample location to the job site offers the potential to address the weaknesses cited above. However, there are a number of different approaches, each with advantages and disadvantages. The objective of the proposed research project was to produce a review of successful methods and practices currently used to sample HMA during production and installation. This included visiting other states and providing detailed documentation of the visits. While achieving this objective, sufficient data were collected to allow IDOT's personnel to draw a final recommendation for the optimum technique to be adopted for HMA sampling in future projects. During the course of this project, sampling practices in six highway agencies were evaluated (Kansas, Iowa, Ohio, Michigan, Florida, and Ministry of Transportation of Ontario). Four of these agencies specify roadway sampling, while one agency is experimenting with a new generation of mechanical sampling device and another agency samples directly from a Material Transfer Device (MTD). During the course of this project, areas of improvement in the current Illinois QC/QA program were also identified.

In general, sampling behind the paver is being conducted by many states without much difficulty. Based on the site visits conducted in this research, the TRP group determined that the roadway sampling procedure adopted by Michigan DOT is the most appropriate for possible implementation in Illinois. In addition to this sampling technique, sealed bags adopted by Iowa DOT may be used, if necessary, to safely transport samples from the field to lab. Results of this research project also indicated that all visited states have a much higher sampling/testing frequency than Illinois and have successfully implemented an incentive/disincentive specification system. In addition, all visited states comply with the FHWA Technical Advisory (TA) or are in the process of making changes to comply with the TA.

Based on these findings, the TRP has determined that the current Illinois QC/QA program is in need of several modifications to ensure successful implementation of roadway sampling, to comply with the TA, and to encourage high-quality construction of HMA. While changing sample location would improve sample security, it would not address shortcomings of the existing QC/QA program. In conjunction with implementation of roadway sampling, it is recommended to base sampling on tons instead of time, that IDOT personnel determine random sampling locations, witness samples taken, and take immediate possession of samples; adopt incentive and disincentive pay; and accept density based on field cores. It is also recommended that the formed TRP group continue effort in revising the QC/QA program to gain compliance with the TA and to introduce changes deemed necessary from our field visits.

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EXECUTIVE SUMMARY

Insuring the integrity and security of hot mix asphalt (HMA) samples is critical to assuring the quality of the installed product and complying with Federal requirements. Samples of HMA are often taken at the plant with limited state supervision. Further, samples are taken from a truck where obtaining a representative sample can be difficult. The concept of moving the sample location to the job site offers the potential to address the weaknesses cited above. However, there are a number of different approaches, each with advantages and disadvantages. The objective of the proposed research project was to produce a review of successful methods and practices currently used to sample HMA during production and installation. This included visiting other states and providing detailed documentation of the visits. While achieving this objective, sufficient data were collected to allow IDOT's personnel to draw a final recommendation for the optimum technique to be adopted for HMA sampling in future projects. During the course of this project, sampling practices in six highway agencies were evaluated (Kansas, Iowa, Ohio, Michigan, Florida, and Ministry of Transportation of Ontario). Four of these agencies specify roadway sampling, while one agency is experimenting with a new generation of mechanical sampling device and another agency samples directly from a Material Transfer Device (MTD). During the course of this project, areas of improvement in the current Illinois QC/QA program were also identified.

In general, sampling behind the paver is being conducted by many states without much difficulty. Based on the site visits conducted in this research, the TRP group determined that the roadway sampling procedure adopted by Michigan DOT is the most appropriate for possible implementation in Illinois. In addition to this sampling technique, sealed bags adopted by Iowa DOT may be used, if necessary, to safely transport samples from the field to lab. Results of this research project also indicated that all visited states have a much higher sampling/testing frequency than Illinois and have successfully implemented an incentive/disincentive specification system. In addition, all visited states comply with the FHWA Technical Advisory (TA) or are in the process of making changes to comply with the TA.

Based on these findings, the TRP has determined that the current Illinois QC/QA program is in need of several modifications to ensure successful implementation of roadway sampling, to comply with the TA, and to encourage high-quality construction of HMA. While changing sample location would improve sample security, it would not address shortcomings of the existing QC/QA program. In conjunction with implementation of roadway sampling, it is recommended to base sampling on tons instead of time, that IDOT personnel determine random sampling locations, witness samples taken, and take immediate possession of samples; adopt incentive and disincentive pay; and accept density based on field cores. It is also recommended that the formed TRP group continue effort in revising the QC/QA program to gain compliance with the TA and to introduce changes deemed necessary from our field visits.

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1. INTRODUCTION

Quality Control (QC) is a set of actions and considerations necessary to assess and adjust production and construction processes in order to control the quality of the HMA being produced (TCN 2002). On the other hand, Quality Assurance (QA) specifications are a combination of end-result and materials and methods requirements to ensure that the quality of the installed HMA and adopted construction practices are satisfactory (Hughes 2005). Adequate QC/QA practices are the key to obtain a satisfactory product and to ensure that the installed HMA is what the designer specified. Years of experiences also confirm that deviation from either material or construction specifications often lead to premature pavement failure.

Although significant attention has been devoted to the development and improvement of QC/QA specifications, the collection and sampling process of the installed product has not been given the same consideration. Moreover, even though the testing can be conducted according to the specifications, sampling is equally important to ensure that the tested material is representative of the installed product. In recent years, various techniques have been suggested to properly collect HMA samples. This includes samples taken either at the plant, from a loaded truck, or on the roadway behind the paver. However, because segregation and contamination of the collected samples can easily occur, a strict and clear protocol needs to be established to ensure success of the sampling process. In addition, to develop effective specifications for HMA sampling, baseline data need to be established and documented based on the experience of practitioners in the field and states.

Samples of HMA in Illinois are currently taken at the hot mix plant with limited state supervision. Further, samples are taken from a truck where obtaining a representative sample can be difficult. The concept of moving the sample location to the job site offers the potential to address the weaknesses cited above. However, there are a number of different approaches, each with advantages and disadvantages. Research is needed to survey these practices as well as arranging visits between practitioners from Illinois and other states.

1.1. RESEARCH OBJECTIVES

The objective of this research project was to develop an understanding of successful methods and practices currently used to sample HMA during production and placement. This includes arranging for practitioners from Illinois to visit other states and providing documentation of the visits. While achieving this objective, it is expected that sufficient data would be collected to allow IDOT's personnel to draw a final recommendation for the optimum technique to be adopted for HMA sampling in future projects. IDOT is currently in the process of reviewing QC/QA regulations. Therefore, research activities proposed in this project will not only achieve the objectives of this study but also to serve as a benchmark for future research projects aimed at assisting the department in their review.

1.2. RESEARCH APPROACH

To achieve the aforementioned objectives, the following tasks were proposed:

A. Survey of existing techniques widely used by Departments of Transportation for sampling HMA during installation.
B. In coordination with IDOT personnel and based on the findings of Task A, select practitioners and states for site visits. Coordinate meetings with experienced practitioners during planned field visits.

C. Conduct and document site visits.

D. Prepare a final report that documents the findings of the site visits and develops recommendations for the most effective technique for HMA sampling in Illinois.

1.3. SCOPE

This report consists of five chapters. Chapter 2 presents a background and an overview of topics related to this project, including QC/QA plans for HMA and sampling techniques. Chapter 3 presents the results of a questionnaire sent to highway agencies to identify their current HMA sampling practices and general aspects of their QC/QA programs. Chapter 4 documents results of site visits and meetings conducted by the Research Group and the Technical Review Panel. Finally, Chapter 5 provides a summary of the findings and offers recommendations to improve the IDOT sampling procedure.

2. LITERATURE REVIEW

The following sections present general information about QC/QA programs and widely-used HMA sampling techniques. At the end of this chapter, a description of the Illinois QC/QA program is provided.

2.1. QC/QA PROGRAMS FOR HOT-MIX ASPHALT

Since the introduction of QC/QA programs in the early 1960s, the methodologies and practices used by state and federal highway agencies in these specifications widely vary in concept and purposes. Despite these large discrepancies, QC/QA specifications are typically statistically-based and consist of three major components: Quality Control, Acceptance Protocols, and Independent Assurance (IA). Quality and process control is the responsibility of the contractor during handling, blending, mixing, and placing operations. Acceptance is the responsibility of the highway agency although test results obtained from the contractor are often used. Independent assurance is usually conducted by an independent third party.

By 1992, an AASHTO survey indicated that all but eight of the 50 states either implemented or had made plans to implement QC/QA specifications (Smith 1998). By 2005, 46 state agencies had implemented QC/QA programs while two agencies still used materials and methods specifications (Hughes 2005). Chapter 3 presents the results of a survey conducted as part of this research project and that allowed identifying various aspects of state agencies QC/QA programs.

2.1.1 QA Specifications

Since the introduction of QC/QA programs during the construction of the AASHO Road Test, various forms of specifications were introduced. This includes materials and methods specifications, performance-based specifications, end-result specifications, and quality assurance specifications. With the exception of method specifications, QC/QA specifications are typically based on various levels of statistical principles such as random sampling and analysis of variance. Currently, materials and method specifications, which guide the contractors to use specific materials and equipment to produce and place HMA, are rarely used in asphalt mixtures applications (Hughes 2005).

Performance-based specifications monitor defined characteristics and properties of the installed HMA that are thought to be indicative of the expected mixture performance. End-result specifications transfer the entire responsibility to the contractor for installing a product that complies with the specifications. Quality assurance specifications, which are widely-used by state highway agencies, include end-result specifications and materials and method specifications. Figure 1 illustrates the major components of a typical statistically-based Quality Assurance specification.

Acceptance sampling and testing (QA Sampling and Testing) enables the state agency to decide on the basis of a limited number of tests whether to accept a lot of mix from the contractor or to apply positive or negative price adjustments. Since the contractor is conducting more testing to control the construction process than what state agencies can regularly conduct, interest was raised to use the contractor test results in the acceptance process. In 1995, FHWA allowed state agencies to use contractor test results in the acceptance process “provided that adequate checks and balances are implemented to protect the public investment” (FHWA 1995). Statistical differences between the contractor and the agency test results should quantify three major sources of variation: material, test procedures and equipments, and sampling. Split samples can only quantify the differences in test procedures, while independent samples can quantify all sources of variation between contractor and agency test results. In Illinois, split samples are used to determine acceptability of the material.

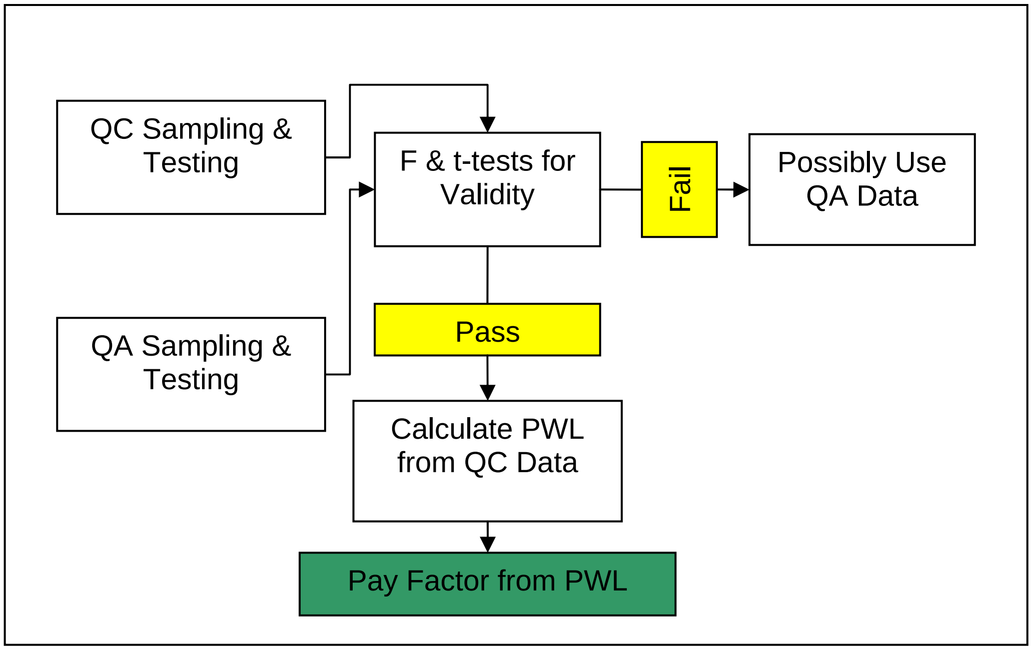


Figure 1. Components of a statistically-based quality assurance specification (after Hand and Epps 2006).

Various studies compared statistically the results obtained from QC and QA activities. In one study conducted in Kentucky, properties such as asphalt content and air voids were statistically different in terms of standard variation while voids in mineral aggregates were equivalent (Mahboub et al. 2004). No difference was found between the means of the different mix characteristics. In a similar study in Georgia, results of tests conducted by the state agency and the contractor were statistically different (Turochy et al. 2006). Differences were more profound in the variances than in the means and were found for about half of the properties considered when comparing split samples. To address concerns over discrepancies between results of tests conducted by the state agency and the contractor, FHWA issued the technical advisory T6120.3. This advisory is presented and discussed in the following section.

2.1.2 THE FHWA TECHNICAL ADVISORY T 6120.3

Discrepancies exist among state Departments of Transportation (DOT) about the proper methods of HMA acceptance. The majority of state DOTs have transferred the responsibility of verifying that the produced HMA complies with the specification to the contractors. While federal guidelines have allowed states to use results of the QC test program conducted by the contractors for verification and payment adjustment, DOTs are required to ensure that the results of the QC program are representative of the placed product. Different statistical quality measures were also introduced in order to determine the quality of the installed HMA. The statistical robustness of these parameters were, however, sometimes doubtful and did not agree with basic statistical principles.

In order to clarify the proper use of contractor test results in the acceptance of the placed HMA, FHWA published a technical advisory to provide regulation and recommendations on “the proper method for the use and verification of contractor’s QC test results for acceptance and payment adjustment of produced HMA mixtures and identification of the contractor and department risks.” Under this advisory, a distinction is made and reiterated between QC and QA programs. Through this technical advisory, state departments are allowed to use QC test results in the acceptance of the placed HMA under the condition that these results are validated by the state verification test results. Sampling and testing of results used in the validation process should be obtained by state personnel and can not be split samples. The validation process compares statistically the QA test results to the QC test results in order to ensure that both data sets come from the same population. The validation process is not required if the state department conducts all the testing and does not wish to use the contractor’s test results in the acceptance process of the installed HMA.

The FHWA technical advisory recommends using the F&t statistical procedure to compare both the variance and the means of the two data sets. The F-test provides a method of comparing the variances of the two data sets. The objective of this test is to determine whether the differences in the variability of the contractor’s tests and the department tests are greater than what might be expected if they came from the same population. On the other hand, the t-test compares the means of the two data sets to assess whether the means are statistically different. The t-test can be used to compare equal or unequal number of contractor vs. state sample sizes. Upon completion of the validation process, the installed HMA can be accepted based on either the combined QA and QC test results, the combined QC test results excluding the data of the split sample and the QA split test results, or only the contractor QC test results.

FHWA has identified the QC/QA programs of the states of Kansas and Georgia as examples of reasonable implementation of the federal requirements (Brown 2006). In Kansas, an F&t test statistical procedure was implemented. Pay adjustment factors are based on the acceptance of both air voids and density. For density, 20 contractor tests and 10 state tests are used per lot. For air voids, four contractor tests and one department test are used per lot. Sample locations are randomly selected and roadway sampling is specified. Pay adjustment factors are based on *percent within limits* (PWL), which identifies the percentage of installed HMA that meets the specification. To receive full payment, 90% of the installed material needs to meet the specification.

2.2. HMA SAMPLING METHODS

In recent years, various techniques have been suggested to properly collect HMA samples. This includes samples taken either at the plant or on the roadway behind the paver. However, because segregation and contamination of the collected samples can easily occur, a strict and clear protocol needs to be established to ensure success of the sampling process. To develop effective specifications for HMA sampling, baseline data need to be established and documented based on the experience of practitioners in the field and other states.

Two major factors usually control the success of HMA sampling operations: the selection of the sample location and the acquiring method. The following sections present a review of some of the most common techniques used in both categories to achieve successful sampling operations. Samples of HMA are normally obtained either from the loaded truck, at the plant, or in the roadway behind the paver. In general, FHWA recommends to use roadway sampling for all operations and to only use truck sampling or sampling at the plant when the first method is not practical (FHWA 1999). Each method possesses its advantages and disadvantages, however.

2.2.1 HMA Sampling Location

Regardless of the adopted sampling method, collected samples should be representative of the installed mixture in order to assess the actual variability of the construction process. To ensure that the collected samples provide an accurate representation of the mixture being installed, a random method of sampling HMA is normally used in accordance with ASTM D 3665 Standard Practice for Random Sampling of Construction Materials. This procedure ensures that intentional or unintentional bias on the part of the person taking the sample is eliminated. This specification has been adopted by many state agencies such as the Utah DOT, South Carolina DOT (SC-T-101), and Michigan DOT, and was reported successful in reducing bias and large ambiguous variability in HMA testing.

Unbiased sampling is achieved only when every element of the material being sampled has an equal chance of being included in the sample. To be entirely unbiased, the element to be sampled must be chosen in advance by use of a random procedure. In this method, the lot to be sampled is divided into the desired number of equal sublots and randomly selected samples are obtained from each sublot. Each sublot represents a specific HMA tonnage quantity from which a sample is randomly obtained. To ensure that the sample is entirely random, a set of random numbers is selected at the beginning of each day from a table of random numbers. These random numbers are then multiplied by the size of each sublot to obtain the truck or the location that will be sampled. A truly random sample cannot always be obtained due to difficulty during the sampling process and the flow of paving operations. Nevertheless, sampling efforts must strive for randomness to obtain the most representative sample possible.

2.2.2 HMA Sampling Techniques

2.2.2.1 Roadway Sampling

As previously noted, samples acquired after placement of HMA are recommended by the FHWA in order to account for variability introduced by the paving equipment. On the other hand, paving contractors usually prefer to avoid this sampling procedure because it disrupts the final surface of the installed pavement and may penalize them during smoothness testing. Another concern raised by practitioners is whether fines can be retrieved from milled surfaces when roadway sampling is used.

There are generally three methods to acquire samples after paving. The *Ring and Plate* method uses a metal plate placed in front of the paving machine. After the laydown of the material and before compaction, a circular template is pressed into the pavement until it makes contact with the metal plate. The ring, plate, and HMA sample are then lifted free of the pavement mat. The *Shovel and Plate* sampling method is similar to the ring and plate procedure except that it uses a specially designed square-pointed shovel instead of the ring to create a sample area with vertical faces. A wire is usually used to locate the plate perimeter but the paver may shift the plate such that there are HMA materials under it. In this case, the sampling process should be repeated. The hole made from the sampling must be always filled with loose HMA. The third sampling method behind the paver uses only a shovel to acquire the HMA materials as shown in Figure 2. During this process, care should be taken to avoid sloughing of material, and contamination of the sample with underlying materials.

Figure 2. The shovel sampling method
(After RR 98 2003).

Previous researchers have shown that the ring and plate method provides similar accuracy to the shovel and plate method. On the other hand, variability of the shovel method is usually greater than the other two methods indicating that this sampling technique is usually less consistent than the ring and plate or the shovel and plate methods. One disadvantage of the ring and plate method is that it is time-consuming and difficult to conduct without appropriate training. AASHTO T168 recommends the shovel and plate method for roadway sampling (AASHTO 1999). However, sufficient field data are needed to back the selection of one procedure over another.

2.2.2.2 Truck Sampling

Truck sampling is usually conducted by first removing approximately one foot of material from the outside of the mass. Using a square shovel, one-third of the sample size is obtained from the sampling area, Figure 3. Each sample should be obtained in three increments, which should be taken from more than one truckload. Other states simplify this procedure by allowing the sample to be obtained in a single increment. However, this may result in creating a significant source of errors in the extracted sample by segregating the material while sampling. Coarse aggregates coated with asphalt binder have a tendency to roll down the side of the pile of HMA mixture and accumulate next to the sides and the ends of the truck bed. If a sample is segregated, coarse mixture may indicate low asphalt binder content during testing due to the low surface area (Roberts et al. 1996). A suitable sampling platform shall be also provided on which the inspector is able to stand and sample the material in the truck bed adequately and safely.

This sampling method allows for a quick turnaround time since the QC laboratory is usually located at the plant. It is also quick and inexpensive since it only requires a shovel, bucket, and sampling platform. However, it may be difficult to obtain a representative sample since most of the sample is taken from the top of the pile and on the side closest to the sampling platform (Turner and West 2006). In addition, this sampling method does not account for any additional asphalt absorption during transportation and compaction.

Figure 3. Sampling from haul units (After FHWA 1999).

2.2.2.3 Remote Truck Sampling Device

A new sampling technique was recently introduced, which makes use of a mechanical sampling device. In this process, a manually-controlled hydraulic arm with a heated probe is moved to the desired location in the truck and then inserted into HMA to the desired depth, from which the sample is obtained. The first generation of the mechanical sampling device was expensive and complex in its operation. A new prototype was recently introduced, which is less expensive and is simpler in its operation (Figure 4). The operation of this device was witnessed during the research team's visit to Ohio. More details about this sampling technique are presented in this report.

Figure 4. Mechanical sampling device.

2.2.2.4 Mechanical Tube Sampling Device

In this method, a 73 mm circular tube sampler is either placed under the silo prior to discharge or is swung through the discharge steam during delivery. After delivery, the tube is removed away from the point of discharge and any material above the top rim is removed to avoid segregation, Figure 5.

Figure 5. Mechanical tube sampling device.

2.2.2.5 Effects of Sampling Techniques

In 2002, Hassan compared the asphalt content obtained from three sampling techniques (Hassan 2002). Colorado DOT allows HMA samples to be obtained using three different methods (Colorado Procedure 41-06): using a tube sampler at the plant, from the windrow prior to laydown, and behind the paver. During this research, samples were collected from 21 different CDOT projects. On each project, samples were collected using at least two of the three methods used by CDOT. The asphalt content was then determined from each collected sample using the ignition method and results were compared statistically. Results of this study indicated that the asphalt contents obtained from the different sampling techniques were statistically equivalent.

A recent study was conducted to evaluate the difference in QC parameters obtained from various sampling techniques (Turner and West 2006). Two mixes were evaluated; one with an asphalt absorption of 0.4% and a second with an asphalt absorption of 0.9%. With respect to asphalt content, truck sampling resulted in values significantly higher than roadway sampling for one mix. For another mix, truck sampling resulted in values comparable to roadway cores. With respect to gradation, no statistical difference was noted between samples obtained from the different sampling techniques. However, finer gradations were noted for the samples obtained from the truck. With respect to air voids, truck sampling had slightly lower air voids than the roadway samples. However, this difference was not statistically different.

In general, the authors concluded that there was little statistical difference among the different sampling techniques with the exception of asphalt content. Samples obtained from the truck appear to be segregated (finer gradation, higher asphalt constant, and lower percent air voids). Use of the mechanical sampling device resulted in values comparable to roadway sampling.

2.3. ILLINOIS QC/QA PROGRAM

IDOT had used a method specification until 1991. With the increasing demand for better control of HMA production and construction, a statistically-based QC/QA program was gradually implemented in the early 1990s. By 1995, most asphalt projects with more than 250 tons of HMA were constructed using QC/QA specifications (Patel et al. 1997). End-

Result/Performance Related Specifications (ERS/PRS) were developed and demonstrated in Illinois in the late 1990s but these specifications have not found wide-spread use (Buttlar and Harrell 1998). Under the current QC/QA specifications, IDOT requires that the contractor develop a QC plan for each HMA plant prior to the construction season. Minimum testing frequency is specified for the different control parameters (gradation, asphalt content, air voids, and density) and is shown in Table 1. In addition to these parameters, Illinois QC/QA program controls dust to asphalt ratio and the moisture content of the mixture.

Table 1. Minimum Testing Frequency for QC Program in Illinois

Parameter	**Frequency of Tests (High and Low ESAL Mixture^)**	**Frequency of Tests (All Other Mixtures^)**
Aggregate Gradation	1 dry gradation per day of production and 1 washed ignition oven test on the mix per day of production	1 gradation per day of production and 1 washed ignition oven test on the first day of production
Asphalt Binder Content by Ignition Oven	1 per half day of production	1 per day
Air Voids	1 per half day of production for first 2 days and 1 per day thereafter	1 per day
Density	1 per 800m for lift less than 75mm 1 per 400m for lift greater than 75mm	Same

^ High and low ESAL mixture covers most types of asphalt mixtures except stabilized subbase and HMA shoulders.

2.3.1 HMA Sampling and Quality Assurance Testing

Under the current QC/QA program, HMA truck sampling is specified at the plant and is conducted by the Contractor. The contractor is required to split the samples and to retain sampled material for possible quality assurance testing by the state representative. IDOT witnesses the contractor sampling process at least twice per month and immediately takes the split sample for testing. For acceptance of the mix, Illinois relies on the results of the contractor QC testing provided that the results fall within allowable validation tolerances. Pay adjustment factors are not used in the current QC/QA program but IDOT does apply them for HMA thickness as disincentives and smoothness as incentives and disincentives. Density testing is used to control the compaction process by means of the nuclear density test method. In this process, the contractor is responsible for establishing a correlation between the nuclear gage and core densities.

3. SURVEY OF DOT'S PRACTICES

A survey was conducted to collect information on HMA sampling techniques and acceptance methods used by state and highway agencies. A summary of the responses is presented in Appendix A. The survey questionnaire was sent to the 50 state agencies, the District of Columbia, FHWA Western Federal Lands, The Ministry of Transportation of Ontario, and Puerto Rico Highway and Transportation Authority. To expedite the response to the questionnaire, the survey was limited to only five main questions (answers were solicited for both QC and QA applications where applicable):

- Which sampling techniques do you currently specify?
- Do you randomly select the location of the sample?
    - If yes, do you randomly select the sample location based on ASTM D3665?
- Do you select your sample based on tonnage? If so, at what frequency?
- If you use truck sampling, how do you obtain the HMA sample?
    - If mechanically, please describe the apparatus.
- Do you accept your HMA based on contractor or state test results?

A copy of the questionnaire is provided in Appendix A. The overall response rate to the questionnaire was 70%. In total, 37 responses were received including 34 states, the Puerto Rico Highway and Transportation Authority, the Ministry of Transportation of Ontario, and FHWA Western Federal Lands. A list of the respondents is provided in Appendix A.

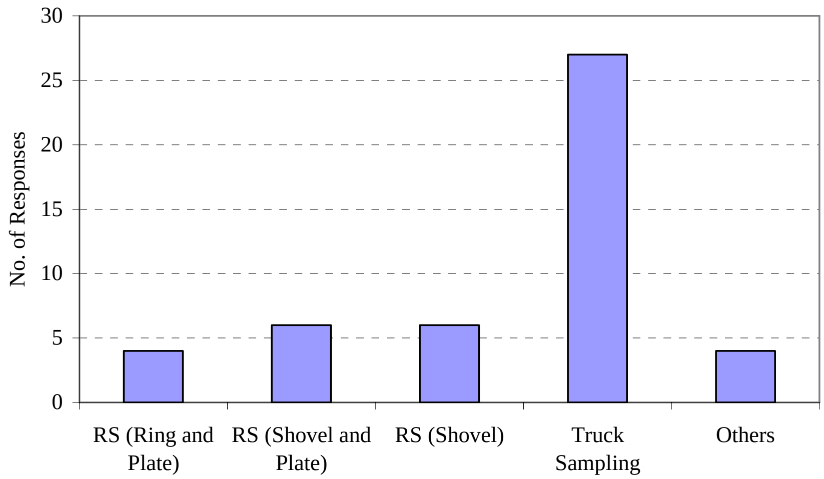
3.1. SURVEY RESULTS

3.1.1 HMA Sampling Techniques

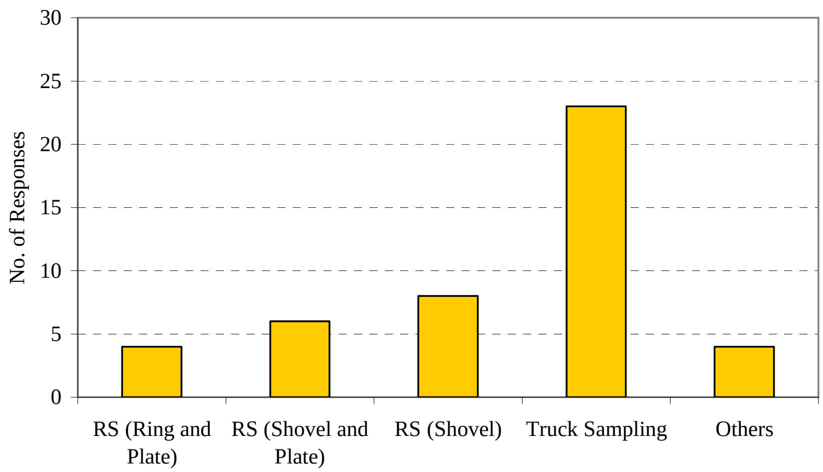
Figures 6(a and b) present the sampling techniques specified by highway agencies for quality control and quality assurance activities. It is worth noting that in total, 55 responses were received since many agencies allow for multiple sampling techniques in their specifications. It is notable from these figures that the majority of highway agencies are using truck sampling (27 and 23 responses for QC and QA). Only two states are allowing the use of the mechanical sampling device.

Among the different roadway sampling techniques, the shovel and plate is the most popular. As previously mentioned, this method is relatively straight-forward and provides an acceptable repeatability as compared to the shovel method. It appears also that the ring and plate method is only used in the Midwest and West regions of the U.S. On the other hand, truck sampling is widely used in the Eastern regions of the U.S. No major difference was noticed between DOTs practices for QC and QA applications, although sampling at the roadway seems to be slightly favored for QA sampling.

In the "others" category, one agency stated that the contractor mainly relies on the results of the quality assurance program and another agency stated that the contractor is responsible for QC sampling without supervision from the state. In the "others" category, two agencies specify sampling directly from the paver hopper. An innovative approach that is currently used by the Ministry of Transportation of Ontario consists of directly sampling from the material transfer device conveyor into a sampling hopper mounted in a pick-up truck, and then reducing the diverted material to an appropriate size using splitting equipment. This sampling technique is further discussed in the following sections of this report.



(a)

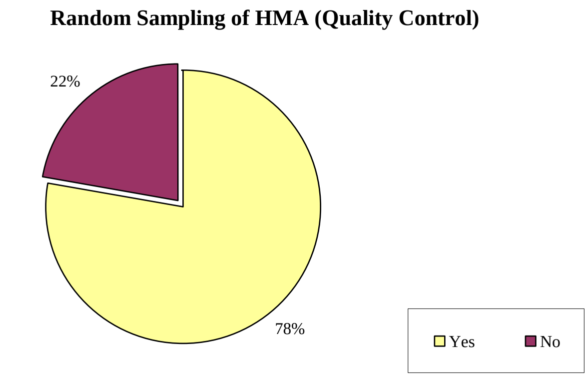


(b)

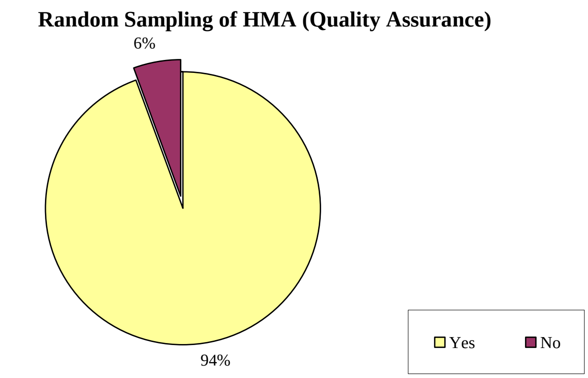
Figure 6. Adopted sampling techniques by different states for (a) quality control and (b) quality assurance.

3.1.2 Random Sampling of HMA

The majority of the states specify that random sampling of HMA must be used to select the location of the collected sample. This is particularly true for QA applications but is less predominant for QC applications (Figure 7). If the selection process varies for QC and QA applications, statistically proving that both data sets come from the same population may be challenging.



(a)



(b)

Figure 7. Use of random selection by different states for (a) quality control and (b) quality assurance.

Random selection of HMA samples is usually based on an in-house random sampling procedure developed by the agency. Despite the similarity between the state-developed methods and ASTM D3665, only 28% of the states are actually using this procedure as is (Figure 8). Most of the state-developed methods are acceptable, but some may not be. For instance, one state allows the project engineer to decide on the selection of a ‘random’ sample. To be entirely unbiased, the element to be sampled must be chosen in advance and can not be selected while the mixture is being sampled.

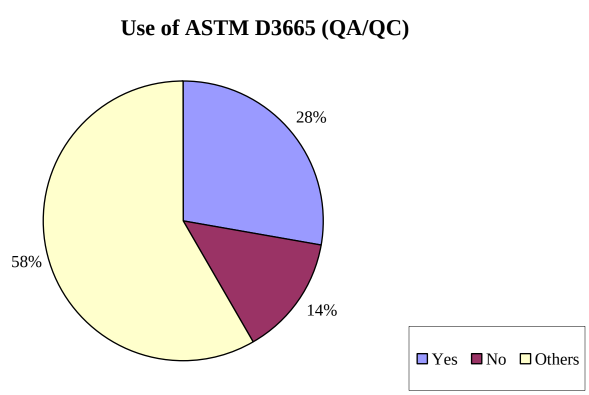
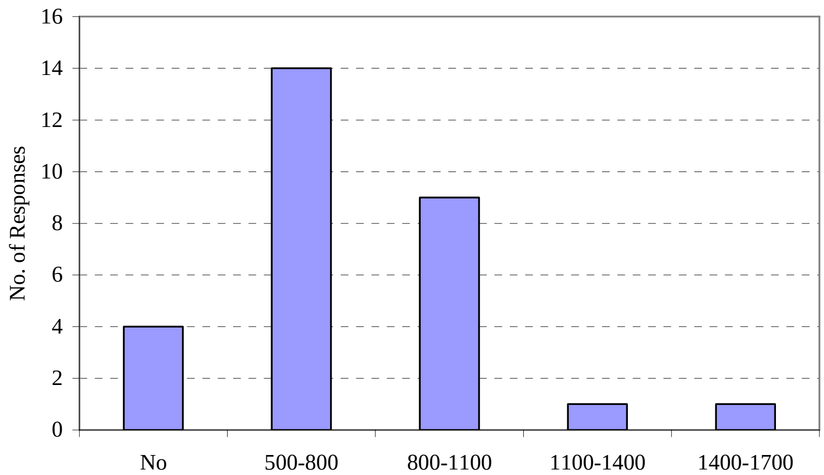


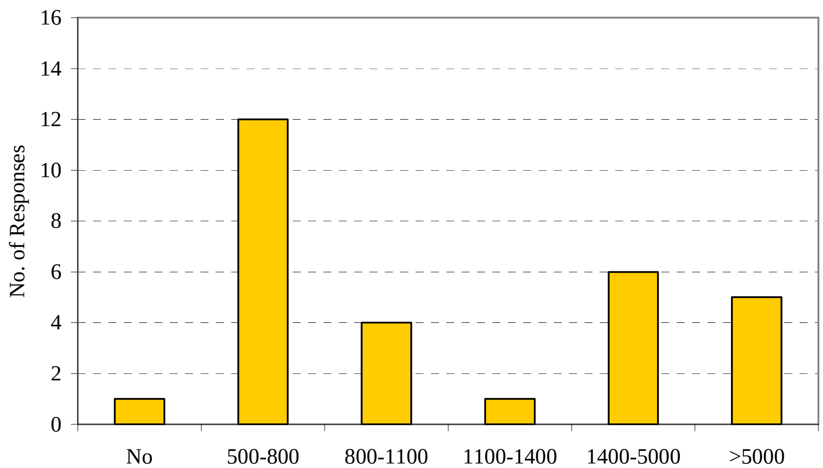
Figure 8. Use of ASTM D3665 for random sampling of HMA materials.

3.1.3 Sampling Frequency

Sampling frequency varies greatly among the different states; Figure 9. For quality control, the majority of the states (80%) specify one sample per 500 to 1100 tons of HMA. The lowest reported sampling frequency for quality control is one sample per 1500 tons. For quality assurance, the sampling frequency is much lower. Fifty-six percent of the states specify one sample per 500 to 1100 tons of HMA. In QA applications, the lowest reported sampling frequency is one sample per 10,000 tons of HMA. Some states specify the sampling frequency for QA applications as a percentage of the sampling frequency for QC applications. A rate of 5% to 10% of the QC sampling frequency was reported. On the other hand, some states specify the sampling frequency in samples per week with a reported rate of two to four samples per week.



(a)



(b)

Figure 9. Adopted sampling frequencies by different states for (a) quality control and (b) quality assurance.

METHOD OF HMA ACCEPTANCE

About 43% of the surveyed states make use of the contractor's test results for acceptance and for payment adjustments after verification using results of the QA program; Figure 10. However, only the state of Kansas reported using the F&t test procedure as recommended by FHWA. About 41% of the surveyed states do not use the contractor's test results in the acceptance decision and rely solely on the QA test results. Sixteen percent of the surveyed states depend solely on the contractor's test results without verification for HMA acceptance, which would not comply with the FHWA Technical Advisory.

As it was indicated during our field trips, some states are currently in the process of revising their QC/QA programs in order to comply with federal recommendations. However, many concerns and problems are still preventing full compliance with the 2004 FHWA technical advisory. Many states are not conducting sufficient tests due to a shortage of staff and do not have a statistically-based acceptance system. This prevents sound statistical analysis. Many contractors also directly appeal if the QC results show compliance with the specifications while the QA results do not. In the states that rely solely on the QA test results, it is not unusual for 10% to 15% of the samples to get appealed (Brown 2006).

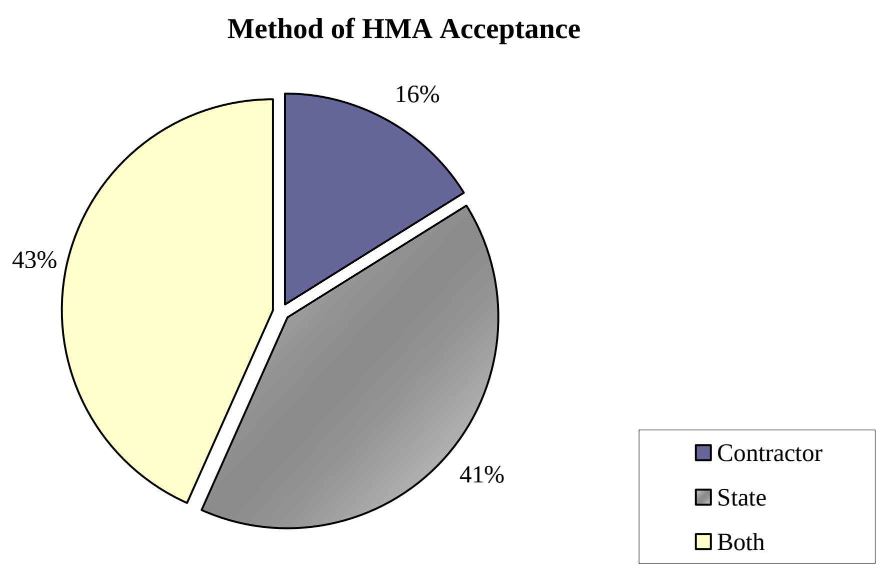


Figure 10. Method of HMA acceptance.

4. FIELD VISITS AND QC/QA EVALUATION

Based on the results of the survey questionnaire, the research team and the Technical Review Panel (TRP) selected a number of states to visit or to coordinate meetings with their practitioners to learn more about their sampling techniques and QC/QA programs. Figure 11 highlights the states that were identified during this review. In addition to these states, a field expert from Ontario was invited to present the MTD sampling technique. A phone conference was also arranged with field experts from Florida DOT to learn about their QC/QA program. The State of Indiana was recently visited by members of the TRP. The following sections present an overview of the site visits conducted during this research program.

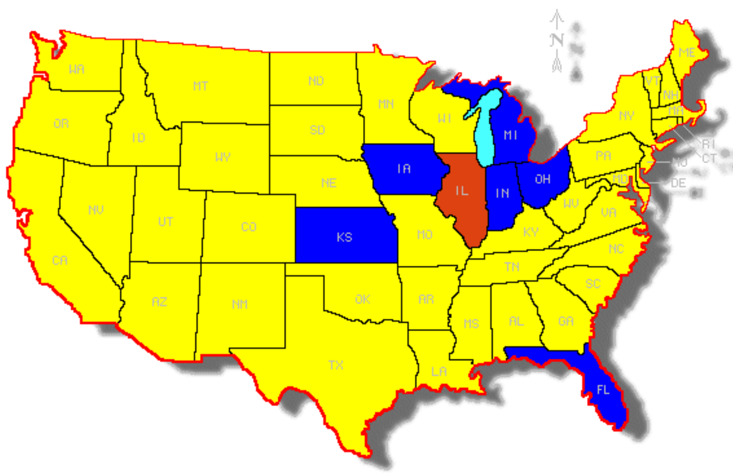


Figure 11. States of interest in the research project.

4.1. KANSAS FIELD TRIP

4.1.1 General Information

The field visit to Topeka, Kansas was conducted on September 20, 2006. Kansas DOT personnel present during our visit were Richard Barezinsky (Field Materials Engineer); Richard Kreider (Assistant Bureau Chief); and Glen Fager (Materials Engineer for District 1). The project for which roadway sampling was witnessed is located on Interstate 35 from about Milepost 143 to near the Junction of US-75 (MP 155) about an hour from Topeka. The scope of the project is Cold Mill 180 mm and put back: 40 mm SM-9.5T (PG76-28 – surface mixture with a nominal maximum size of 9.5 mm); 60 mm SR-19A (PG76-28 – intermediate mixture with a nominal maximum of 19 mm); and 80 mm SR-19A (PG64-22). The research panel witnessed the installation of the 80 mm SR-19A. The original pavement was found to suffer from stripping identified through coring and ground penetrating radar (GPR). During our visit, the weather was partly sunny and paving was supported by a MTD.

4.1.2 Description of Apparatus and Sampling Process

The State of Kansas has a great deal of experience with roadway sampling since this is the only method they have ever used. Roadway samples are obtained from behind the paver before compaction. A three-side template is pushed into the mat prior to compaction (Figure 12). A square shovel without sides is then used to extract all asphalt mixtures from the selected locations. The sample is obtained from a minimum of three locations randomly selected throughout one truck load of placed material by the KDOT personnel. The selection process involves one random number for the sampled tonnage (truck load) and two random numbers for transverse and longitudinal locations. The sample is collected into a cooler with a steel lining and is then transferred to the field lab for testing. Sample size is typically 60 lbs. The sampling process is conducted by the Contractor agent under supervision of the KDOT personnel present at the plant. The sampling template has dimensions of 25"x20"x11". The sampling process takes approximately five minutes to complete. The sampling process was judged efficient, causing little damage to the installed mat, and providing good indication of the installed product. Loose mixture is used to fill the sampling holes. KDOT did not notice any problems with the final smoothness or performance of the mat at the sampling location. It is worth noting, however, that Kansas generally uses fine-graded mixes, which are more conducive to roadway sampling. Concerns were raised by the TRP that the adopted shovel does not pick all fines from the bottom of the mat when it used on a milled surface.

Figure 12. Roadway sampling process adopted by KDOT.

4.1.3 Sampling Frequency

Prior to construction, a KDOT District lab physically verifies the contractor mix design. A pre-production phase of 200 tons is then initiated. During the pre-production phase, split samples are obtained. The produced mix is required to agree with the proposed mix design as well as KDOT specifications. These samples are tested at the Contractor field lab, the

KDOT field lab, and the KDOT District lab. This is a crucial phase in ensuring that the Gyratory compactor at the Contractor field lab is calibrated and accurate. This is accomplished by comparing the results of the Contractor field lab to the KDOT District lab. It is worth noting that the KDOT field lab is not equipped with a Gyratory compactor or an ignition oven but instead uses the equipment in the Contractor field lab. If the mixture produced during the pre-production phase severely fails to meet the specifications, removal may be required.

During the production phase, the Contractor takes four quality control (QC) samples per lot of 3,000 tons. After two lots meet all the requirements, the lot size is increased from 3,000 to 4,000 tons. After two more lots meet all the requirements, the lot size is increased from 4,000 to 5,000 tons. For Quality Assurance, KDOT takes one independent sample per lot. Field verification of VMA is implemented by KDOT, which allows a minimum of 1.0% less VMA during production compared with the design.

4.1.4 QC/QA Specifications

Kansas DOT specifications consist of three sets of regulations. The first specification (90M/P-230R15) is used for new construction and thick overlays. In this specification, air voids and density are used for Percent within Limit (PWL) pay adjustments. The second specification (90M/P-272R05) is mainly used for thin overlays (2in or less). In this specification, only air voids are used for PWL pay adjustments. Density is not used as it was found that the nuclear gage is not accurate in thin HMA layers. The voids in mineral aggregate (VMA) requirements are also relaxed by one point for most mixes from the minimum required VMA. The third specification is the commercial SuperPave and is used for small jobs in urban areas (e.g., intersection, bridge approaches). In this case, no QC/QA is done by the state and the Contractor has to provide a certification that adequate mixture is being produced.

As recommended by FHWA, the F&t test procedure is used to compare KDOT test results (air voids and density) to the contractor test results. In this process, 20 contractor tests results are compared to five state test results. This means that the comparison is established for every five lots. If there is no significant statistical difference between the two sets of results, the contractor results are used in the acceptance process. Otherwise, KDOT results are used. KDOT specifications require the Contractor to provide field labs at the plant for QC and QA testing. However, Gyratory compactor and ignition oven are only required in the Contractor field lab. The use of the same Gyratory compactor in both the contractor and KDOT verification tests helps minimize the variability due to the equipment. In addition, statistical analysis is conducted at a level of significance of 0.01. It was noted that air voids seldom fail the F&t test while density often fails this test. This may be due to the fact that the same compactor is used for both QC and QA.

Based on KDOT PWL specifications, payment adjustment factors are applied based on air void and density measurements. Payment incentive (with a maximum of $4,650 for a lot size of 5,000 tons) and penalty (with a maximum of $18,600 for a lot size of 5,000 tons) are then applied based on the results of this analysis. Percent within Limit is used on 50 to 80% of projects. The air void payment adjustment factor is determined as follows:

$$P_V = ((PWL_{UV} + PWL_{LV} - 100)x0.0030) - 0.270 \tag{1}$$

$$\text{Air Void Payment Adjustment} = P_v \text{ x tons in lot x Price per Ton} \tag{2}$$

where

PWL_{UV} = Upper percentage of asphalt mixture violating air void upper threshold (5.00%);
PWL_{LV} = Lower percentage of asphalt mixture violating air void lower threshold (3.00%).

The density payment adjustment factor is determined as follows:

$$P_D = (PWL_{LD} \times 0.004) - 0.360 \quad (3)$$

$$\text{Density Payment Adjustment} = P_D \times \text{tons in lot} \times \text{Price per Ton} \quad (4)$$

where
PWL_{LD} = Lower percentage of asphalt mixture violating density lower threshold (91% Gmm for thickness less than 2 in and 92% Gmm for thickness greater than 2 in).

4.1.5 Summary of Observations from the Kansas Field Trip

Based on the Technical Research Panel comments, the following observations are noted:

- Sampling Technique
  - Simple sampling template
  - Efficient and quick sampling process
  - Representative of final product including asphalt absorption
  - Available field labs allow quick testing
  - Fines may be lost to a milled surface
- Random Sampling
  - Three random locations for sampling (Left, Center, and Right)
- QC/QA Program
  - Field VMA spec is used
  - Zero tolerance for dust to binder ratio
  - Use F&t test procedure
  - Financial incentive and penalties are used
  - Contractor and state use the same equipment in QC and QA
- Kansas Condition
  - Kansas has six districts, mostly rural
  - 75% of the plants are portable (only seven plants are stationary)
  - Most of Kansas mixes are fine-graded with typical AC contents in the low 5% range for binders and in the low 6% range for surface mixes
  - Man power is available (Each district has typically six field QA labs/projects running at the same time. KDOT QA specifications require two state personnel for each project (i.e., 12 KDOT staff dedicated to QA per district).

4.2. IOWA FIELD TRIP

4.2.1 General Information

The field visit to Ames, Iowa was conducted on September 21, 2006. Iowa DOT personnel present during our visit were Mike Heitzman (Bituminous Materials Engineer) and a Senior Technician. Due to unfavorable rain conditions, a site visit was not conducted. However, a video presenting the roadway sampling process was shared with the TRP.

4.2.2 Description of Apparatus and Sampling Process

Roadway sampling has been used in Iowa from the late 1960s to address field segregation of the mixture and in order to obtain a truly representative sample of the mix. Roadway samples are obtained from behind the paver before compaction. A four-side template is forced down through the entire depth of the mat (see Figure 13a). The dimensions of the sampling template are 8 in x 8 in with a depth of 4 in. The larger template shown in Figure 13 is also accepted but is rarely used. A small square scoop is used to remove the sample from the inside of the template (Figure 13b). Attention is given to extract all the material from the template including any mixture that adheres to the scoop.

A minimum of four template samples is required in each sampling process to collect at least 30 pounds of material. Sampling is distributed over at least 30 tons of mixture (approximately two different truckloads). Tonnage to be sampled is selected randomly by the state personnel and is only revealed to the Contractor prior to collection. The sample transverse locations are selected as follows: one sample is collected at 1 ft from the left edge of the mat, one sample is collected 1ft from the right edge of the mat, one sample is collected 1 ft from the left of the center of the screed, and one sample from the right of the center of the screed.

The sampling process takes approximately 15 minutes to complete as care is given to collect all the materials inside the template. According to Iowa DOT, the sampling process is efficient, causing little damage to the installed mat, and provides a truly representative sample of the placed product. Loose mixture is used to fill the sampling holes. Iowa DOT did not detect any problems with the final smoothness or performance of the mat at the sampling location. Collected samples are placed in carton boxes that are available for purchase by the contractor from Iowa DOT (Figure 13c). It is worth noting that Iowa DOT mainly used fine-graded mixes, which are less susceptible to sampling behind the paver.

(a)

(b)

(c)

Figure 13. Roadway sampling template adopted by Iowa DOT.

4.2.3 Sampling Frequency

Iowa DOT does not require pre-production testing. During production, split samples are collected. The first production sample is collected within the first 500 tons excluding the first 100 tons. For QC, the contractor is required to collect four samples per day and split each one of them. Of these four samples, the state selects one of them for QA testing at one of the six district labs. Delivery of the sample is the responsibility of the contractor. QA testing is usually conducted the next day with the results being available promptly after that. Testing conducted on the collected samples include lab density and air voids determination. For small jobs (less than 2,000 tons), QA testing is not required. The contractor is required to conduct one QC test but is not required to submit its result. For field density measurements, seven cores are collected for QC and one core is collected for QA. Since nuclear density gage is not used for acceptance by Iowa DOT, cores are transported to the lab districts for testing. Nuclear density gages are used by the contractor for QC but the results are not used in the acceptance process.

4.2.4 QC/QA Specifications

Iowa DOT is in the process of changing its QC/QA program to address the FHWA technical advisory. Split samples will no longer be used. Instead, paired samples (side-by-side sample) will be required to provide QC samples to the contractor and QA samples to the state. Paired samples may not be more than 4 in apart. State personnel will witness the sampling process. After sampling, the state personnel will immediately take possession of one of the two boxes, secure it in a bag (Figure 14), seal it, and return the sample to the contractor for transportation to a District lab.

Figure 14. Sampling bag along with the sealed sample identification form.

To monitor the asphalt content during production, Iowa DOT has adopted a film thickness specification. Calculated film thickness is required to range between 8 and 14 microns. Iowa DOT is also considering adopting a new generation of Pavement Quality Indicator (PQI) for field density measurements. Payment adjustment factors (disincentive) are applied based on density measurements.

4.2.5 Summary of Observations from the Iowa Field Trip

Based on the Technical Research Panel comments, the following observations are noted:

- Sampling Technique
    - Simple sampling template
    - Efficient sampling process
    - Sample security is achieved using sealed bags
    - Fines may be lost to a milled surface
    - Sample size is small
- Random Sampling
    - Four lateral locations collected from a random tonnage
    - Sample mixture is taken close to the pavement edge
    - Two different trucks are sampled
- QC/QA Program
    - Controls film thickness
    - Sample security is achieved effectively
    - Relies solely on field cores for density measurements
- Iowa Conditions
    - Rural state with low asphalt production
    - 75% of the plants are portable

4.3. OHIO FIELD TRIP

4.3.1 General Information

The field visit to Columbus, Ohio was conducted on September 28, 2006. Ohio DOT personnel present during our visit were David Powers (Asphalt Materials Engineer); Bob McQuiston (Pavement & Materials Engineer - FHWA); and John Muhlke (HMA Lab Supply, Inc.). The mechanical sampling device was witnessed in a HMA plant near Columbus. The sampled mixture was a surface course. During our visit, the weather was partly cloudy.

4.3.2 Description of Apparatus and Sampling Process

Ohio is currently experimenting with a mechanical sampling device that is used to automatically sample mixtures from trucks at the plant (Figure 15). The traditional method of sampling from trucks consist of a technician climbing on a platform, removing approximately 1 ft of material, and collecting a sample that is representative of the produced mix. In addition, concerns are often raised about this operation especially regarding the safety of the technician and their ability to obtain a truly representative sample. A mechanical sampling device was previously developed but was expensive and complicated in its operation.

The new prototype developed by HMA Lab Supply Inc. is priced at approximately $9,500 and is much simpler in its operation. Using a manually-controlled hydraulic actuator, the sampling device is moved to the desired sampling location on the truck. Then, a grip is used to remove 1 ft of mixture, and to sample the produced material. The operation of the device is extremely simple and members of the Technical Panel were able to operate it without any problems. The collected sample (approximately 50 lbs) is then poured into a funnel which splits the mix into four metallic buckets using a Quartermaster splitter; Figure 15(b). The splitting process was cumbersome due to the small size of the funnel and the inadequate leveling of the splitter. The representative of HMA Lab Supply indicated that several modifications are expected in the near future to address this problem and to improve the operation. This will include the use of a larger funnel; modification of the splitting process; an infrared thermometer that will be used to monitor the mix temperature during sampling; and an automatic actuator.

(a)

(b)

(c)

Figure 15. Mechanical sampling device experimented by Ohio DOT.

In general, the mechanical sampling device is promising and provides three major advantages: safety of the technician conducting the sampling process (a member of the TRP noted that avoiding one minor accident may cover the cost of the sampling device), more uniform and representative sample, and compatibility with all truck sizes and types. This device was also successfully tested in Virginia and North Carolina. Ohio DOT indicated their strong interest in expanding the use of this device. However, its use will not be required but encouraged given its aforementioned benefits.

Research conducted by Tennessee DOT on a similar sampling device developed by Pavement Technology, Inc. compared the sample obtained mechanically to the sample obtained manually by a technician (TDOT 2002). Two mixtures were evaluated including one mixture containing RAP materials. Results indicated that the samples obtained from the mechanical sampler agreed more favorably with the gradation and asphalt content of the job mix formula than the samples obtained manually. The mechanical sampling device consistently provided samples with finer gradations and higher asphalt content than the samples obtained manually from the truck.

4.3.3 Sampling Frequency

Ohio DOT requires that the contractor obtain and test two QC samples per day or once every 1300 tons, whichever is less. The Contractor's technician is required to randomly select the truck in which to take a sample by using a random procedure. For low production tonnage, the first three trucks are not sampled. For QA testing, the state randomly selects a split sample for verification once every four days. In addition, the state randomly samples or witnesses the sampling of the mixture once every four days. This provides the state with two samples every four days. For density control, the Contractor is required to obtain 10 cores for the Department to test to determine the in-place density of the compacted mixture as a percentage of the average Maximum Specific Gravity for the production day the material was placed.

4.3.4 QC/QA Specifications

Ohio DOT started its QC/QA program in the late 1970s. Roadway sampling was used until 1995 but was then dropped due to understaffing. Truck sampling at the plant is currently specified. Ohio DOT has two major specifications for produced HMA: the 446 specification is used for major highway construction and the 448 specification is used in light traffic applications. Testing on uncompacted mixtures includes gradation, asphalt binder content, and air voids. Ohio DOT specifies a minimum asphalt binder content of 5.0% for SuperPave surface mixtures. Testing on compacted mixtures focuses on density measurements using either core density measurements for 446 or nuclear density gages for 448. Payment adjustment factors with incentives and penalties are implemented providing a bonus of up to 4% if the average density is between 94% and 95.9% of the maximum theoretical specific gravity. If the average density is greater than 98% of the maximum theoretical specific gravity, the contractor is required to remove and replace the installed mixture.

Ohio DOT has recently introduced some changes to address the FHWA Technical Advisory. As previously mentioned, an independent random sample is obtained once every two days for verification. This is in addition to a split sample randomly selected once every two days. Even though sampling may be conducted by the Contractor, the state will randomly select the truck to be sampled and will witness the sampling process. The state representative will keep the sample in the Department's possession until delivered to the District lab. The state representative will split its sample with the Contractor in the lab at the plant. The Contractor will then test their split of the verification sample with the state representative witnessing. The state technician may elect to use the Contractor's lab at the plant to test the independent sample.

4.3.5 Summary of Observations from the Ohio Field Trip

Based on the Technical Research Panel comments, the following observations are noted:

- Sampling Technique (Mechanical Sampling Device):
  - Improve safety conditions for the technician
  - Compatible with all truck sizes
  - Less expensive than previous versions
  - Splitting process is tedious
  - Is not specified but only recommended
  - May not include asphalt absorption during placement (Ohio DOT requires 2 hrs curing of HMA prior to testing to simulate asphalt absorption during production)
- QC/QA Program:
  - Payment adjustment factors are implemented
  - Sample security is effectively achieved
  - Only density is considered in payment
  - State representative may test their verification sample at the Contractor lab
- Ohio DOT conditions are similar to IDOT but at a slightly smaller scale

4.4. MTD SAMPLING: THE MINISTRY OF ONTARIO

4.4.1 General Information

Mr. Paul Lum (Director of Asphalt QC/QA at the Lafarge Group) was invited as a guest speaker on December 12, 2006 in Springfield. His presentation was scheduled as part of the IDOT HMA Technical Working Group Meeting. Mr. Lum gave an overview of the End-Result Specification (ERS) used by the Ministry of Transportation of Ontario and the jobsite sampling process from the Material Transfer Device.

4.4.2 Description of Apparatus and Sampling Process

The Ministry of Transportation of Ontario (MTO) has used MTD sampling, as an option to wire-plate sampling, since 2001. Prior to 2001, roadway wire-plate sampling was used since 1987. The change to MTD sampling was driven by the prospect of obtaining a more uniform sample and reducing disturbance to the pavement final surface. Samples are obtained from the MTD during placement of HMA and prior to transferring the mix to the paver; Figure 16. If a MTD is not used in a specific project, wire-plate sampling is used instead. For MTD sampling, the mix is processed in 2 connected, but separate, operations. First, the mix is dumped directly from the MTD into a specially designed funnel which splits the mix into four containers, each holding approximately 100 lbs of mix. The mix from one of the containers is then poured into a separate splitting apparatus that is similar to a Gilson Quartermaster splitter which is placed on a level surface. This apparatus splits the sample into four buckets, each with 25 lbs capacity. The split is repeated once or twice until a uniform sample is obtained. Each 25 lbs of sampled material is sufficient to prepare two gyratory-compacted specimens and two Rice samples. Sampled material is then transferred to carton boxes and then into bags for security sealing and shipment to the laboratory. The contractor must deliver samples to the laboratories within two days. One 25-lb sample is used for QC, another is used for QA, and a third is used by the referee lab if necessary.

The success of the sampling process depends primarily on the leveling of the sampling device and should be conducted while the MTD is under full operation (sampling should be avoided if the MTD is not thoroughly heated). The sampling process is conducted by the contractor under supervision by the owner representative. This process usually requires two laborers, who also conduct the density testing and various activities related to quality control at the site.

Figure 16. MTD sampling process adopted by MTO.

4.4.3 Sampling Frequency

Since 1998, the sampling frequency was set at one sample per 500 metric tonnes for MTD sampling and density measurements. Although cores are exclusively used for density quality assurance, nuclear density gages may be used by the contractor for additional control of the mix. Cores must be taken within 24 hours of placement of the mix. For payment adjustment, 5 QA samples are compared to 10 QC samples. QC samples are accepted and are used for payment if the payment factor is within 1.5% of the QA results; otherwise QA is used. A referee system is available in case of dispute. Referee testing is conducted by independent labs, retained by the Ministry of Transportation of Ontario (MTO). Results of the referee are binding for both parties. The sampling process is completely random as set by the owner with only half an hour notice to the contractor. Ontario is divided into five regions; each of these regions has a QA lab. Results of QA testing are usually available within three weeks for comparison with the QC results.

4.4.4 QC/QA Specifications

The Ministry of Transportation of Ontario has adopted end-result specifications (ERS) with bonuses and penalties since 1995. The switch to ERS has been mainly driven by the need to reduce duplicative testing and to address staff downsizing taken place at that time. Originally, ERS focused on controlling the following variables (see Table 4):

- Gradation;
- Asphalt Cement Content (both asphalt recovery and ignition oven are allowed);
- Air Voids; and
- Compaction.

Through a system of bonuses and penalties, payment is provided based on the quality of the product installed. This system encourages the contractors to apply appropriate QC measures to ensure that the installed mix meets or exceeds the specified level of quality. To provide the contractors time to adjust with this system, a phase-in technique was used. During that transition period, a limited number of contracts were bid with this specification and reduced penalties were imposed.

Table 2. Ministry of Transportation of Ontario ERS Specification Limits.

Variable	**LL (%)**	**UL (%)**
Asphalt Concrete Content	JMF – 0.50	JMF + 0.50
% Passing, Designated Large Sieve	JMF – 5.0	JMF + 5.0
% Passing, 4.75mm Sieve	JMF – 5.0	JMF + 5.0
% Passing, 600μm Sieve	JMF – 3.5	JMF + 3.5
% Passing, 75μm Sieve	JMF – 2.0	JMF + 2.0
% Air Voids (except Dense Friction Course [DFC])	2.5	5.5
% Air Voids (Dense Friction Course)	2.2	4.8
% Compaction (except DFC and Heavy Duty Binder Course [HDBC])	91.5	97.0
% Compaction (HDBC)	90.5	97.0
DFC	90.5	98.0

JMF: Job Mix Formula; LL: Lower Limit; UL: Upper Limit; LL and UL are used in Percent within Limit (PWL) calculations.

The Percentage within Limits (PWL), which represents the percentage of the lot falling above the LL and beneath the UL, is used to determine the Payment Factors. A bonus not exceeding 7% is granted if the contractor achieves a PWL greater than 95%. Full payment is given if the contractor achieves a PWL between 80% to 95%. A penalty is imposed if the PWL is less than 80%. The product is rejected and possibly removed if the PWL is less than 50% for any of asphalt content, air voids, or compaction and if it is less than 25% for any sieve on gradation. In 1998, the ERS system was improved by adding smoothness and segregation specifications. A separate payment factor is determined for smoothness and segregation. For smoothness, if the profile index is less than 230 mm/km, a bonus ranging from 0% to 20% is awarded. For segregation, a $0.50 per tonne bonus is granted for each lane-km of segregation free pavement. Although segregation is judged visually, dispute between the owner and the contractor is resolved through the sandpatch test.

4.4.5 Summary of Observations from the MTO QC/QA Evaluation

Based on the Technical Research Panel comments, the following observations are noted:

- Sampling Technique (Sampling from Material Transfer Device):
  - Efficient and quick sampling process
  - Representative of final product including asphalt absorption during hauling
  - Provides uniform and complete sample including fines
  - Ensures sample security
  - Eliminates disturbance to the pavement final surface
  - Sampling is conducted by the contractor under owner's supervision
  - IDOT does not use MTD in the majority of the projects
  - Two contractor personnel are used at each jobsite
- Sampling frequency:
  - Sampling frequency is adequate and is based on random selection
- QC/QA Program:
  - Financial incentive and penalties are used
  - Bonuses resulted in improved product quality and competitive pricing between contractors
  - Core density eliminates error associated with nuclear density gages
- MTO Conditions:
  - Amount of HMA mixture installed is significantly less than in Illinois.

4.5. FLORIDA QC/QA PROGRAM

A phone conference was organized with experienced practitioners from Florida DOT. Although we attempted to invite a field practitioner from Florida, this proved difficult due to travel restrictions currently imposed by the State of Florida. Personnel present in the phone conversation was Gregory A. Sholar (Bituminous Research Engineer), James Musselman (State Bituminous Engineer), Susan Andrews (Bituminous Mix Design Coordinator), Maurice McReynolds (Bituminous Field Support Specialist), and Gregory Sheetz with FHWA. The main objective of the meeting was to collect information about Florida QC/QA specifications. Although Florida DOT utilizes truck sampling similar to Illinois, the sampling security process is different.

4.5.1 Sampling Technique and Frequency

Truck sampling is specified at the plant. Specifications call for samples to be collected from three different locations in the truck and at a depth of 12 in below the surface. Some districts are currently evaluating roadway sampling and are collecting data related to this procedure. Collected mix is split into three samples, one for quality control, one for verification testing (Quality Assurance), and one for resolution testing. Mixtures are tested at the plant with respect to gradation, asphalt content, and air voids.

Sampling frequency calls for one sample in each 500 tons sublot in the initial production phase. Following the initial production phase, the sampling frequency may be increased to one sample in each 1000 tons sublot. Sample location is selected randomly by a state representative present full time at the plant. After placement, 6 in cores are obtained from the roadway for control of the density. Five 6 in cores are collected within each 24 hours of placement at randomly-selected locations.

4.5.2 QC/QA Specifications

Florida DOT has adopted a QC/QA specification system with bonuses and penalties since 2002. For quality control, the contractor is required to test all collected samples at a laboratory set at the plant. Results of QC testing should be conducted within one working day from the time the sample was collected. Samples are tested with respect to gradation (Passing #8 and #200), asphalt content, and air voids. For verification, one sample is randomly tested in each lot of 4,000tons. Testing of the verification sample is conducted by a state representative (often a consultant) using the contractor lab at the plant. If QC and verification testing do not compare favorably, resolution testing is conducted at the District material labs.

The Percentage within Limits (PWL), which represents the percentage of the lot falling above the LL and beneath the UL, is used to calculate Payment Factors. A composite payment factor is then calculated based on the payment factors for air voids, asphalt binder content, percent passing No. 200, and percent passing No. 8. A spreadsheet is used for calculation of the PWL. Table 6 presents the specification limits. Payment factors are also applied to small quantities and incorporate single test pass/fail criteria.

Table 3. Specification Limits

Variable	Specification Limits
Passing No. 8 (Percent)	Design ± 3.1
Passing No. 200 (Percent)	Design ± 1.0
Asphalt Content (Percent)	Target ± 0.40
Air Voids – Coarse Mixes (Percent)	4.00 ± 1.40
Air Voids – Fine Mixes (Percent)	4.00 ± 1.20
Density – Coarse Mixes (Percent of G_{mm})	94.50 ± 1.30
Density – Fine Mixes (Percent of G_{mm})	93.00 + 2.00, -1.20

4.6. MICHIGAN FIELD TRIP

4.6.1 General Information

The field visit to Jones, Michigan was conducted on June 27, 2007. Michigan DOT personnel present during our visit were Marc Beyer (Bituminous Materials/Mixtures Specialist) and Robert Conway (FHWA Pavement and Materials Engineer). The project for which roadway sampling was witnessed, is located on M60 about 15 minutes from Jones. The scope of the project was to rubblize and to resurface the eastbound lane of M60. The lane was closed to traffic during reconstruction. The research panel witnessed the installation of 100 mm of a 19 mm intermediate mix. During our visit, the weather was partly sunny and paving was supported by means of an Ingersoll Rand track paver and 48 to 51 tons live bottom trucks.

4.6.2 Description of Apparatus and Sampling Process

Roadway samples are obtained from behind the paver before compaction. Two sampling methods are specified by MDOT: sampling with a specially-developed shovel is used when HMA is placed on top of HMA or a concrete surface; and sampling with plates and shovel is used when HMA is placed on top of an aggregate base, rubblized concrete, or a cold-milled surface. The research panel witnessed the sampling with plates and shovel. In this method, three plates (360 mm x 720 mm) with 600 mm-long wires attached to them are placed prior to placement of HMA (Figure 17a). The location of the plates is selected randomly in the longitudinal direction. In the transverse direction, the three plates are staggered over the lane (two plates at 150 mm from the edges of the lane and one at the center of the lane). The wires are extended beyond the edge of the pavement to allow locating the sampling plates after the mixture is placed (Figure 17a). The plates are sprayed with a release agent (cooking spray) prior to placement of the mixture. After placement of the mix, the wires are pulled until the plate is located (Figures 17b and d). Once the plate edges are defined, a specially-developed shovel is dug downward until it comes in contact with the plate then slid forward on the plate far enough to obtain enough material to fill one-third of the specified sample container (Figure 17c). The shovel is then lifted slowly until all the material is recovered. The sample is placed directly into the sample container. This process is repeated at the other two locations. The sample is stored into a non-absorbent metal container with a capacity of at least 3.5 gallons that is cleaned and reused in collecting HMA samples. The contractor then fills and levels the sampling location with prefilled 3.5 gallon buckets of HMA obtained from the paver's auger (Figure 17e and f). Additional pictures of this sampling process are presented in Appendix B.

For QA testing, the sampling process is conducted by trained MDOT personnel present at the site. The sampling process takes approximately five minutes to complete. The sampling process was judged efficient and quick, causing little damage to the installed mat, and providing good indication of the installed product (Figures 17g and h). Sampling locations are marked as smoothness testing is not conducted where the samples are collected. MDOT demonstrated to the research panel the thermal profile in the sampling locations as compared to the rest of the mat. No thermal difference could be noticed. Due to the use of plates, this sampling method picks all fines from the bottom of the mat even when it used on a milled surface.

4.6.3 QC/QA Specifications

Michigan DOT does not rely on results of QC samples for acceptance of the mixture; only QA samples are used. For QC and QA activities, Michigan DOT specifies one sample per 1,000 tons sublot. For density measurements, four 6-inch cores are taken per sublot. Coring is conducted by the contractor and a construction staff takes immediate possession of the cores. Michigan DOT specifies mixtures designed according to Marshall or SuperPave mix design methods. For SuperPave mixes, MDOT controls the % air voids, asphalt content, and the field density. Percent within Limits are used to determine the pay factor for the produced mix.

(a) (b) (c)



(d) (e) (f)


(g) (h)

Figure 17. Roadway sampling process adopted by MDOT.

4.6.4 Summary of Observations from the Michigan Field Trip

Based on the Technical Research Panel comments, the following observations are noted:

- Sampling Technique:
  - Simple sampling template
  - Efficient and quick sampling process
  - Minimizes the effects of paver segregation
  - Representative of final product including asphalt absorption
  - Sampling is conducted by state representative
  - Fines are recovered from milled surface
  - Overfilling of holes (three buckets of loose mixtures for one bucket of sample) allows restoration of final surface
  - To avoid segregation, loose mixture should be dumped vertically and not horizontally
  - Sampled surface does not seem to be substantially affected after compaction
  - MDOT's turnaround time for test results is 48 hours
- Random Sampling:
  - Three random locations for sampling (left, center, and right)
  - Sampling scheme minimizes the effects of paver segregation
- QC/QA Program:
  - Relies on QA samples for acceptance
  - Complies with the FHWA Technical Advisory

    - Cores are used for density acceptance
    - Asphalt extraction is specified for asphalt content determination
    - MDOT relies on four or five consultant laboratories to assist with assurance testing
- Michigan Conditions:
    - Four million tons are placed in Michigan compared to eight million in Illinois
    - Michigan uses fine-graded mixes which are more conducive to sampling behind the paver.

5. CONCLUSIONS AND RECOMMENDATIONS

The objective of this research project was to develop an understanding of successful methods and practices currently used to sample HMA during production and placement. During the course of this project, areas of improvement in the current Illinois QC/QA program were also identified. Sampling practices in six highway agencies were evaluated (Kansas, Iowa, Ohio, Michigan, Florida, and the Ministry of Transportation of Ontario). Four of these agencies specify roadway sampling, while one agency is experimenting with a new generation of mechanical sampling device and another agency samples directly from a Material Transfer Device (MTD). In general, sampling behind the paver is being conducted by many states without much difficulty. Based on the site visits conducted in this research, the TRP group determined that the roadway sampling procedure adopted by Michigan DOT is the most appropriate for possible implementation in Illinois. This sampling procedure offers the following advantages:

- Simple sampling technique providing an adequate quantity of mixture for laboratory testing
- Efficient and quick sampling process (5 mins)
- Representative of final product including asphalt absorption
- Fines are recovered from milled, or rough textured surfaces
- Overfilling of holes (three buckets of loose mixtures for one bucket of sample) allows better compaction and restoration of final surface
- To avoid segregation while filling sample holes, loose mixture is dumped vertically and not horizontally
- Sampled surface does not seem to be substantially affected after compaction

In addition to this sampling technique, sealed bags adopted by Iowa DOT may be used, if necessary, to safely and securely transport samples from the field to the lab. With respect to other factors related to the QC/QA programs of visited states, the following findings are noted:

- All visited states have a much higher sampling/testing frequency than Illinois.
- Sampling frequency is based on Tons for all states visited.
- Kansas and Michigan comply with TA. The Ministry of Ontario uses an F&T statistical procedure as recommended by FHWA and the QC/QA program of the State of Indiana is similar to Michigan.
- Iowa, Florida, and Ohio have made efforts to gain compliance with TA.
- Illinois does not meet all of the recommendations of the TA.
- Under current IDOT staffing conditions, changing the sample location to behind the paver would improve sample security.
- All visited states utilize an incentive/disincentive system.
- Sample location closer to final incorporation in the work will be more beneficial if an incentive/disincentive system is adopted.
- Sampling behind the paver is the most representative location to characterize the final product.
- All visited states use coring for density control and acceptance.

Based on the aforementioned findings, the TRP has determined that the current Illinois QC/QA program is in need of several modifications to ensure successful implementation of roadway sampling, to comply with the TA, and to encourage high-quality construction of HMA. Therefore, the following recommendations are made:

- While changing sample location would improve sample security if sufficient controls are instituted to assure samples are taken by state personnel or under state supervision, it would not address shortcomings of the existing QC/QA program.
- In conjunction with implementation of roadway sampling, the following changes are recommended:
  - Base sampling on tons instead of time.
  - IDOT personnel should determine random sampling locations, witness samples taken and take immediate possession of samples. Sample locations should not be disclosed prior to sampling.
  - Adopt incentive and disincentive pay.
  - Accept density based on field cores.

- The TRP group should continue effort in revising QC/QA program to gain compliance with the TA and to introduce changes deemed necessary from our field visits.

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7. APPENDIX A

List of respondents to the survey questionnaire:

Alabama
Arizona
Connecticut
District of Colombia
Florida
Georgia
Hawaii
Idaho
Indiana
Illinois
Iowa
Kansas
Kentucky
Louisiana
Maine
Ministry of Transportation of Ontario
Mississippi
Nebraska
Nevada
New Hampshire
New Jersey
New York
North Carolina
North Dakota
Ohio
Oregon
Pennsylvania
Porto Rico
Rhode Island
South Carolina
South Dakota
Tennessee
Texas
Virginia
Washington
West Virginia
Wisconsin
Western Federal Lands

		Sampling of HMA (QC)				
		RS (Ring and Plate)	RS (Shovel and Plate)	RS (Shovel)	Truck Sampling	Others
1	Alabama				X	
2	Arizona	X	X		X	
3	Connecticut				X	
4	District of Colombia				X	
5	Florida				X	
6	Georgia			X	X	
7	Hawaii					
8	Idaho	X			X	
9	Indiana		X		X	
10	Illinois				X	
11	Iowa	X				
12	Kansas		X			
13	Kentucky				X	
14	Maine				X	
15	Minister of Ontario		X			X*
16	Mississippi				X	
17	Nebraska			X		
18	Nevada				X	
19	New Hampshire		X	X	X	
20	New Jersey				X	
21	New York				X	
22	North Carolina				X	
23	North Dakota			X		
24	Ohio				X	

25	Oregon				X	
26	Pennsylvania				X	
27	Porto Rico					X[~]
28	Rhode Island					X[%]
29	South Carolina				X	
30	South Dakota			X		X[$]
31	Tennessee			X	X	
32	Texas				X	
33	Virginia				X	
34	Washington				X	
35	West Virginia				X	
36	Wisconsin				X	
37	Western Federal Lands	X	X			

^ Uses a three-sided template and a shovel at the site
* Allows sampling from MTD directly into a sampling hopper
@ Samples taken from paver hopper
~ Contractors rely on the results of the quality assurance
% Contractors are responsible for their quality control
$ Windrow sampling in front of the pick up machine at the paver
+ Sampling from the paver at auger

	Sampling of HMA (QA)				
	RS (Ring and Plate)	RS (Shovel and Plate)	RS (Shovel)	Truck Sampling	Others
Alabama				X	
Arizona	X	X			
Connecticut				X	
District of Colombia			X		
Florida				X	
Georgia			X	X	
Hawaii				X	X[+]
Idaho	X				
Indiana		X			
Illinois				X	
Iowa	X				
Kansas		X^			
Kentucky				X	
Maine					X[@]
Minister of Ontario		X			X*
Mississippi				X	
Nebraska			X		
Nevada			X	X	
New Hampshire		X	X		
New Jersey				X	
New York				X	
North Carolina				X	
North Dakota			X		

Ohio				X	
Oregon				X	
Pennsylvania		X			
Porto Rico				X	
Rhode Island				X	
South Carolina				X	
South Dakota			X		X[$]
Tennessee			X	X	
Texas				X	
Virginia				X	
Washington				X	
West Virginia				X	
Wisconsin				X	
Western Federal Lands	X	X			

See legends in the previous table (Sampling of HMA – QC).

	Random Selection of Sample (QC)	
	Yes	No
Alabama	X	
Arizona		X
Connecticut	X	
District of Colombia	X	
Florida	X	
Georgia	X	
Hawai		X
Idaho	X	
Indiana		X
Iowa	X	
Kansas	X	
Kentucky	X	
Maine	X	
Minister of Ontario	X	
Mississippi	X	
Nebraska	X	
Nevada		X
New Hampshire	X	
New Jersey		X
New York	X	
North Carolina	X	
North Dakota	X	
Ohio	X	
Oregon	X	
Pennsylvania	X	
Porto Rico		X
Rhode Island		X
South Carolina		X
South Dakota	X	
Tennessee	X	
Texas	X	
Virginia	X	
Washington	X	
West Virginia	X	
Wisconsin	X	
Western Federal Lands	X	

	Random Selection of Sample (QA)	
	Yes	No
Alabama	X	
Arizona	X	
Connecticut	X	
District of Colombia	X	
Florida	X	
Georgia	X	
Hawai	X	
Idaho	X	
Indiana	X	
Iowa	X	
Kansas	X	
Kentucky	X	
Maine	X	
Minister of Ontario	X	
Mississippi	X	
Nebraska	X	
Nevada	X	
New Hampshire	X	
New Jersey	X	
New York	X	
North Carolina	X	
North Dakota	X	
Ohio	X	
Oregon	X	
Pennsylvania	X	
Porto Rico	X	
Rhode Island		X
South Carolina	X	
South Dakota	X	
Tennessee	X	
Texas	X	
Virginia	X	
Washington	X	
West Virginia		X
Wisconsin	X	
Western Federal Lands	X	

Use of ASTM D3665

	Yes	No	Others
Alabama^			X
Arizona		X	
Connecticut	X		
District of Colombia		X	
Florida*			X
Georgia#			X
Hawaii	X		
Idaho$			X
Indiana@			X
Iowa-			X
Kansas*			X
Kentucky~			X
Maine	X		
Minister of Ontario+			X
Mississippi	X		
Nebraska^			X
Nevada			X
New Hampshire	X		
New Jersey			X
New York^			X
North Carolina	X		
North Dakota		X	
Ohio			X
Oregon	X		
Pennsylvania			X
Porto Rico	X		
Rhode Island		X	
South Carolina			X
South Dakota	X		
Tennessee		X	
Texas			X
Virginia	X		
Washington			X
West Virginia			X
Wisconsin			X
Western Federal Lands			X

^	Very similar to ASTM D3665
*	Uses a random number generator
#	According to GDT-73 (Method of Random Selection)
$	According to a sampling method developed by WAQTC
@	According to a sampling method developed by InDOT
-	Random sample selected by the project engineer
~	According to Kentucky 64-113 (Methods of Random Selection)
+	Requires the use of a table of random numbers
a	According to Nevada test method #T200D
b	According to NJDOT own sampling procedure

Sample Frequency - Quality Control

	Base Course	Surface Course	Intermediate Course
Alabama	700	700	700
Arizona	1000	1000	1000
Connecticut^	600	600	600
District of Colombia	500	500	500
Florida	500-1000	500-1000	500-1000
Georgia	500	500	500
Hawaii			
Idaho	1000	1500	1500
Indiana			
Iowa	500-750	500-750	500-750
Kansas	750	750	750
Kentucky	1000	1000	1000
Maine	500	500	500
Minister of Ontario	500	500	500
Mississippi	800	800	800
Nebraska*	750	750	750
Nevada	1000	1000	1000
New Hampshire	500	500	500
New Jersey			
New York	1250	1250	1250
North Carolina	750	750	750
North Dakota	1500	1500	1500
Ohio[a]			
Oregon	1000	1000	1000
Pennsylvania			
Porto Rico			
Rhode Island			
South Carolina			
South Dakota	1000	1000	1000
Tennessee	1000	1000	1000
Texas			
Virginia	500	500	500
Washington			
West Virginia			
Wisconsin	500-900	500-900	500-900
Western Federal Lands	750	750	750

^	0-150: no test required, 151-1100 tons: 2 test, 1101-1700: 3 test, 1701 and greater: 4 test. QA: on 1:6 ratio
*	A minimum of 200 tons between consecutive samples
a	QC: one sample per half day or night

	Sample Frequency - Quality Assurance		
	Base Course	Surface Course	Intermediate Course
Alabama	2800	2800	2800
Arizona	4/day	4/day	4/day
Connecticut	3600	3600	3600
District of Colombia	500	500	500
Florida	2000-4000	2000-4000	2000-4000
Georgia	500	500	500
Hawaii	500	500	500
Idaho	1000	750	750
Indiana	1000	600	1000
Iowa	500-750	500-750	500-750
Kansas	3000	3000	3000
Kentucky	4000	4000	4000
Maine	1000	1000	1000
Minister of Ontario	500	500	500
Mississippi	8000	8000	8000
Nebraska	750	750	750
Nevada^	9000	9000	9000
New Hampshire	750	750	750
New Jersey	3300	3300	3300
New York	1250	1250	1250
North Carolina	7500	7500	7500
North Dakota			
Ohio[a]			
Oregon	10000	10000	10000
Pennsylvania	500	500	500
Porto Rico			
Rhode Island	500	500	500
South Carolina	500	500	500
South Dakota	5000	5000	5000
Tennessee			
Texas			
Virginia[b]			
Washington	800	800	800
West Virginia[c]			
Wisconsin	500-900	500-900	500-900
Western Federal Lands	750	750	750

^	Frequency depends on the test to be performed. Stated frequency is for air voids determination. 9000t or twice per week, whichever is less.
a	QA: one sample per 4 days
b	4 samples the first week of production then 2 per week thereafter
c	Does not specify frequency of sampling for QA

Method of HMA Acceptance	Contractor	State	Both
Alabama^			X
Arizona		X	
Connecticut^			X
District of Colombia		X	
Florida^			X
Georgia	X		
Hawaii		X	
Idaho	X		
Indiana*		X	
Iowa^			X
Kansas^			X
Kentucky	X		
Maine		X	
Minister of Ontario^			X
Mississippi	X		
Nebraska^			X
Nevada		X	
New Hampshire		X	
New Jersey		X	
New York[a]	X		
North Carolina^			X
North Dakota	X		
Ohio^		X	X
Oregon^			X
Pennsylvania[b]		X	
Porto Rico		X	
Rhode Island		X	
South Carolina^			X
South Dakota^			X
Tennessee		X	
Texas		X	
Virginia^			X
Washington		X	
West Virginia^			X
Wisconsin^			X
Western Federal Lands^			X

^	Uses contractor results upon verification with the QA results
*	Miscellaneous HMA items such as patching are accepted by Certification from HMA producers
a	under the process of reviewing QC/QA program
b	for small quantities, HMA producers certify that their HMA meets the department requirements

8. APPENDIX B

Additional pictures of the Michigan Sampling Procedure:


DAY CARE


Ingersoll Rand


TRACTOR SUPPLY Co
WARNING
Ingersoll-Rand


Little TYKE'S
DAY CARE
476-1804


Little TYKE'S
DAY CARE
476-1804


Little TYKE'S
DAY CARE
476-1804


Little TYKES
DAY CARE


Michigan CAT
CAT