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Sampling and testing for quality assurance of pavement preservation and treatments

Muestreo y ensayo para el aseguramiento de la calidad en la preservación y tratamientos de pavimentos

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Abstract

Pavement preservation is essential to maintaining viable road infrastructure, slurry seal and microsurfacing, referred to as “slurry system” are widely used as cost-effective techniques for preserving asphalt concrete pavements. However, there is a need for better quality assurance (QA) tools to ensure compliance with approved job mix formulas. This research aimed to devise a field sampling procedure for slurry systems and develop a reliable and accurate QA system to determine the water content and asphalt residue content present in slurry mixes. To be deemed adequate, sampling techniques must satisfy three main criteria: sufficient amount of sampled mixture to determine asphalt residue content, safety of the sampler, and uniform and consistent collected samples. The utility cover sampling technique involves placing a non-absorptive material over a utility cover, as the mix spreader applies the mixture, the cover gets coated with a layer of slurry. This study found that asphalt felt was the most successful material for slurry mix sample collection from utility covers. The study concluded that the oven evaporation method is effective in determining the water content and the ignition oven test is effective in determining the asphalt residue content in slurry mixes.

Keywords: Asphalt emulsion; water content; asphalt residue; slurry seal; microsurfacing; cold in-place recycling.

Resumen

La preservación de pavimentos es esencial para mantener una infraestructura vial viable. El sellado con lechada asfáltica y el micropavimento en frío, conocidos como "sistema de lechada", son técnicas ampliamente utilizadas y rentables para conservar pavimentos de concreto asfáltico. Sin embargo, se requiere contar con mejores herramientas de aseguramiento de la calidad (QA) para garantizar la aplicación de los diseños de mezcla. El objetivo de esta investigación fué diseñar un procedimiento de muestreo de campo para sistemas de lechada y desarrollar un sistema de QA confiable y preciso para determinar el contenido de agua y el contenido de residuo asfáltico presente en las lechadas. Unas adecuadas técnicas de muestreo deben cumplir tres criterios principales: una cantidad suficiente de mezcla muestreada para determinar el contenido de residuo asfáltico, seguridad del operario, y muestras recolectadas uniformes y consistentes.La técnica de muestreo sobre tapas de servicios consiste en colocar un material no absorbente sobre una tapa de servicio. Al aplicar la mezcla con el esparcidor, la tapa queda recubierta con una capa de lechada. Este estudio encontró que el fieltro asfáltico fue el material más exitoso para recolectar muestras de lechada sobre las tapaderas. El estudio concluyó que el método de evaporación en horno es efectivo para determinar el contenido de agua y que la prueba con horno de ignición es efectiva para determinar el contenido de residuo asfáltico en lechadas.

Keywords: Emulsión Asfáltica; contenido de agua; residuo asfáltico; lechada asfáltica; micropavimento; reciclado en frío en sitio.

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1. Introduction

To ensure that roads remain viable over an extended period of time, pavement preservation is a must. Pavement Preservation is defined by the U.S. Federal Highway Administration (FHWA) as; "a program employing a network level, long-term strategy that enhances pavement performance by using an integrated, cost-effective set of practices that extend pavement life, improve safety and meet motorist expectations" (FHWA, 2010). One of the most popular pavement preservation techniques is the application of a slurry system, which comprises either a slurry seal or a microsurfacing.

The slurry system is a widely used and effective technique for preserving asphalt concrete (AC) pavements, offering a relatively low-cost solution while improving long-term performance. Its primary purpose is to extend pavement service life. The slurry mix seals the pavement surface, corrects bleeding, improves surface friction, and provides a new wearing surface, whereby preserving the initial asphalt concrete construction investment. The optimal time for the first slurry system application is between 3 and 5 years after construction, followed by a second application between 7 and 9 years after construction (Hajj et al., 2013). The cost comparison of preservation versus rehabilitation or reconstruction shows that a slurry seal is a cost-effective way to delay the need for major repairs and maintain the structural value of existing pavement. Where every $1 spent on preservation potentially delays the need to spend $4.5 on rehabilitation or $57 on reconstruction (FHWA, 2010).

As pavement preservation gains popularity by offering cost-effective pavement solutions, better quality assurance (QA) tools are needed (Douglas, 2010). Slurry mixtures are designed with aggregates, asphalt emulsion, and water. The asphalt emulsion contains asphalt binder, water, and additives. After construction is completed the water evaporates leaving the asphalt binder, which is referred to as the asphalt residue. Current test methods do not allow for the determination of asphalt residue in slurry mixtures. Determining the asphalt residue of these mixtures is challenging because the asphalt binder is in the form of an emulsion, which contains up to 40% water and other additives. However, the amount of asphalt residue in the mixture is crucial for the performance of the slurry seal. Therefore, there is a need for reliable, repeatable, and practical field test methods that agencies can use to ensure compliance with the approved job mix formula (JMF) for a project.

2. Background

The amount of asphalt residue in the slurry mix controls their long-term performance. The emphasis of state departments of transportation (DOT) regarding quality assurance for slurry mixtures has been primarily on testing the aggregates and asphalt emulsion, with lower attention given to water content and asphalt residue in the produced slurry mixes.

The Illinois DOT requires the contractor to gather a minimum of one sample per job mix formula from the loading shoot of the pug mill before it falls into the drag box. The presence of the Engineer is required during this sampling operation. The collected sample is then placed in a 3.8 L sealed plastic bag. Enough material should be sampled to form roughly 12.5mm of material that is evenly distributed and laid flat. The bag is then squeezed to remove excess air, sealed, and placed on a hard, flat surface. After the bag is left to sit flat for 15 minutes, it is picked up and examined to ensure that it has turned black and is exhibiting positive signs of stiffening. The condition of the sample is documented in 15 minutes and the sealed bag is placed into a 3.8 L friction top container and sent for asphalt residue testing, which is conducted through chemical extraction (Illinois DOT, 2022).

The Australian Ministry of Public Works requires three 1 kg samples to be collected during a paving run - near the start, middle, and end. A clean ladle is used to carefully collect a sample of the slurry mixture coming from the outflow of the pugmill and going into the spreader box. The collected sample is immediately poured into a container. The collected sample should be representative of the bituminous slurry coming from the pugmill. If the sample appears heterogeneous or different from the slurry mix in the pugmill, a new sample should be taken. After verifying the homogeneity of the collected sample, the sample container is placed on a flat surface and left uncovered until the slurry mix sets. If necessary, residual water should be decanted without losing any binder or aggregate. The sample is then taken into the laboratory for determination of asphalt residue (Australian Road Research Board, 2018).

The Alberta Ministry of Public Works requires three samples of slurry seal mix for each day of production. Samples are collected at the diverter and shall consist of a cross-section of the entire flow of the mix. To obtain a representative sample, the following steps should be followed: 1) a plastic bag is placed inside a 1 liter can with the bag folded over the sides of the can, 2) the slurry machine is allowed to produce a mix to the slurry box for at least 30 meters, this is crucial to ensure the mix is at the proper moisture content, 3) the can containing the plastic bag is passed

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across the steady stream of the slurry mix at the diverter, and approximately ¾ liter of the mix is collected. The plastic bag is then sealed, and the can lid is placed. The can is cleaned, labeled using an Asphalt Sample Identification form (MAT 6-13) and shipped to the laboratory for the determination of asphalt residue content (Government of Alberta, 1995).

3. Objective

The overall objective of the research effort was the development of a QA system that can be used for the preservation of asphalt pavements. The preservation activity covers both slurry seal and microsurfacing. The first step in developing a QA system is to identify an effective field sampling technique. Currently, there isn't a standard field sampling technique for slurry mixes. Therefore, the research focused on evaluating a field sampling technique for slurry mixes. The slurry mix is designed with water and asphalt emulsion. Therefore, the QA system must include methods to determine the water content and asphalt residue.

4. Sampling of slurry mixes

The first objective of this study was to identify a field sampling procedure for slurry mixtures. The desired sampling technique must meet three main criteria: 1) the amount of the sampled mixture needs to be adequate for running multiple replicates to determine asphalt residue accurately, 2) the procedure does not interfere with construction operations or put the sampler at risk of any safety hazard, and 3) the uniformity and consistency of the sampled slurry mix should be preserved. This study evaluated three sampling techniques: direct sampling from the mixer shout using a bucket, sampling from a slurry seal mixture pile using a shovel and sampling over a utility cover. Only the sampling over utility cover met the three criteria and is fully described in the next sections.

The idea behind the utility cover sampling technique is to lay down a non-absorptive material over the cover and as the spreader lays down the slurry mix, the cover gets coated with a layer of the slurry mix. After the equipment passes, the cover is removed, and the slurry mix sample is collected. The suggested sampling procedure has the following characteristics: it does not pose any safety concerns, a substantial quantity of mix can be sampled, and the sampled mixture is highly representative of the slurry mixture laid down on the pavement surface.

In order to determine which nonabsorbent materials could be utilized to sample slurry seal mixtures from utility covers, various options were tested, including; plastic sheet, aluminum plate, and asphalt felt.

Given that thin plastic sheets are already commonly implemented to safeguard utility covers against smudging caused by slurry mix, they were evaluated first. Workers typically hold a roll of thin plastic sheeting and cut the required length depending on the dimensions of the utility cover. The cut plastic sheet is subsequently secured in place using duct tape. Although the plastic lining was easy to place and handle by itself, it was challenging to handle with the slurry sample on it, this is due to the fact that the plastic sheet has no structural strength. Thus, extreme care should be taken not to spill any slurry sample. Furthermore, the material on the plastic lining must be removed as soon as possible before the material hardens, because it is impossible for the set sample to be scraped off the plastic sheet. Thus, the drawback of using this method is that the slurry sample is hard to remove from the plastic sheet and the sample is hard to handle since the plastic sheet has no structural integrity. (Figure 1) shows plastic film used as a utility cover for sampling.

To try to mitigate the issues with the plastic sheet, a thin aluminum plate was manufactured, placed over the utility cover, and secured with duct tape. The slurry spreader was then driven over it to gather a sample of the slurry mix. The slurry sample collected on the aluminum plate did not meet the visual inspection for uniformity and consistency. The unevenness and inconsistency in the sample's texture and composition were a result of the slurry spreader dragging the slurry sample unevenly across the smooth surface of the plate. (Figure 2) shows the aluminum plate used as a utility cover for sampling and the condition of the slurry mix sample. It should be noted that the non-uniformity of the sample over the aluminum plate is mainly due to the smooth texture and lack of friction of the plate causing the sample to be randomly distributed.

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Figure 1. Slurry mix sample collected using plastic sheet placed over utility cover.

Figure 2. Slurry mix sample collected using aluminum plate placed over utility cover.

To resolve the problem of unevenness and inconsistency in the slurry samples obtained through the use of the plastic sheet and aluminum plate, a material with a rough texture was required. This was necessary to prevent the slurry sample from slipping off the sampling plate while being dragged by the slurry spreader. Asphalt felt was thought of as an option as it is light, non-absorptive, and has some structural rigidity. Furthermore, the slurry mix on the asphalt felt could be easily scrapped off and collected. Moreover, the asphalt felt offered a financial advantage as it is relatively inexpensive and could be cut using a pair of scissors to fit the required dimensions of the utility cover encountered in the field. Since asphalt felt is sold in rolls it tends to take the curvature of the roll. Thus, when an asphalt felt piece is cut to the dimensions of the utility cover, the cut asphalt felt piece will tend to curl back into its original shape. The curling can be mitigated by firmly securing the asphalt felt to the utilities cover using duct tape. If the asphalt felt is not flat or secured properly using duct tape, it can get stuck and get dragged by the slurry spreader

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box leading to streaks in the spread slurry. This would require the slurry spreader truck to be stopped and the spreader box to be lifted to remove the stuck piece of asphalt felt manually. Additionally, the streaked slurry seal system would need to be redone which would lead to additional construction costs and road closure time. (Figure 3) shows the asphalt felt used over the utility cover and the slurry mix being collected. It should be noted that the method can still be used on roads that do not have utility access, where the asphalt felt will be placed directly over the pavement surface.

Figure 3. Asphalt felt was used over the utility cover to collect slurry mix samples.

5. Testing for slurry mix components

The next step in a QA system is to identify test methods to determine the components of the slurry mix, namely: water content and asphalt residue. The process of identifying the appropriate test methods requires reference values that can be compared to the values determined by the identified methods. Laboratory-produced slurry mixtures were used in order to offer the required reference values.

Three distinct slurry mixtures were designed following the mix design method recommended by the International Slurry Seal Association (ISSA) (ISSA, 2015). A single aggregate source and a single gradation, along with three different asphalt emulsions were used to design the three slurry mixes (8). The three asphalt emulsions were; Cationic Quick Setting with 3.0% Latex (CQS 3.0%), Microsurfacing Emulsion with 3.5% and 4.0% latex (MSE 3.5% and MSE 4.0%). (Table 1) summarizes the properties of the three slurry mixes.

Table 1. Summary of the Slurry Mix Designs.

Slurry Mix	Asphalt Residue in Emulsion, %	Optimum Emulsion Content, % dwa	Added Water, % dwa	Asphalt Residue in Slurry Mix, % dwa
CQS 3.0%	65	11.8	10.0	7.7
MSE 3.5%	64	11.6	9.9	7.4
MSE 4.0%	64	11.2	10.2	7.3

Actual weights of aggregate, water, and asphalt emulsion in the slurry mixes were used to calculate the reference values for water content and asphalt emulsion by dry weight of aggregate (dwa). The calculated values are compared with the values determined through the test methods.

6. Test method for water content

The test method evaluated for determining the water content of the slurry mix used the oven evaporation technique. Slurry mixes contain water from two sources; added water and emulsion water. The total amount of water in the mix is the sum of the two values. The following procedure was used to determine the water content of the slurry mix using the oven evaporation technique:

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1. Measure the weight of the empty aluminum pan with dimensions of 65x17x2.cm.
2. Transfer the slurry mix sample into the pan. Spread the slurry seal mixture uniformly across the pan.
3. Measure the weight of the pan and the slurry mix.
4. Place the pan with the slurry mix in a preheated oven at 110 ± 5°C to a constant weight. Constant weight is achieved when two consecutive weight measurements, taken at 30-minute intervals, differ by less than 0.1%. To expedite the drying process: Remove the sample from the oven after 4 hours of drying and mix the sample using a scraper to try to expose different parts of the slurry mix to the air convection of the oven.
5. Remove the pan with the dried slurry mix from the oven and measure the weight.
6. Calculate the moisture content of the slurry mix using (Equation 1):

$$\mathrm{MC}\,,\% = \left[\frac{(m_\mathrm{i} - m_\mathrm{P}) - (m_\mathrm{f} - m_\mathrm{P})}{m_f - m_\mathrm{P}} \mathrm{x}100\right] \quad \textbf{(1)}$$

Where:
MC= Moisture Content, % by dwa.
mp = Mass of the pan, g.
mi = Initial mass of the pan with the wet slurry mixture, g.
mf = Final mass of the pan with the dry slurry mixture, g.

Five replicate samples were produced for each of the three slurry mixes and tested following the oven evaporation procedure listed in steps 1 – 6. (Figure 4) presents the measured and calculated water contents of the three slurry mixes. The height of the bars represents the average value while the whiskers represent the 95% confidence interval (CI). Overlapping of the 95% CIs indicates statistically similar values of the measured and calculated water contents. Because of the high repeatability of the measurements, the 95%CIs are very small, however, it can be observed that the measured and calculated water contents for the CQS 3.0% and MSE 3.5% mixtures are statistically similar. The difference between the average of measured and calculated water contents is 0.10, 0.0, and 0.24% for CQS 3.0%, MSE 3.5%, and MSE 4.0%, respectively. The differences between the average of measured and calculated water contents are very small relative to any practical field control, which indicates that the oven evaporation method for the determination of water content of slurry mixtures is accurate and can be used in QA for slurry seals and microsurfacing.

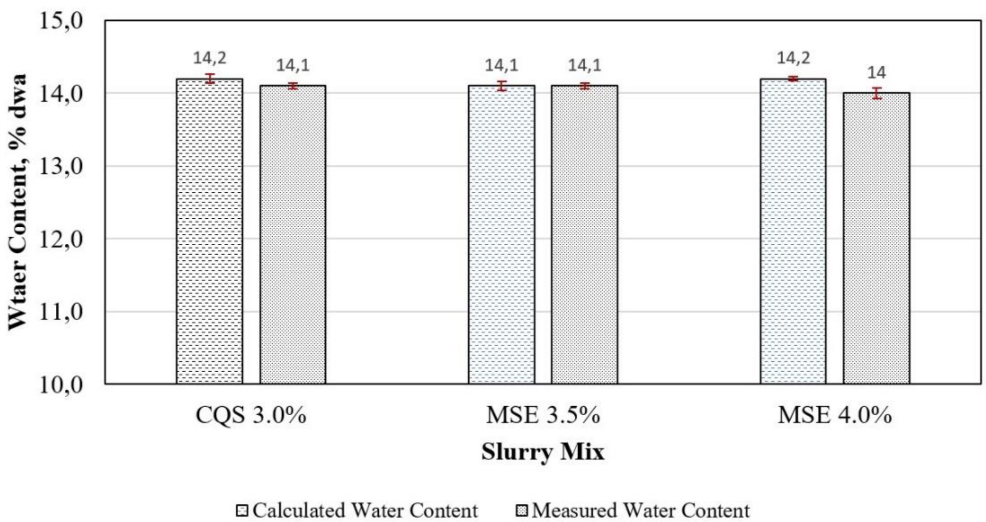

Figure 4. Comparison of the measured and calculated water contents for slurry mixes.

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7. Test for asphalt residue

The second major part of the QA for slurry systems is the determination of the asphalt residue in the slurry mix. The following two methods were evaluated in this study:

AASHTO T 164: Standard Method of Test for Quantitative Extraction of Asphalt Binder from Hot Mix Asphalt (HMA).
AASHTO T 308: Standard Method of Test for Determining the Asphalt Binder Content of Asphalt Mixtures by the Ignition Method.

The same three slurry mixes used in the water content determination experiment were also used to evaluate the T 164 and T 308 methods for the determination of asphalt residue. Five replicate samples from each slurry mix were used in each test method. The slurry mix samples were first subjected to water evaporation as described earlier followed by the determination of asphalt residue. (Figure 5) and (Figure 6) present the measured and calculated asphalt residues for the T 164 and T 308 methods, respectively.

(Table 2) summarizes the difference between the averages of calculated and measured asphalt residue from AASHTO T 164 and T 308. The data in (Table 2) shows that the difference between the averages of calculated and measured asphalt residue is below 1% for all three slurry mixes and for both test methods, while the T 308 method showed significantly lower difference. Typical mix design tolerance for asphalt residue is ±1%, therefore, both methods would be acceptable with T 308 being more accurate.
Even though the data showed that both T 164 and T 308 have acceptable accuracy for the determination of the asphalt residue in slurry mixes, there is a major difference between the two methods, which will control the method to be selected by an agency. The T 164 method uses chemicals to extract the asphalt residue from the slurry mix while T 308 burns the asphalt residue from the slurry mix. In other words, the asphalt residue will be available for recovery and further testing when the T 164 is used while in the T 308, the asphalt residue is burned-off. If the owner agency desires to recover the asphalt residue and subject it to further testing as part of QA testing, then the T 164 is the only test that will be applicable.

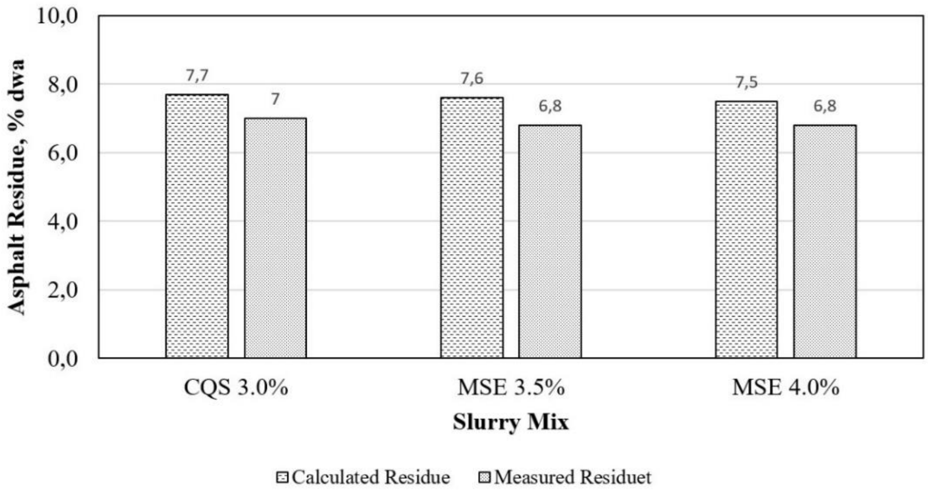

Figure 5. Comparison of the measured and calculated asphalt residue from AASHTO T 164 for slurry mixes.

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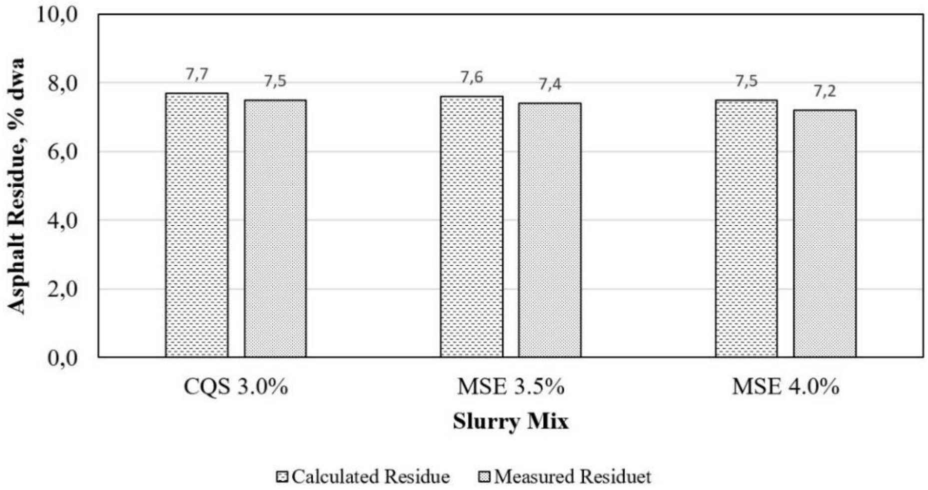

Figure 6. Comparison of the measured and calculated asphalt residue from AASHTO T 308 for slurry mixes.

Table 2. Summary of Difference between Calculated and Measured Asphalt Residue.

Slurry Mix	Difference between Calculated and Measured Asphalt Residue, % dwa	
	AASHTO T 164	AASHTO T 308
CQS 3.0%	0.68	0.23
MSE 3.5%	0.75	0.18
MSE 4.0%	0.73	0.14

8. Summary and Findings

The research effort presented in this paper evaluated sampling and testing methods for inclusion in QA testing for slurry systems, i.e., slurry seal and microsurfacing. The research evaluated multiple field sampling techniques against three criteria; 1) sufficient sample, 2) safety of sampler, and 3) uniformity of sample. For determining the components of the slurry and CIR mixes, the research identified a technique to measure water content using oven evaporation and evaluated two existing methods to measure the asphalt residue. The sampling method was tested in the field while the two methods for mixing components were evaluated in the laboratory using three slurry mixes. Based on the analyses of the data collected from the field and laboratory experiments, the following findings were made:

• The use of asphalt felt over utility cover offers a very practical and reliable method to sample slurry mixes. The method was found to be safe and collects sufficient and uniform samples of the slurry mix. In addition, the method can still be used on roads that do not have utility access, where the asphalt felt will be placed directly over the pavement surface.

• The water content of the slurry mix can be effectively and accurately determined using the oven evaporation method. The difference between the calculated and measured water contents was less than 0.3% by dwa for all slurry mixes. This indicates that the oven evaporation method is a very practical and highly accurate method for determining the water content of slurry mixes. The oven evaporation method is very simple and does not require specialized equipment or additional personnel training, which makes it practical to incorporate into QA testing for slurry mixes.

• The two AASHTO methods, T 164 and T 308, for determining the asphalt binder content of asphalt mixtures were proven applicable for determining the asphalt residue of slurry mixes. The difference between the calculated and measured asphalt residues were less than 0.75% and 0.23% by dwa for T 164 and T 308, respectively.

• Even though T 308 exhibited better accuracy, it does not allow for further testing of the extracted asphalt residue. Therefore, if the owner agency desires to test the asphalt residue for compliance with the asphalt emulsion specification, AASHTO T 164 will have to be used. Since T 308 does not use chemicals which makes it friendlier to testers and the environment, it is recommended that T 164 be conducted on a limited basis to verify the conformance of the asphalt emulsion with specifications, while the T 308 can be used more frequently for QA testing.

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