RESEARCH & DEVELOPMENT

Implementation of the Tack Lifter

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Implementation of the Tack Lifter

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The emulsion application rate (EAR) is critical to the performance of both tack coats and chip seals. Typically, only the change in volume of emulsion in the distributor tank before and after construction is measured for acceptance, which cannot quantify local variability in the applied EAR. In addition, the current practice is to adjust the required target EAR to account for absorption into the existing pavement based on visual inspection, which is subjective. This study identifies suitable test frameworks for in-situ measurements of EARs, leveraging the results of FHWA/NCDOT 2014-03. In FHWA/NCDOT 2014-03, the Tack Lifter was proposed as a practical means to obtain in-situ EAR measurements. The results of this study demonstrate that in tack coat projects, measurements of the applied EAR can be made by simply placing pre-weighed plates on the roadway prior to emulsion application. The net mass of the plate after emulsion application is used to determine the applied EAR. In chip seal projects, the applied EAR can be measured by performing Tack Lifter tests on impermeable plates placed in the roadway prior to emulsion application. The Tack Lifter uses an absorbent sheet that is pressed onto the application surface with a weighted device to obtain spot checks of EARs. By conducting Tack Lifter tests directly on the pavement, the "effective" EAR (i.e., the amount of emulsion available after absorption) can be measured in both tack coats and chip seals; this can better inform target EAR selection. Residual binder rates can be obtained by collecting pre-weighed plates or Tack Lifter sheets in-situ and weighing after curing; this mitigates time constraints and the need for leveling and shielding a balance from wind in the field. Training tools for the NCDOT, including guidelines, videos, and draft AASHTO standard practices were developed to facilitate implementation into practice.</td></tr>
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EXECUTIVE SUMMARY

Emulsions are used as tack coats to bond asphalt concrete layers and as a bonding agent in pavement surface treatments. The emulsion application rate (EAR) is critical to the performance of both tack coats and surface treatments. The EAR can vary longitudinally along the length of paving as a result of fluctuations in distributor speed and flow rates. Currently, the only measure for quality control of the EAR along the length of paving is to measure the change in the volume of emulsion in the distributer tank before and after paving. This practice lacks the ability to quantify local variability in the applied EAR. In addition, the existing paving surface will absorb a portion of the applied emulsion which will be unavailable to act as a bonding agent for aggregate or asphalt concrete placed on top of the emulsion. To compensate, the current practice is to adjust the required target EAR used in the construction based on visual inspection of the existing pavement surface, which is subjective.

The Tack Lifter test was developed in FHWA/NCDOT HWY-2014-03 to overcome the limitations of the current technology to allow for in-situ measurements of applied EARs and pavement emulsion absorption rates. The Tack Lifter consists of a simple, weighted device that is placed on top of a super-absorbent, polyurethane foam sheet applied to a pavement or plate within a frame. The foam sheet absorbs emulsion on the application surface. The mass of emulsion absorbed by the sheet, combined with the known sheet area, is used to obtain a local EAR measurement. The Tack Lifter can either be conducted on a pan placed on the roadway prior to emulsion application or directly on the pavement after emulsion application. When the Tack Lifter is applied to a steel pan which is smooth and impermeable, the sheet will absorb all of the applied emulsion, thereby providing a measurement of the applied EAR. When applied directly to a pavement, the Tack Lifter absorbs the “effective” EAR on the pavement, neglecting emulsion absorbed into the pavement. Thus, the difference in results of Tack Lifter tests conducted on a pan and the adjacent pavement can be used to determine the rate by which a pavement absorbs emulsion.

The implementation of the Tack Lifter into practice by the NCDOT will improve the quality of tack coats and chip seals constructed, which will ultimately lead to prolonged pavement service life, long-term cost savings, and enhanced safety. In this project, the Tack Lifter device was be optimized for routine use by Instrotek, Inc. Laboratory and field experiments were used to establish proposed testing frameworks for quantifying pavement emulsion absorption rates and longitudinal variability in the applied EAR. The results demonstrate that in tack coat projects, measurements of the applied EAR can be made by simply placing pre-weighed plates on the roadway prior to emulsion application. The net mass of the plate after emulsion application is used to determine the applied EAR. In chip seal projects, the applied EAR can be measured by performing Tack Lifter tests on impermeable plates placed in the roadway prior to emulsion application. By conducting Tack Lifter tests directly on the pavement, the “effective” EAR (i.e., the amount of emulsion available after absorption) can be measured in both tack coats and chip seals; this can better inform target EAR selection. Residual binder rates can be obtained by collecting pre-weighed plates or Tack Lifter sheets in-situ and weighing after curing; this mitigates time constraints and the need for leveling and shielding a balance from wind in the field. Training tools have been developed to instruct the NCDOT personnel in the use of the

Tack Lifter. Draft AASHTO standard practices for the measurement of application rates in chip seals and tack coats have been prepared.

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INTRODUCTION

Asphalt emulsions are used as tack coats to bond asphalt concrete layers and as a bonding agent in chip seal surface treatments. The emulsion application rate (EAR) is critical to the performance of both tack coats (*1-2*) and chip seals (*3,4*). The EAR can vary longitudinally along the length of paving as a result of fluctuations in distributor speed and flow rates (*3, 5*). Currently, most agencies only measure the change in the volume of emulsion in the distributor tank before and after construction for acceptance (*6*). This practice lacks the ability to quantify local variability in the applied EAR. In addition, the existing paving surface will absorb a portion of the applied emulsion, which will be unavailable to act as a bonding agent for aggregate or asphalt concrete placed on top of the emulsion. To compensate, the current practice is to adjust the required target EAR used in the construction based on visual inspection of the existing pavement surface, which is subjective.

ASTM D2995 (*7*) is the only standardized test procedure for obtaining local measurements of EARs. The procedure targets distributor calibration rather than in-situ measurements during construction and does not allow for quantifying pavement emulsion absorption. ASTM D2995 (*7*) includes provisions for two test methods. In Method A, the distributer applies emulsion to 12 in by 12 in (30.48 cm by 30.48 cm) tarps placed on the roadway, aligned transversely or longitudinally. In Method B, containers are placed directly under each nozzle and the distributer releases emulsion to address transverse EAR variability prior to construction. In FHWA/NCDOT 2014-03, an attempt was made to use ASTM D2995 to measure the transverse and longitudinal EAR variability during chip seal construction (*8*). It was concluded that ASTM D2995 Test Method B may be effective for addressing transverse variability by allowing the calibration of individual nozzles. However, ASTM D 995 Test Method A was deemed impractical for in-situ EAR measurements due to difficulties encountered with the tarps adhering to distributor wheels and dripping of emulsion during transport.

The Tack Lifter, shown in Figure 1, was developed under FHWA/NCDOT 2014-03 by Castorena et al. (*8*) in partnership with Instrotek, Inc. to enable in-situ measurements of applied EARs and pavement emulsion absorption rates. To conduct a Tack Lifter test, the area of interest is first isolated by using the Tack Lifter frame with gasket. Next, a pre-weighed absorbent sheet is placed inside the frame. The Tack Lifter weighted device is placed on top of the absorbent sheet for 30 seconds. The weighted device is removed and the sheet is transferred to a balance. The mass of the sheet after the application of the Tack Lifter minus the initial mass provides the mass of emulsion absorbed by the sheet. The test is conducted prior to emulsion breaking.

Equation (1) is used to determine the applied EAR using the Tack Lifter test results applied to the plate and the effective EAR using the Tack Lifter results applied to the pavement.

$$EAR, \frac{gal}{yd^2} = \frac{A}{26.01 in^2 \times G_s} \times 0.000264 \frac{gal}{cc} \times 1296 \frac{in^2}{yd^2} \qquad (1)$$

Where A = net mass of emulsion absorbed by the sheet, g; G_s = specific gravity of the asphalt emulsion.

The Tack Lifter can either be conducted on a plate placed on the roadway prior to emulsion application or directly on the pavement after emulsion application. When applied to steel plates, the sheet absorbs all of the applied emulsion and provides a measurement of the applied EAR. When applied to a pavement, the sheet absorbs the "effective" emulsion on the pavement, neglecting emulsion absorbed into the pavement. The difference between Tack Lifter measurements of EAR on the plate (i.e., $EAR_{Applied}$) and pavement (i.e., $EAR_{Effective}$) is used to determine the pavement absorbs emulsion rate (i.e., $EAR_{Absorbed}$) as shown in Equation (2).

$$EAR_{Absorbed} = EAR_{Applied} - EAR_{Effective} \tag{2}$$

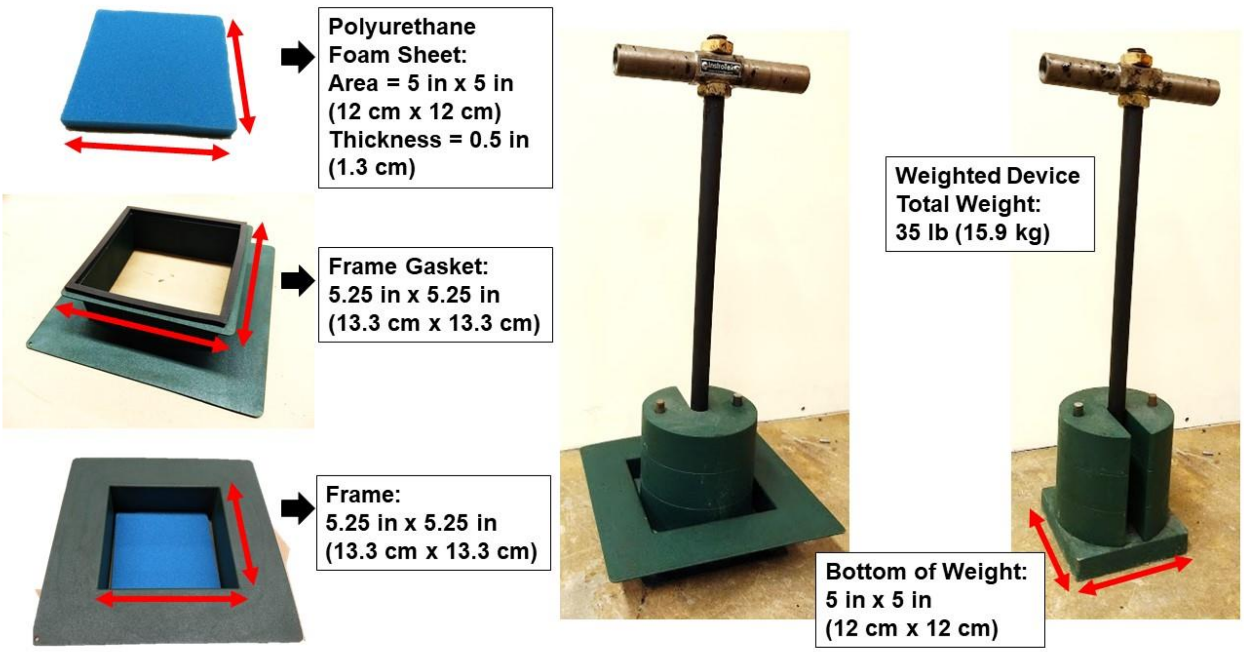


Figure 1. Tack Lifter components.

Based on the results of FHWA/NCDOT 2014-03, Castorena et al. (*8-10*) The Tack Lifter has been proposed for use just prior to construction to measure the pavement emulsion absorption rate, which can inform adjustment of the target EAR. In addition, the Tack Lifter has been proposed to assess the longitudinally variability in the applied EAR for acceptance testing (*8, 10*). The elevated plate and peel system shown in Figure 2 can be used when conducting measurements of the applied EAR to assess longitudinal variability during chip seal construction where aggregate application quickly follows emulsion application. The elevated plate is placed on the paving surface prior to emulsion application. Following emulsion application, the elevated plate is removed from the pavement and placed on a level surface off the roadway prior to application of the frame, sheet, and weighted device to allow the construction operations to proceed without delay.

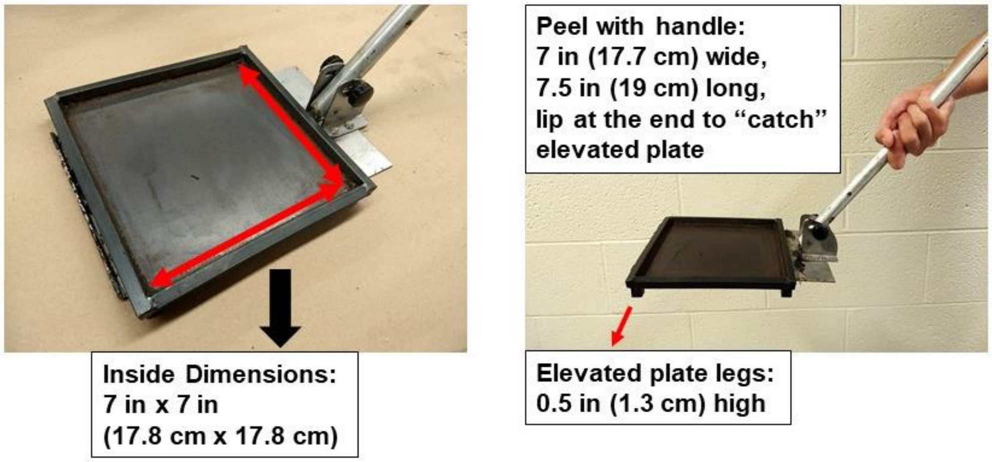


Figure 2. Elevated plate and peel used in chip seal field trials.

Preliminary Tack Lifter field experiments demonstrate that the Tack Lifter can effectively capture pavement emulsion absorption rates and longitudinal variability in the applied EAR in chip seal applications (*8*, *10*). Results of FHWA/NCDOT 2014-03 (*8*) demonstrated that the amount of emulsion absorbed by a pavement is influenced by pavement surface type (e.g., asphalt concrete versus chip seal) and pavement surface texture.

While results in FHWA/NCDOT 2014-03 are promising, there are several aspects of testing that must be addressed before the Tack Lifter test is implemented into practice. The device should be optimized. The applicability of the Tack Lifter to tack coat field projects merits investigation. Past field experiments focused on chip seals with relatively high EARs (*8*). If the Tack Lifter is found to be ineffective for tack coat application, an alternative means to measure the EAR should be identified. Lastly, past efforts have focused on the use of the Tack Lifter for the measurement of EAR. However, the test can also potentially be used to measure the residual binder application rate by preserving the Tack Lifter sheets after testing and weighing after the emulsion has fully cured. Weighing the Tack Lifter sheets in the field takes time and can be challenging because the balance must be level and shielded from wind. Therefore, conducting Tack Lifter tests in the field and then weighing the sheets later in the laboratory may improve the feasibility of implementing the test for acceptance testing. In addition, training tools should be developed to instruct the NCDOT personnel in the use of the Tack Lifter. Draft standard procedures should be developed and submitted to AASHTO for consideration as provisional standards.

OBJECTIVES

The objectives of the project are to:

(1) Optimize the Tack Lifter device for routine use
(2) Develop training tools and provide Tack Lifter training to the NCDOT personnel
(3) Establish field test procedures for measurement of pavement emulsion absorption rates and longitudinal variability in the applied EAR
(4) Develop draft AASHTO standards for the measurement of application rates in chip seals and tack coats

TACK LIFTER OPTIMIZATION

In this project, the research team worked with Instrotek, Inc. to optimize the Tack Lifter. The primary modification from the original design was the improvement of the elevated and peel design. The updated design is shown in Figure 2. The refined elevated and plate improves the ability to lock the peel onto the plate and remove from the roadway while keeping the plate level. Note that the elevated plate and peel are only required in chip seal projects where the aggregate spreader directly follows the emulsion distributor. In tack coat projects, there is a significant time gap between emulsion application and placement of the overlay, negating the need for elevated plates. The research team also refined the calculation of the EAR from Tack Lifter results. Initially, the original sheet area (i.e., 5 in by 5 in) was used as the basis for the calculation. However, it was found that the Tack Lifter sheet increases to dimensions of 5.1 in by 5.1 in when the weighted device is applied; this is reflected in the EAR calculation given in Equation 1. Preliminary field experiments conducted in this study used a pocket scale. However, the precision of the pocket scale and inability to level in the field compromised measurements; these preliminary field experiments are omitted from the results presented in this report. It was concluded that a larger scale with 0.01 g resolution and leveling capabilities was required to obtain reliable in-situ mass measurements. Furthermore, a wind shield was developed to mitigate the influence of wind on in-situ mass measurements. The scale utilized in this study is detailed within the experimental plan. All of the aforementioned experimental factors are detailed within guidelines for conducting EAR measurements given in Appendix A and within the proposed AASHTO standards for application measurements in chip seals and tack coats given in Appendices B and C, respectively.

EXPERIMENTAL PLAN

Laboratory Experiments

To assess the accuracy of Tack Lifter measurements and the associated variability in test results, a set of laboratory experiments were conducted where the applied EAR could be precisely controlled. For tack coat experiments, a CRS-1h emulsion was applied to flat and level steel plates in the laboratory at three typical tack coat target EARs: 0.04, 0.06, and 0.08 gal/yd^2 (0.18, 0.27, and 0.36 L/m^2). Six replicate Tack Lifter tests were conducted at each EAR. In addition, a CRS-2L emulsion was applied to flat and level steel plates at two common chip seal EARs: 0.25 and 0.35 gal/yd^2 (1.13 and 1.58 L/m^2). Three replicate Tack Lifter tests were performed at each EAR. The application temperature for both emulsions was 60°C. To precisely control the applied EAR in laboratory experiments, a frame gasket was affixed to the steel plates to designate a 5.25 by 5.25 in^2 (13.34 by 13.34 cm^2) square area for emulsion application. Emulsion was applied evenly within this area using a foam brush while the plate and gasket were on a balance to allow precise control. The applied emulsion was within ±0.002 gal/yd^2 (0.01 L/m^2) of the target EAR value in all laboratory experiments. Tack Lifter tests were conducted on the plate and sheets were weighed within 60 seconds of emulsion application.

Field Experiments

Three tack coat and three chip seal field experiments were conducted, which are summarized in Tables 1 and 2. All chip seal field trials consisted of a double seal; application rates were measured in both the bottom and surface layers. CRS-1h emulsion was applied in all three tack coat field trials and all three chip seal field trials utilized CRS-2L emulsion in both layers. Tables 1 and 2 show the target EARs in each field project.

Table 1. Summary of Tack Coat Field Trials

Field Trial ID	Location	Date	Existing Surface Condition	Target EAR of CRS-1h gal/yd^2 [L/m^2]
TC-1	Raleigh, NC	04 June 2018	Oxidized Asphalt	0.06 [0.27]
TC-2	Raleigh, NC	19 June 2018	Oxidized Asphalt	0.06 [0.27]
TC-3	Raleigh, NC	10 July 2018	Milled Asphalt Surface	0.06 [0.27]

Table 2. Summary of Chip Seal Field Trials

<table>
<tr><th>Field Trial ID</th><th>Location</th><th>Date</th><th>Existing Surface Condition</th><th>Target EAR of CRS-2L gal/yd^2 [L/m^2]</th></tr>
<tr><td rowspan="2">CS-1</td><td rowspan="2">Manson, NC</td><td rowspan="2">31 May 2018</td><td rowspan="2">Aged Chip Seal</td><td>Bottom Layer: 0.30 [1.36]</td></tr>
<tr><td>Surface Layer: 0.25 [1.13]</td></tr>
<tr><td rowspan="2">CS-2</td><td rowspan="2">Durham, NC</td><td rowspan="2">07 June 2018</td><td rowspan="2">Oxidized Asphalt</td><td>Bottom Layer: 0.30 [1.36]</td></tr>
<tr><td>Surface Layer: 0.25 [1.13]</td></tr>
<tr><td rowspan="2">CS-3</td><td rowspan="2">Saratoga, NC</td><td rowspan="2">10 July 2018</td><td rowspan="2">Oxidized Asphalt</td><td>Bottom Layer: 0.25 [1.13]</td></tr>
<tr><td>Surface Layer: 0.25 [1.13]</td></tr>
</table>

Prior to emulsion application, the mean texture depth (MTD) of the existing pavement surface was quantified using the sand patch test, in accordance with ASTM E965-15 (*11*). Past experiments suggest that the mean texture depth will influence the amount of emulsion absorbed by the pavement (*8*), which was further evaluated in this study.

A Sartorius Entris 3202-1S balance (3200 g capacity with 0.01 g resolution) powered by a battery pack was used to obtain all mass measurements of emulsion application in the field. A shield was constructed and placed around the balance to mitigate the influence of wind on mass measurements. Prior to performing any measurements, the balance, battery pack, and draft shield were set up close to measurement site. The balance was levelled. Figure 3 shows the balance and draft shield at a field trial. To minimize errors due to evaporative loss and delay in the construction activity, all measurements of emulsion application at a test site were taken in close proximity to the weighing station.

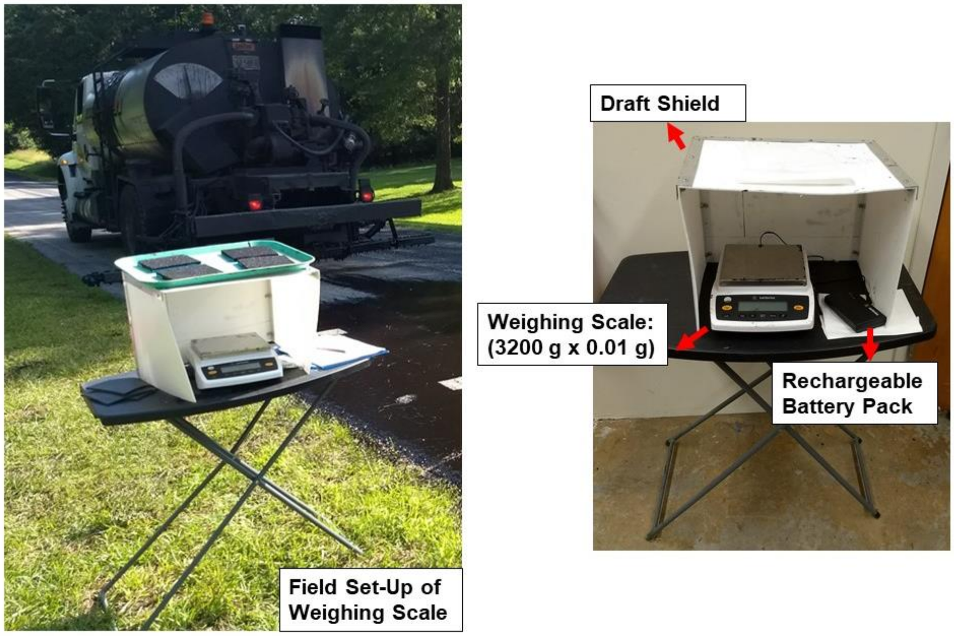


Figure 3. Balance set-up for field data collection.

In tack coat field experiments, two methods were used to measure EARs: (1) pre-weighed plates, and (2) Tack Lifter tests conducted on the pavement. The pre-weighed plates are flat, steel plates with dimensions of 8 in by 8 in (20.32 cm by 20.32 cm). They were placed on the roadway prior to emulsion application in a single wheel path, as shown in Figure 4 (a). The wheel path was selected as a critical location for testing as it represents the location where pavement distress is most likely to develop. The plates were removed from the pavement following emulsion application with the aid of a spatula to determine the net mass of applied emulsion. The EAR was calculated from the pre-weighed plate measurements using an analogous approach to the Tack Lifter tests, by converting the net mass of the applied emulsion to EAR using the known plate area and emulsion density. Initial laboratory Tack Lifter experiments suggested that Tack Lifter measurements of applied EARs in tack coat applications may be erroneously low. Thus, the pre-weighed plates were used in lieu of Tack Lifter tests to measure applied EARs in tack coat experiments, which is discussed in detail in the results. The pre-weighed plates overcome the issues associated with the light and pliable tarps used in ASTM D2995 Method A (*7*). The pre-weighed plates are sufficiently heavy to prevent pickup by the distributor tires. They are also easy to remove from the roadway and transport to the scale without the loss of emulsion. All pre-weighed plates were weighed within 60 seconds of emulsion application for EAR determination. Tack Lifter tests on the pavement were conducted in the same wheel path and in close proximity to the pre-weighed plate measurements to obtain measurements of the effective EAR. The difference between applied EAR measurements from the plates and effective EARs from Tack Lifter tests conducted on the pavement were used to calculate the pavement absorption rates. Tack Lifter tests were completed within 60 seconds of emulsion application; the sheets were weighed for EAR determination within 60 seconds of removal from the pavement. The pre-weighed plates were securely transported to the laboratory and re-weighed following curing for residual binder application rate measurements.

Each tack coat field trial included two to three test sites. Two Tack Lifter tests on the pavement were performed at a single test site in each field trial to measure the pavement absorption rate as the existing pavement surface was determined to be uniform within a field trial location. Two to four pre-weighed plates were placed at each testing site, depending on the length of pavement. Due to constraints in the time available for set-up, only one plate could be placed in one of the test sites in TC-2.

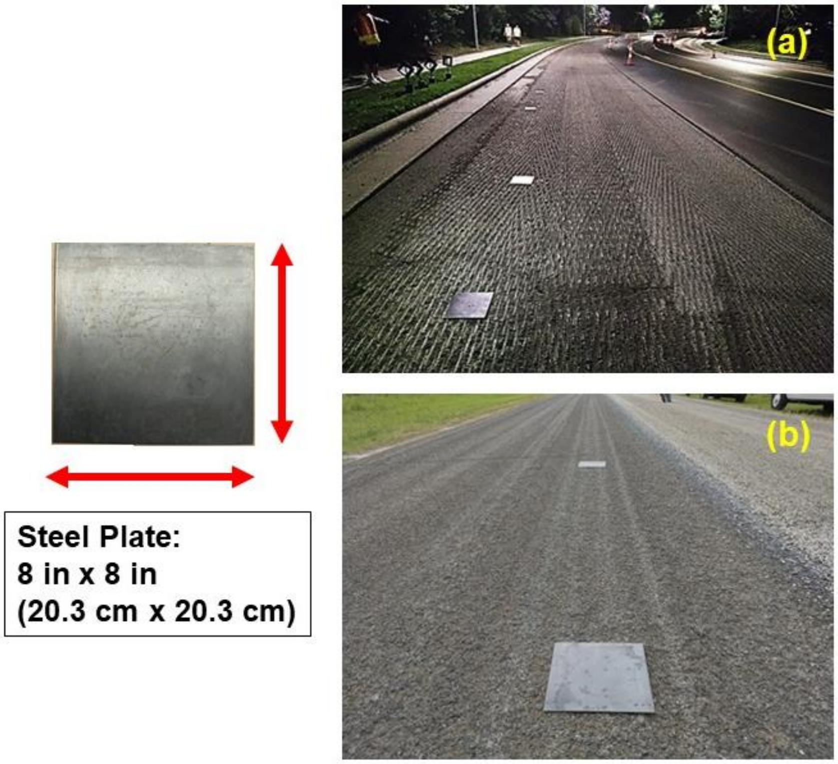


Figure 4. Steel plates placed on the roadway prior to emulsion application in (a) tack coat and (b) chip seal projects.

In each chip seal field trial, EAR measurements were made for both bottom and surface layers of the double seal. During the construction of the bottom layer, flat, 8 in by 8 in steel plates were placed in the wheel path prior to emulsion application, as shown in Figure 4 (b). Tack Lifter tests were conducted on the plates as well as on the pavement in the same wheel path, adjacent to the plates. It should be noted that the pre-weighed plate method of application rate determination used in tack coat projects cannot be used in chip seal projects. The relatively high application rates used in chip seals does not allow for removing and transporting the steel plates after emulsion application without the emulsion dripping from the plate edges.

Only measurements of the applied EAR were made in the surface layer. Loose aggregate from the bottom chip seal layer adhered to the foam sheets when Tack Lifter tests were conducted directly on the pavement during surface layer application as shown in Figure 5. Hence, the absorption rate could not be determined for the surface layer of chip seals. Surface layer Tack Lifter tests were conducted using the addition of elevated plates shown in Figure 2 to minimize delays in aggregate application. Elevated plates were placed in the lane center to avoid crushing by the distributor. Immediately following emulsion application, the elevated plates were moved to a level surface off of the roadway to conduct Tack Lifter tests. Tack Lifter sheets from the tests on plates and pavement were first weighed in the field for EAR measurements and subsequently re-weighed in the laboratory following curing for residual rate measurements.

In each chip seal field trial, testing was conducted at two sites for the bottom layer and one to two sites for the surface layer. For each test site in the bottom layer, two Tack Lifter tests each were conducted on plates and the adjacent pavement. For the surface layer, three to four Tack Lifter tests were conducted on elevated plates. All Tack Lifter tests were conducted within 120 seconds of emulsion application; all sheets were weighed within one minute of removal from the pavement.

Figure 5. Aggregate chips adhered to Tack Lifter foam sheet applied to upper chip seal layer of a double seal.

Asphalt emulsions samples were collected from the distributor in a subset of the field trials. Residual binders were recovered in the laboratory following the procedure detailed in AASHTO R 78 Procedure B (*12*) to measure water content. The water content was used to calculate the corresponding applied EAR values from residual binder application rate measurements; these values were compared with the corresponding in-situ measurements of applied EAR for that test site.

EXPERIMENTAL RESULTS

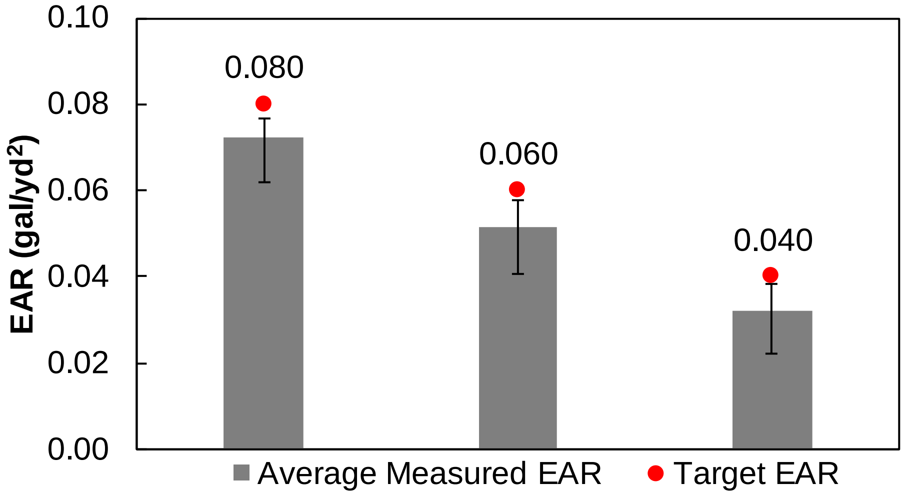
Laboratory Experiments

Figure 6 and Figure 7 show the results of the laboratory study that evaluated the accuracy and associated variability in Tack Lifter measurements of applied EARs for tack coat experiments and chip seal experiments, respectively. Note that all tests and associated mass measurements were made within 60 seconds of emulsion application at ambient temperature to mitigate any evaporative loss. Figure 6 demonstrates that the Tack Lifter measurements of the applied EAR are erroneously low and that the variability in the measured EAR values is relatively high. While the effect of water loss in these experiments is expected to be minimal, the results suggest that the emulsion may have begun to break after application to the steel plates, leading to a small amount of binder adhering to the plate that was not absorbed by the Tack Lifter sheets. These results suggest that the Tack Lifter is not suitable for measuring the applied EAR or the residual application rate in tack coat applications.

The use of pre-weighed steel plates is recommended in lieu of Tack Lifter testing to measure the application rate in tack coat applications. Pre-weighed plates are simply placed on the pavement prior to the arrival of the emulsion distributor and removed for weighing to determine the applied EAR or stored for later measurement of the residual binder rate. Following emulsion application, the plates can be easily removed from the roadway with the aid of a spatula. The plates can either be weighed immediately upon removal from the roadway to obtain the applied EAR or allowed to cure for determination of the residual application rate. Note that the ability to obtain reliable EAR measurements using pre-weighed plates without the influence of water loss is evaluated within the field trial results.

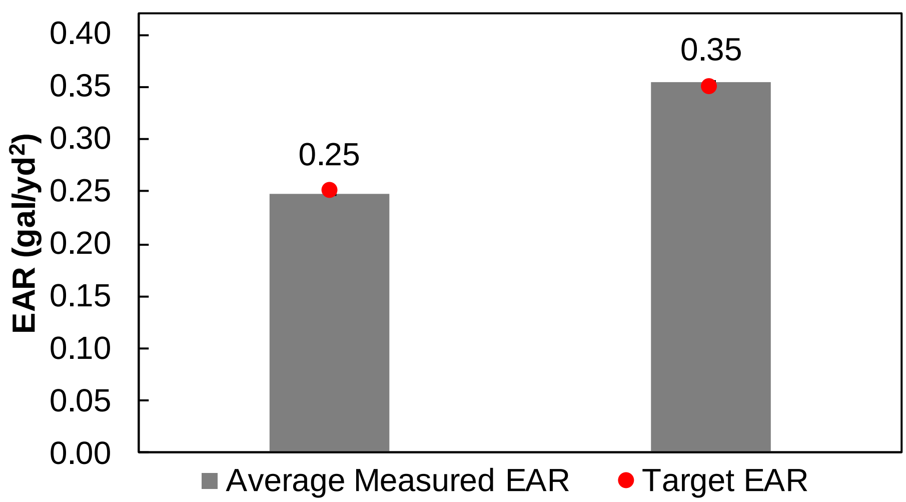
The Tack Lifter is still deemed suitable for obtaining effective application rate measurements in tack coat applications. The goal of Tack Lifter testing on the pavement is to measure the quantity of binder available for bonding to overlay placed on top of the tack coat. Any residual binder that adheres to the existing pavement but not the Tack Lifter sheet directly following emulsion application is deemed ineffective and therefore, the concerns associated with residual binder adhering to the steel plates is not relevant when measuring the effective application rate on the pavement.

Figure 7 shows that the chip seal applied EAR measurements are highly accurate and exhibit very low sample-to-sample variability; note that error bars are included but so small that they are not easily seen. Thus, the Tack Lifter test is recommended for applied EAR measurements during chip seal construction. The results demonstrate that two replicates can yield accurate results. Note that pre-weighed plate measurements, as proposed for tack coat applications, cannot be used in chip seal applications as the higher amounts of emulsion on the plates would lead to dripping of emulsion from the plate edges upon removal from the pavement.



Note: *Error bars indicate range of values.*

Figure 6. Measured EAR results using the Tack Lifter laboratory experiments to reflect Tack Coat application rates using CRS-1h.



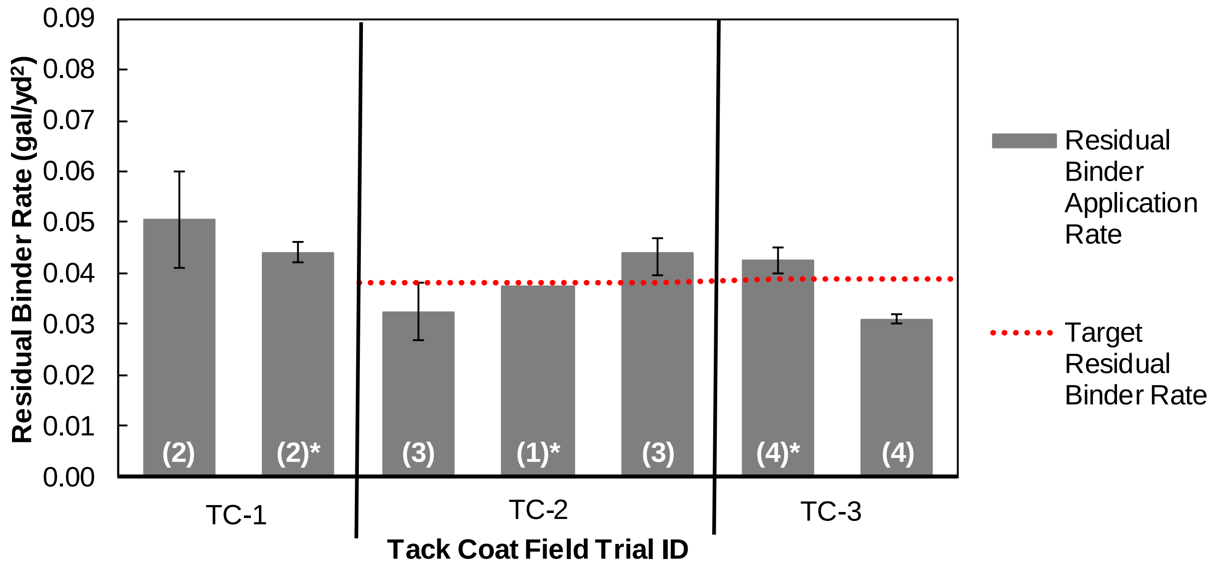
Note: *Error bars showing range of values are on the order of graph point size.*

Figure 7. Measured EAR results using the Tack Lifter laboratory experiments to reflect chip seal application rates using CRS-2l.

Field Experiments

Tack Coat

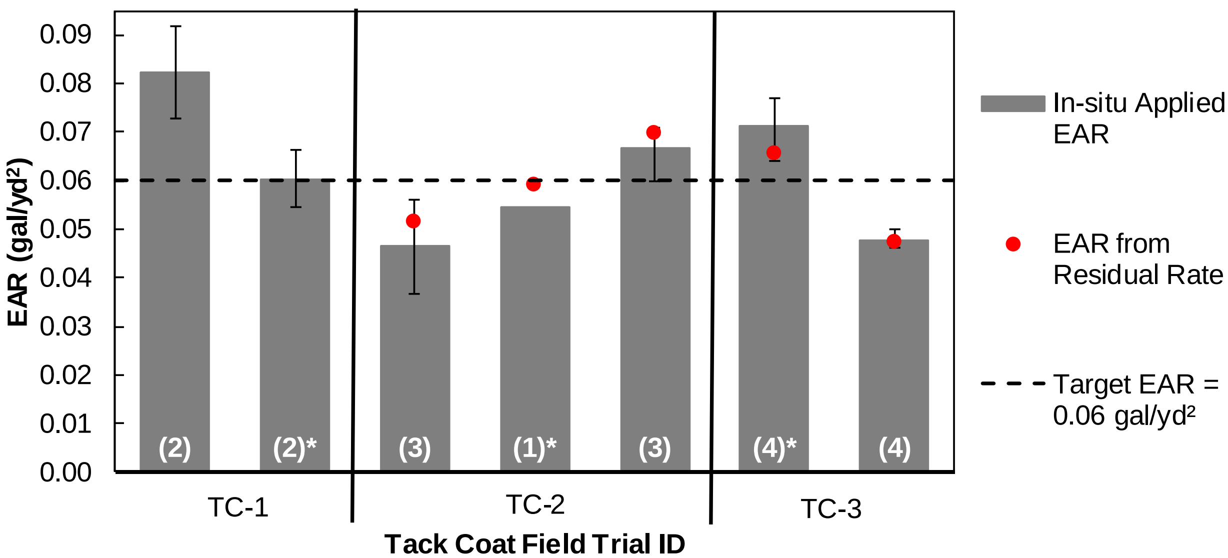
Due to the low applied EAR and visual observation of rapid breaking in the field, there was some initial concern that in-situ EAR measurements in tack coat applications may be compromised by water loss prior to mass measurements. Therefore, residual binder application rate measurements using the pre-weighed plates were first evaluated to preclude any potential influence of water loss on in-situ mass measurements. Figure 8 shows the results of residual binder application rate measurements in tack coat field experiments using the pre-weighed plates. The water content of emulsions collected from the second and third field trials (TC-2 and TC-3) were measured using residue recovery. Based on the water content value, the corresponding target residual binder application rates at TC-2 and TC-3 for the known target EAR of 0.06 gal/yd^2 were calculated. Note that the water content of the two emulsions were approximately equal. The error bars in Figure 8 demonstrate good repeatability in the residual rate measurements; the error bars for experiments where four replicates were conducted show no increase in the range of observed values compared to experiments where only two replicates were conducted. The results indicate some longitudinal variability in the residual binder application rate by comparing the results of different test sites within each field experiment. The residual binder application rate for the first field trial (TC-1) was notably higher and more variable than the others.



Note: *Error bars indicate range of values. Number of replicates shown in parentheses.*
**Measurements from sites where Tack Lifter tests were used to determine pavement absorption.*

Figure 8. Residual binder application rate measurements in tack coat field experiments.

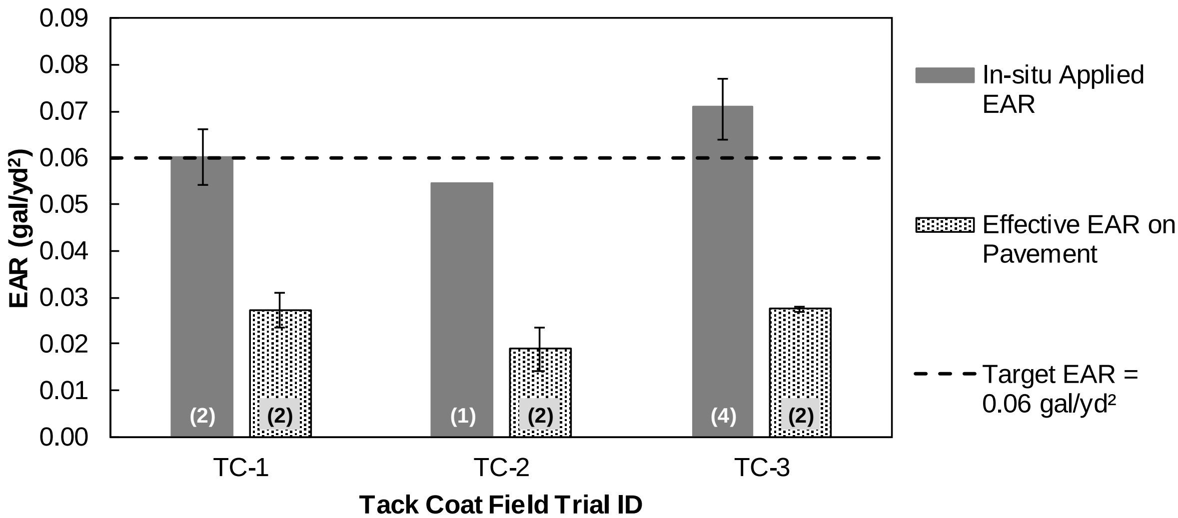
The applied EAR results of the tack coat field experiments obtained using the pre-weighed plates are shown in Figure 9. Two EAR results are reported: (1) the in-situ applied EAR measured by weighing the pre-weighed plates directly following emulsion application and (2) the applied EAR based on the residual binder applicate rate measurements coupled with the known water content of the emulsions. Because an emulsion sample was not obtained from TC-1, the latter measurement is omitted. The two EAR values were compared to evaluate the potential influence of water loss on in-situ EAR measurements. All EAR measurements were made within 60 seconds of the distributor passing over the plate to mitigate the influence of water loss as much as possible. While the target application rates at all field trials were the 0.06 gal/yd^2, the measured EAR values exhibit site-to-site variability, with many sites falling outside of the NCDOT tolerance range for acceptance of ± 0.01 gal/yd^2 (*13*). Variability in applied EAR values could be discerned visually while conducting field measurements. The applied EAR measurements and expected EAR measurements from the residual binder application rate results are generally in good agreement, indicating the effect of water loss on the applied EAR measurements was minimal. There was no bias in the applied EAR results to the order in which the masses were recorded, further suggesting water loss was negligible. These results suggest that either applied EAR or residual binder application rates can be reliably measured. However, the variability in the test results is generally lower for residual rate results than EAR results as evident by comparing the error bars in Figure 8 and Figure 9. While the sample-to-sample variability increases somewhat with the use of in-situ EAR measurements, the error bars indicate no clear trend in the range of measured values when two versus four replicate measurements are conducted. Therefore, it is suggested that two replicate plates be obtained per testing location to allow for testing a representative number of testing locations and to minimize the time required for weighing pre-weighed plates following emulsion application if in-situ EAR measurements are obtained.



Note: *Error bars indicate range of values. Number of replicates shown in parentheses.*
**Measurements from sites where Tack Lifter tests were used to determine pavement absorption.*

Figure 9. Applied EAR measurements using pre-weighed plates in tack coat field experiments.

In each tack coat field trial, measurements of effective EAR measurements were made using Tack Lifter testing on the pavement at one of the locations where in-situ applied EAR was measured using the pre-weighed plates. The comparison of applied and effective EAR measurements in tack coat field experiments are shown in Figure 10. The results demonstrate that the effective EAR measurements are consistently lower than the applied EAR measurements, indicating that the pavement absorbed a portion of the applied emulsion. The sample-to-sample variability of effective EAR measurements using the Tack Lifter is low, indicating two replicates are sufficient.



Note: *Error bars indicate range of values. Number of replicates shown in parentheses.*

Figure 10. Comparison between applied and effective EAR measurements in tack coat field experiments.

Average effective EAR and average in-situ applied EAR measurements from Figure 10 were used to calculate the absorbed EAR in each tack coat field experiment using Equation (2). The absorbed EAR results were compared to the sand patch MTD results. The results are shown in Figure 11. The results demonstrate pavement emulsion absorption rates ranging from approximately 0.03 to 0.04 gal/yd^2, which indicates that a high percentage of the applied emulsion was absorbed by the existing pavement and remained unavailable to bond to the overlay placed on top of the tack coat. The MTD values of the three field trials were relatively similar, precluding relating the absorbed EAR results to pavement surface texture. These results suggest measurements of applied and effective EARs can be conducted on a test section prior to the start of construction to inform adjustment of the target EAR. Because these measurements would likely be conducted directly prior to the start of construction, it is recommended that in-situ EAR rather than residual binder rates be used to inform adjustment of the target EAR to account for emulsion lost to absorption.

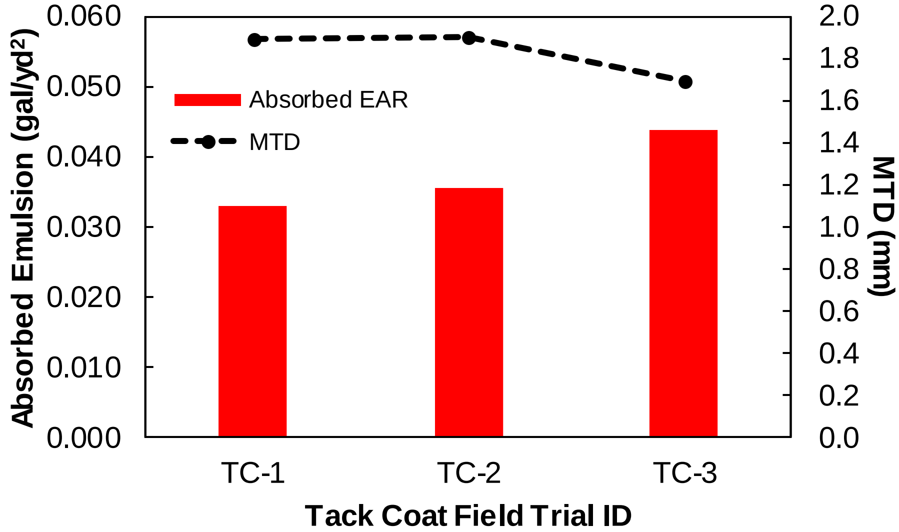


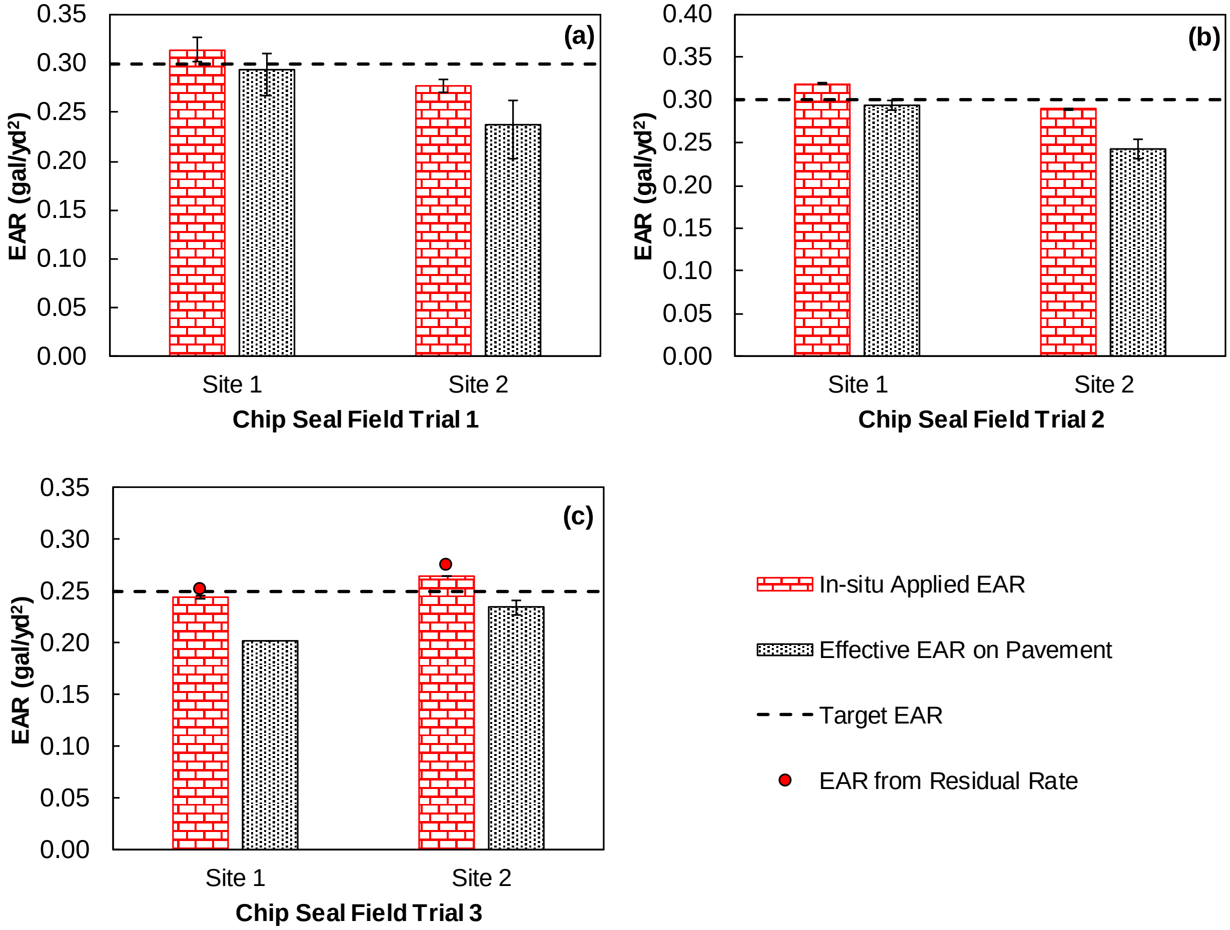
Figure 11. Absorbed EAR results from tack coat field experiments.

Chip Seal

Figure 12 shows the results of Tack Lifter EAR measurements in the bottom layer of each chip seal field experiment. Two measurements are shown: (1) in-situ applied EAR, corresponding to Tack Lifter testing conducted on a plate placed on the roadway prior to the arrival of the distributor, and (2) effective EAR, corresponding to the result of Tack Lifter testing conducted on pavement. All mass measurements in the field were conducted within 2 minutes of Tack Lifter testing and therefore, water loss was not expected to affect the results significantly. Water loss was not as much of a concern in chip seal EAR measurements due to the relatively high quantity of binder applied and positive past experience (*8*). Two replicates were conducted for each test. An emulsion sample could only obtained for water content measurement from chip seal field trial 3 (CS-3). For CS-3, the measured water content of the emulsion sample and the average measured residual binder rate were used to back-calculate the applied EAR for comparison to in-situ EAR measurements. These values are also shown in Figure 12 (c).

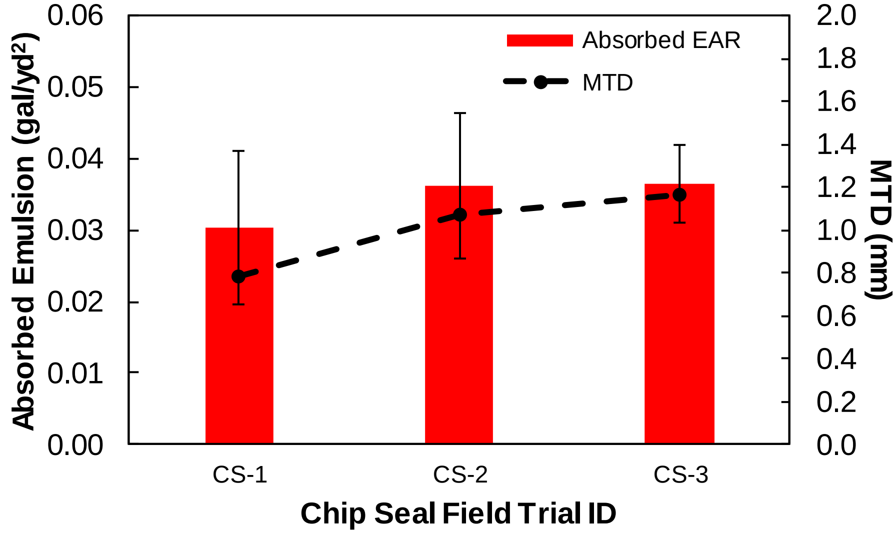
Figure 12 demonstrates that for each field trial, in-situ measurements of applied EAR using the Tack Lifter were all within the NCDOT tolerance range for chip seal emulsion application of ±0.03 gal/yd^2 of the target (*14*). For CS-3, the average applied EARs calculated based on residual binder application rate measurements was within 0.01 gal/yd^2 of the in-situ measurements. Given the relatively good agreement between the EARs determined from in-situ mass measurements and residual binder mass measurements, both methods of obtaining applied EAR measurements are deemed valid.

Figure 12 shows that the effective EAR measurements are consistently lower than the applied, indicating that the existing pavement absorbed a portion of the applied emulsion. Figure 13 shows the absorbed EAR results for the bottom layer of each field experiment, calculated based on the differences between applied and effective EAR measurements. The sand patch results are also included. The pavement absorption rates range between 0.02 to 0.045 gal/yd^2, demonstrating some variability in the pavement emulsion absorption rate at different locations. This indicates that measurements of pavement absorption at multiple locations prior to construction may be helpful in obtaining reliable corrections to the target EAR. The average absorbed EAR results show a positive relationship with MTD, indicating pavements with higher surface texture absorb more emulsion, which is consistent with the findings of FHWA/NCDOT 2014-03 (*8*).



Note: *Two replicates for all; error bars indicate range of values; some error bars are on the order of graph point size.*

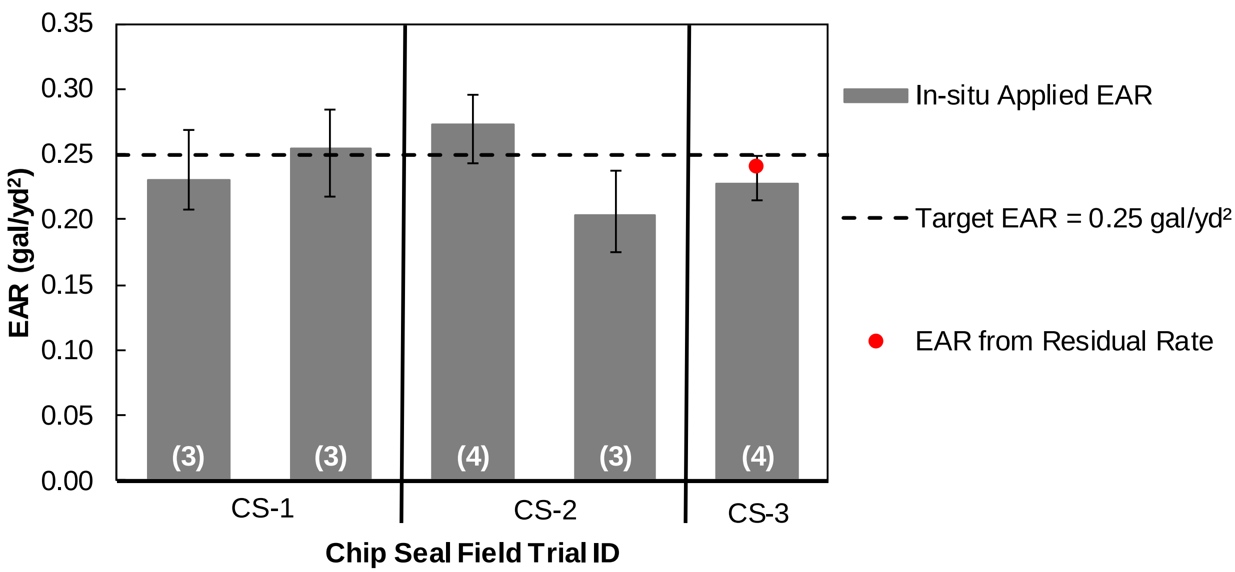
Figure 12. Applied and effective EAR measurements using Tack Lifter in bottom layers of chip seal field experiments.



Note: *Error bars indicate range of values.*

Figure 13. Absorbed EAR results from chip seal field experiments.

Figure 14 shows the results of Tack Lifter EAR measurements in the surface layer of each chip seal field experiments. The results show similar findings to the bottom layer but indicate higher sample-to-sample variability in the applied EAR measurements and somewhat higher deviations from the target EAR. These results could indicate that the use of the elevated plates introduce somewhat higher variability than the flat plates. Consequently, it may be advantageous to conduct three to four replicate tests when using elevated plates to assess longitudinal variability in the applied EAR.



Note: *Error bars indicate range of values. Number of replicates shown in parentheses.*

Figure 14. Applied EAR measurements using Tack Lifter in surface layers of chip seal field experiments.

RECOMMENDED FIELD TEST PROCEDURES

Tack Coat

Tack Lifter tests conducted on the pavement coupled with in-situ measurements of the applied EAR using pre-weighed plates are recommended to measure the pavement emulsion absorption on a test section just prior to construction to inform refinement of the target EAR to account for emulsion lost to absorption. Tack Lifter tests should be conducted directly following emulsion application and the sheets should be weighed within one minute of removal from the roadway. Two replicates are deemed sufficient for both Tack Lifter and pre-weighed plate measurements, given the sample-to-sample variability observed in this study coupled with the practical constraint of conducting measurements without water loss.

Pre-weighed plates can be used to obtain field measurements of the applied EAR or residual binder application rate at multiple locations to address longitudinal variability in the applied EAR for acceptance testing. The results suggest that the pre-weighed plates yield accurate EAR results given that measurements are made within one minute of emulsion application. Alternatively, residual application rates can be measured using the pre-weighed plates by storing the plates for mass determination after the emulsion has fully cured. The use of residual binder application rates eliminates the need for leveling of scale and shielding from wind in the field and also eliminates the time pressure for obtaining mass measurements after emulsion application. Given the variability observed in field measurements and taking practical considerations of obtaining mass measurement at the test site, it is recommended that two pre-weighed plates per test site be used.

While the aforementioned testing protocol has been proven to be effective for measuring application rates, the testing protocol cannot account for the effect of haul trucks tracking the applied emulsion. Visual observations in field experiments suggest that haul trucks often drive over the applied emulsion prior to overlay placement, removing a significant portion of the tack coat material in wheel path. An example is shown in Figure 15. Comprehensive acceptance testing must address the effect of tracking by haul trucks in addition to accuracy in emulsion application.

Figure 15. Evidence of emulsion tracking by haul trucks in tack coat project.

Chip Seal

The results of this study confirm those of FHWA/NCDOT 2014-03 (*8*) that suggest that the Tack Lifter is an effective means for measuring applied and effective EARs during chip seal construction. Tack Lifter tests conducted on the pavement and adjacent flat plate are recommended to measure the pavement emulsion absorption on a test section just prior to construction are recommended to inform refinement of the target EAR. If the condition of the existing pavement varies along the length of construction, testing should be conducted at multiple locations. Two replicates per testing location is sufficient to obtain representative results. Testing should be conducted emulsion application within two minutes of emulsion application and sheets should be weighed within one minute of removal from the pavement. It should be noted that pavement absorption rates cannot be measured to inform adjustment of the EAR in surface layers of double seals due to the presence of loose aggregate from the bottom layer.

Tack Lifter tests conducted on elevated plates can be used to obtain field measurements of the applied EAR at multiple locations to address longitudinal variability in the applied EAR for acceptance testing. Alternatively, residual binder application rates can be measured by storing the Tack Lifter sheet after testing for mass determination after the emulsion has fully cured. The sample-to-sample variability observed when conducting measurements using elevated plates increased somewhat; therefore, three to four replicate tests should be conducted when using elevated plates. Note that the aggregate spreader directly follows emulsion application in chip seal projects, so the tracking issue induced by haul trucks observed in tack coat projects is not a problem in chip seals.

FINDINGS AND CONCLUSIONS

The following conclusions are drawn from the results of this study:

- Pre-weighed plates are a simple and effective method for quantifying the in-situ applied EAR and residual binder application rate in tack coat projects.

- The Tack Lifter is an effective test method for measuring the in-situ applied EAR and residual binder application rate in chip seal projects. The Tack Lifter is also an effective test method for measuring the effective EAR in both tack coat and chip seal.
- In-situ EAR measurements should be made directly following emulsion application to avoid the influence of water loss. Pre-weighed plates should be removed following emulsion application and weighed within one minute. Tack Lifter tests should be conducted directly following emulsion application and sheets should be weighed within one minute of removal from the roadway.
- For both tack coats and chip seals, the values of the in-situ EAR measurements and the EARs calculated from residual binder application rate measurements combined with the emulsion water content are in good agreement.
- The findings of this study informed the development of guidelines for conducting field measurements of application rates, given in Appendix A and proposed AASHTO standard practices for chip seals and tack coats, given in Appendices B and C, respectively. In addition, demonstration videos have been prepared for the NCDOT to further facilitate training and implementation.

RECOMMENDATIONS

It is recommended that the NCDOT implement the proposed test frameworks for pavement emulsion absorption rate measurements prior to construction and local measurements of application rates during the construction of chip seals and tack coats. The pavement emulsion absorption rates can be used to inform adjustment of the target EAR to account for emulsion absorbed into the existing pavement. Local measurements of the application rate during construction can be used to quantify longitudinal variability as part of acceptance testing.

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APPENDIX A: GUIDELINE FOR CONDUCTING APPLICATION RATE MEASUREMENTS

The following includes step-by-step procedures for conducting measurements to inform adjustment of the target EAR to account for emulsion lost to absorption and conducting in-situ measurements of the applied EAR and residual binder application rates during construction for both tack coats and chip seals. Detailed procedures are given in AASHTO standard formation in Appendices B and C for chip seals and tack coats, respectively.

Adjustment of Target EAR Prior to Construction for Tack Coats

It is recommended that two pre-weighed plates be placed on the roadway prior to the arrival of the emulsion distributor and that two Tack Lifter tests be conducted on the adjacent pavement to quantify the pavement absorption rate. Such testing can be used to inform the adjustment of the target EAR during construction. If the existing pavement condition varies along the length of paving, measurements should be repeated at each instance of a noted change and the corresponding target EAR should be adjusted based on the absorption measurement.

Apparatus:

1. Pre-weighed flat steel plates, 8 in by 8 in with thickness of less than 0.25 in (2)
2. Spatula(s)
3. Pre-weighed Tack Lifter foam sheets, 5 in by 5 in (2)
4. Tack Lifter frames with gasket applied (2)
5. Tack Lifter weighed devices (2)
6. Scale with resolution of 0.01 g and bubble level indicator or a levelling table
7. Draft shield – to protect scale from wind at the project site

Procedure:

1. Set up a weighing station with levelled scale and draft shield, such as the one shown in Figure 16.

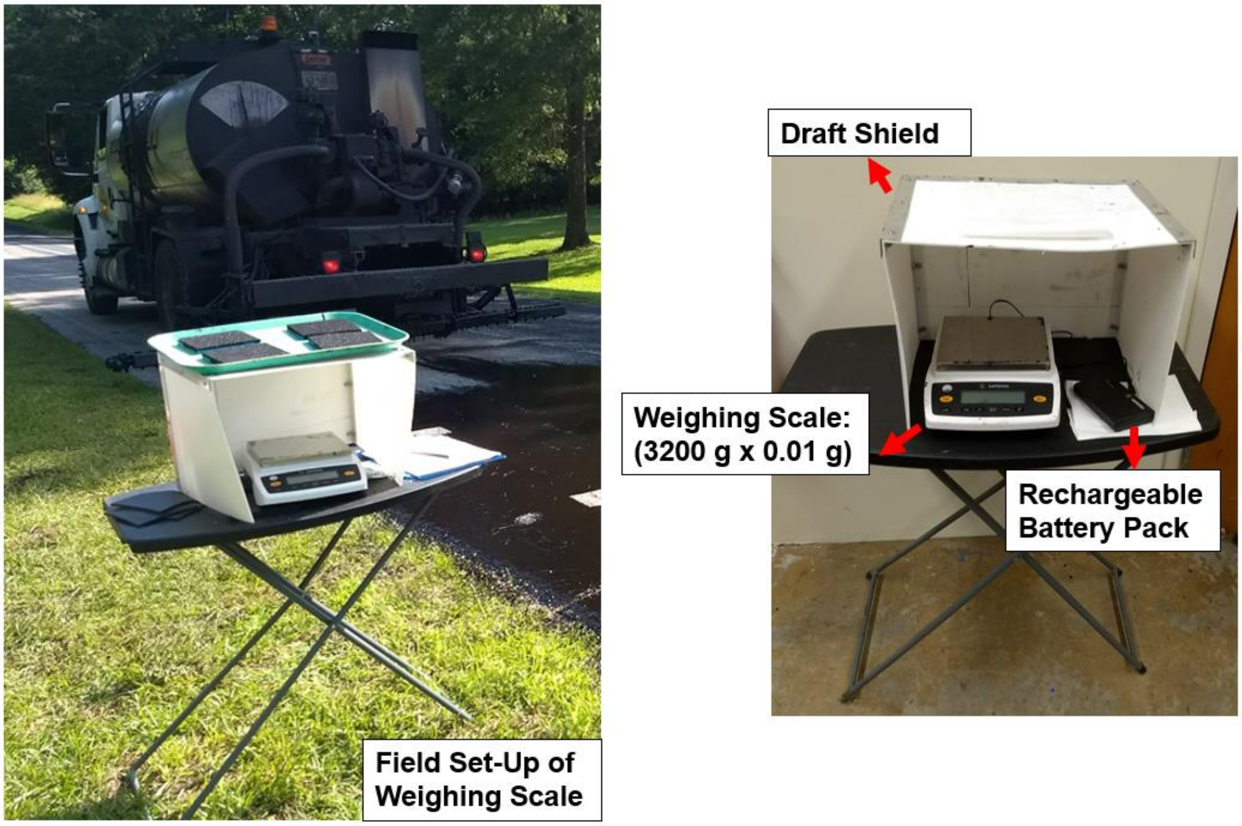

Figure 16. Scale setup.

2. Place two pre-weighed plates on the test section prior to emulsion application. It is recommended that the plates be placed in the same wheel path in close proximity to the weighing station as shown in Figure 17.

Figure 17. Plates on roadway of tack coat project.

3. Allow the distributor to apply emulsion over the plates at the current target EAR.
4. Immediately after emulsion application, place Tack Lifter frames on the pavement adjacent to the steel plates in the same transverse location, place the pre-weighed foam sheets into the frames and apply the weighted devices on top of the sheets. Allow the weights to remain on the sheets for 30 seconds.

5. With the aid of a spatula, remove the plates with applied emulsion and record their gross mass with emulsion applied to the nearest 0.01 g. The masses should be recorded within one minute of emulsion application.
6. Remove the Tack Lifter weight and pick up the foam sheets with absorbed emulsion. Record their masses to the nearest 0.01 g. The masses should be recorded within one minute of removal from the roadway.
7. Remove the Tack Lifter frames from the pavement surface.

Calculations:

1. The applied EAR from the distributor can be determined from the net mass of emulsion applied on the steel plates using Equation A1 as follows:

$$EAR_{Applied}, {}^{gal}\!/_{yd^2} = \frac{W}{Area \times G_s} \times 0.000264\, {}^{gal}\!/_{cc} \times 1296\, {}^{in^2}\!/_{yd^2} \qquad \text{(A1)}$$

Where W = net mass of emulsion applied (mass of plate after emulsion application – mass of plate before emulsion application), g; *Area* = area of the flat steel plate, in^2; G_s = specific gravity of the asphalt emulsion.

2. The effective EAR on the pavement surface can be determined from the Tack Lifter tests using Equation A2 as follows:

$$EAR_{Effective}, {}^{gal}\!/_{yd^2} = \frac{A}{26.01 in^2 \times G_s} \times 0.000264\, {}^{gal}\!/_{cc} \times 1296\, {}^{in^2}\!/_{yd^2} \qquad \text{(A2)}$$

Where A = net mass of emulsion absorbed by the sheet, g; G_s = specific gravity of the asphalt emulsion.

3. The amount of absorbed emulsion on the pavement can be determined using Equation A3 as follows:

$$EAR_{Absorbed} = EAR_{Applied} - EAR_{Effective} \qquad \text{(A3)}$$

In-situ Measurements of Applied EAR for Tack Coats

Local variation of emulsion application can be determined by performing spot-checks with in-situ measurements. It is recommended that two replicates be performed at each location of testing.

Apparatus:

1. Pre-weighed flat steel plates, 8 in by 8 in with thickness of less than 0.25 in
2. Spatula(s)
3. Scale with 0.01 g resolution and bubble level indicator or a levelling table

4. Draft shield – to protect scale from wind at the project site

Procedure:

1. Set up a weighing station with levelled scale and draft shield, as shown in Figure 16.
2. Place two pre-weighed plates on the test section prior to emulsion application as shown in Figure 17. It is recommended that the plates be placed in the wheel path in close proximity to the weighing station.
3. Allow the distributor to apply emulsion over the plates at the target EAR.
4. With the aid of a spatula, remove the plates with applied emulsion and record their gross mass with emulsion applied to the nearest 0.01 g. The mass should be recorded within one minute of emulsion application.

Calculations:

The applied EAR from the distributor can be determined from the net mass of emulsion applied on the steel plates using Equation A1.

Measurements of Residual Binder Application Rates for Tack Coats

To mitigate challenges with the time constrained measurements and obtaining accurate mass values in the field, residual binder rates can be used to check local variation of emulsion application. It is recommended that two replicates be performed at each location.

Apparatus:

1. Pre-weighed flat steel plates, 8 in by 8 in with thickness of less than 0.25 in (2)
2. Spatula(s)
3. Trays and cover for secure transport of plates with emulsion
4. Scale with resolution of 0.01 g and bubble level indicator or a levelling table

Procedure:

1. Place two pre-weighed plates on the test section prior to emulsion application. It is recommended that the plates be placed in the wheel path as shown in Figure 17
2. Allow the distributor to apply emulsion over the plates at the target EAR.
3. With the aid of a spatula, remove the plates with applied emulsion and secure them for transport.
4. Allow the emulsion to cure on the plates by air-drying in the laboratory for at least 24 hours.
5. Record the gross mass of plates with residual binder to the nearest 0.01 g.

Calculations:

1. The residual binder application rate on the steel plates can be determined using equation A4 as follows:

$$EAR_{\text{Residual}},\ {}^{gal}\!/_{yd^2} = \frac{R}{Area \times G_s} \times 0.000264\ {}^{gal}\!/_{cc} \times 1296\ {}^{in^2}\!/_{yd^2} \qquad \text{(A4)}$$

Where R = net mass of residual binder (mass of plate after emulsion application and curing – mass of plate before emulsion application), g; *Area* = area of the steel plate, in^2; G_s = specific gravity of the residual binder.

2. The corresponding applied EAR in the field can be obtained using the residual binder rate and emulsion water content as shown in equation A5.

$$EAR_{Applied}, \, gal/yd^2 = EAR_{\mathrm{Residual}} \times \frac{100}{WC} \tag{A5}$$

Where WC = water content in emulsion sample, %.

Adjustment of Target EAR Prior to Construction for Chip Seals

Tack Lifter tests should be conducted on steel plates as well as the existing pavement surface to quantify the pavement absorption rates to inform any adjustment to the target emulsion application rate (EAR). It is recommended that two Tack Lifter tests each be done to quantify the applied EAR and the effective EAR, respectively. Note that pavement absorption can only be measured in bottom layers of a double seal. If the existing pavement condition changes along the length of construction, measurements should be repeated at the location of the noted change and used to inform refinement of the target EAR to account for the change in the pavement absorption rate.

Apparatus:

1. Flat steel plates, 8 in by 8 in with thickness of less than 0.25 in (2)
2. Spatula(s)
3. Pre-weighed Tack Lifter foam sheets, 5 in by 5 in (4)
4. Tack Lifter frames with gasket applied (4)
5. Tack Lifter weighed devices (2)
6. Scale with resolution of 0.01 g and bubble level indicator or a levelling table
7. Draft shield – to protect scale from wind at the project site

Procedure:

1. Set up a weighing station with levelled scale and draft shield, as shown in Figure 16.
2. Place two steel plates on the test section prior to emulsion application. It is recommended that the plates be placed in the wheel path in close proximity to the weighing station as shown in Figure 18.


Figure 18. Plates on roadway of chip seal project.

3. Allow the distributor to apply emulsion over the plates at the current target EAR.
4. Immediately after emulsion application, place Tack Lifter frames on the steel plates. Also, place two frames on the pavement adjacent to the steel plates. Place the pre-weighed foam sheets into the frames and apply the weighted devices on top of the sheets. Allow the weights to remain on the sheets for 30 seconds. Complete Step 4 within 2 minutes of emulsion application.
5. Remove the Tack Lifter weights and pick up the foam sheets with absorbed emulsion. Record their masses to the nearest 0.01 g. The masses should be recorded within one minute of removal from the roadway.
6. With the aid of a spatula, remove the plates from the roadway. Also, remove all Tack Lifter frames.

Calculations:

1. The EAR of the Tack Lifter foam sheets can be determined Equation A6 as follows:

$$EAR, {}^{gal}\!/\!{}_{yd^2} = \frac{A}{26.01in^2 \times G_s} \times 0.000264\, {}^{gal}\!/\!{}_{cc} \times 1296\, {}^{in^2}\!/\!{}_{yd^2} \tag{A6}$$

2. The amount of absorbed emulsion on the pavement can be determined using Equation A7 as follows:

$$EAR_{Absorbed} = EAR_{Applied} - EAR_{Effective} \tag{A7}$$

Where $EAR_{Applied}$ corresponds to the average EAR measurements from the Tack Lifter tests conducted on the steel plates and the $EAR_{Effective}$ corresponds to the average EAR measurements from the Tack Lifter tests conducted on the adjacent pavement for a given location of testing.

In-situ Measurements of Applied EAR for Chip Seals

Local variation of emulsion application can be determined by performing spot-checks with in-situ measurements. It is recommended that two replicates be performed at each spot-check location.

Apparatus:

1. Flat steel plates, 8 in by 8 in with thickness of less than 0.25 in or Tack Lifter elevated steel plates (2)
2. Spatula(s)
3. Pre-weighed Tack Lifter foam sheets (2)
4. Tack Lifter frames with gasket applied (2)
5. Tack Lifter weighed devices (2)
6. Scale with resolution of 0.01 g and bubble level indicator or a levelling table
7. Draft shield – to protect scale from wind at the project site

Procedure:

1. Set up a weighing station with levelled scale and draft shield.
2. Place the plates on the test section prior to emulsion application. If elevated plates are being used, place them in the center of the lane to avoid crushing by the distributor tires. Allow the distributor to apply emulsion over the plates.
3. Immediately after emulsion application, place Tack Lifter frames on the steel plates. If elevated plates are being used, transport them to the side of the road while keeping level using the peel before applying the frames as shown in Figure 19. Place the pre-weighed foam sheets into the frames and apply the weighted devices on top of the sheets. Allow the weights to remain on the sheets for 30 seconds. Complete this step within 2 minutes of emulsion application.

4. Figure 19. Elevated plate removal.

5. Remove the Tack Lifter weights and pick up the foam sheets with absorbed emulsion. Record their masses to the nearest 0.01 g. The masses should be recorded within one minute of removal from the roadway.

Calculations:
The applied EAR from the distributor can be determined from the net mass of emulsion applied on the steel plates using Equation A6.

Measurements of Residual Binder Application Rates for Chip Seals

To mitigate challenges with time constrained measurements and obtaining accurate mass values in the field, residual binder rates can be used to check local variation of emulsion application. It is recommended that two replicates be performed at each location.

Apparatus:
1. Flat steel plates, 8 in by 8 in with thickness of less than 0.25 in or Tack Lifter elevated steel plates (2)
2. Spatula(s)
3. Pre-weighed Tack Lifter foam sheets (2)
4. Tack Lifter frames with gasket applied (2)
5. Tack Lifter weighed devices (2)
6. Trays and cover for secure transport of plates with emulsion

7. Scale with resolution of 0.01 g and bubble level indicator or a levelling table

Procedure:

1. Place the plates on the test section prior to emulsion application. If elevated plates are being used, place them in the center of the lane to avoid crushing by the distributor tires. Allow the distributor to apply emulsion over the plates.
2. Immediately after emulsion application, place Tack Lifter frames on the steel plates. If elevated plates are being used, transport them to the side of the road while keeping level using the peel before applying the frames as shown in Figure 19. Place the pre-weighed foam sheets into the frames and apply the weighted devices on top of the sheets. Allow the weights to remain on the sheets for 30 seconds. Complete this step within 2 minutes of emulsion application.
3. Remove the Tack Lifter weights and pick up the foam sheets with absorbed emulsion. Secure them for transport to the laboratory.
4. Allow the emulsion to cure on the foam sheets by air-drying for 24 hours or placing them in an oven at 60°C for one hour.
5. Record the amount of residual binder on the Tack Lifter sheets to the nearest 0.01 g.

Calculations:

1. The residual binder application rate on the foam sheets can be determined using Equation A8 as follows:

$$EAR_{\text{Residual}}, {}^{gal}\!/_{yd^2} = \frac{R}{26.01in^2 \times G_s} \times 0.000264\,{}^{gal}\!/_{cc} \times 1296\,{}^{in^2}\!/_{yd^2} \qquad \text{(A8)}$$

Where R = net mass of residual binder (mass of sheet after emulsion application and curing – mass of sheet before emulsion application), g; G_s = specific gravity of the residual binder.

2. The corresponding applied EAR in the field can be obtained using the residual binder rate and emulsion water content as shown in Equation A9.

$$EAR_{Applied}, {}^{gal}\!/_{yd^2} = EAR_{\text{Residual}} \times \frac{100}{WC} \qquad \text{(A9)}$$

Where WC = water content in emulsion sample, %.

APPENDIX B: PROPOSED PRACTICE FOR MEASUREMENT OF APPLICATION RATES IN CHIP SEALS

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1. SCOPE

1.1 This practice covers the measurement of application rates in chip seals. The measurements include: (A) measurement of transverse variability, (B) adjustment of target EAR to account for emulsion absorbed by the existing pavement, (C) in-situ measurements of the EAR during construction, and (D) measurements of the residual binder application rate during construction.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in inch-pound units are to be regarded as the standard.

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2. REFERENCED DOCUMENTS

2.1 *ASTM Standards*:

- D 2995-15, Standard Practice for Estimating Application Rate of Bituminous Distributors

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3. SUMMARY OF PRACTICE

3.1 *Test Method A*:

3.1.1 This test method follows ASTM D 2995 Test Method B. Elliptical containers are placed under each nozzle of an emulsion distributor. Emulsion is sprayed into the containers for a specified time. The volume of emulsion in each container is then measured. Comparison between the quantities of emulsion deposited into each container allows for assessment of transverse variability in emulsion application. If the emulsion output of any nozzle deviates more than 10 percent from the mean, adjustment is required to correct the problem and testing should be repeated.

3.2 *Test Method B*:

3.2.1 Two steel plates are placed on the pavement in front of the emulsion distributor in a single wheel path. The emulsion distributor is driven over the steel plates while spraying asphalt emulsion. Frames are placed on each plate and the adjacent pavement within the wheel path. Pre-weighed foam sheets are placed into each frame. A weighted device is placed onto each foam sheet for 30 seconds. The foam sheets are removed from the frames and re-weighed. The mass of emulsion absorbed by each sheet is determined by subtraction and converted to EAR using the known sheet area. The difference between the average EAR measurements corresponding to sheets placed on plates and the pavement is calculated and reported as the absorption rate. Absorbed emulsion is not available for bonding to material placed on top of the emulsion. Therefore, the target application EAR can be increased by the measured absorption rate in order to improve quality.

3.3 *Test Method C*:

3.3.1 Two elevated, steel plates are placed on the pavement in front of the emulsion distributor in the lane center. The emulsion distributor is driven over the elevated plates while spraying asphalt emulsion. Each plate is transferred to a level surface on the side of the roadway directly following emulsion application using a steel peel. A frame is placed onto each plate. A pre-weighed foam sheets is placed into each frame. A weighted device is placed onto each foam sheet for 30 seconds. The foam sheets are removed from the frames and re-weighed. The mass of emulsion absorbed by each sheet is determined by subtraction and converted to EAR using the known sheet area. The measurement can be repeated at multiple locations along the length of construction. Differences in EAR values measured along the length of construction can be used to infer longitudinal variability.

3.4 *Test Method D*:

3.4.1 Two elevated, steel plates are placed on the pavement in front of the emulsion distributor in the lane center. The emulsion distributor is driven over the elevated plates while spraying asphalt emulsion. Each plate is transferred to a level surface on the side of the roadway directly following emulsion application using a steel peel. A frame is placed onto each plate. A pre-weighed foam sheets is placed into each frame. A weighted device is placed onto each foam sheet for 30 seconds. The foam sheets are removed from the frames and securely transported to a laboratory. After 24 hours, the sheets are weighed. The residual binder absorbed by each sheet is determined by subtraction and converted to the residual binder application using the known sheet area. The measurement can be repeated at multiple locations along the length of construction. Differences in residual binder application rate values measured along the length of construction can be used to infer longitudinal variability. Note that the use of Test Method D as opposed to Test Method C negates the time constraints and challenges associated with leveling and shielding a scale from wind in the field.

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4. APPARATUS

4.1 *Test Methods A, B, C, and D*:

4.1.1 *Scale* – with resolution of 0.01 g and leveling bubble

4.2 *Test Methods A, B, and C*

4.2.1 *Wind Shield* – to protect scale from wind when used at the project site

4.3 *Test Method A*:

4.3.1 *Elliptical Containers* – containers measuring approximately 3.5 in along the short axis and 9 in along the long axis of the ellipse with 8 in height with approximately one gallon capacity.

4.3.2 *Rubber Bands* – used to hold the plastic bags in place around the elliptical containers.

4.3.3 *Stopwatch* – capable of recording to the nearest 0.1s.

4.3.4 *Plastic Bags* – capable of fitting inside elliptical containers but of a sufficiently larger dimension to allow folding over the edge of the container once placed inside.

4.4 *Test Methods B, C, and D:*

4.4.1 *Tack Lifter* – consisting of a weighted device including a base and handle, weighing 35 lb. The device has a square base that measures 5 in by 5 in. A 2 ft. long handle is attached through the center of the weights.

4.4.2 *Sheet* – consisting of a 5 in by 5 in super-absorbent, polyurethane foam with density of 1.8 lb/ft^3, firmness of 0.6 psi. Sheets can be purchased from McMaster Carr.

4.4.3 *Frame* – consisting of a steel with a rubber, pliable gasket along its bottom edges. The gasket conforms to the surface texture, sealing the area of interest from intrusion of additional emulsion. The inner dimensions of the gasket are 5.25 in by 5.25 in. The out dimensions of the gasket are 5.75 in by 5.75 in.

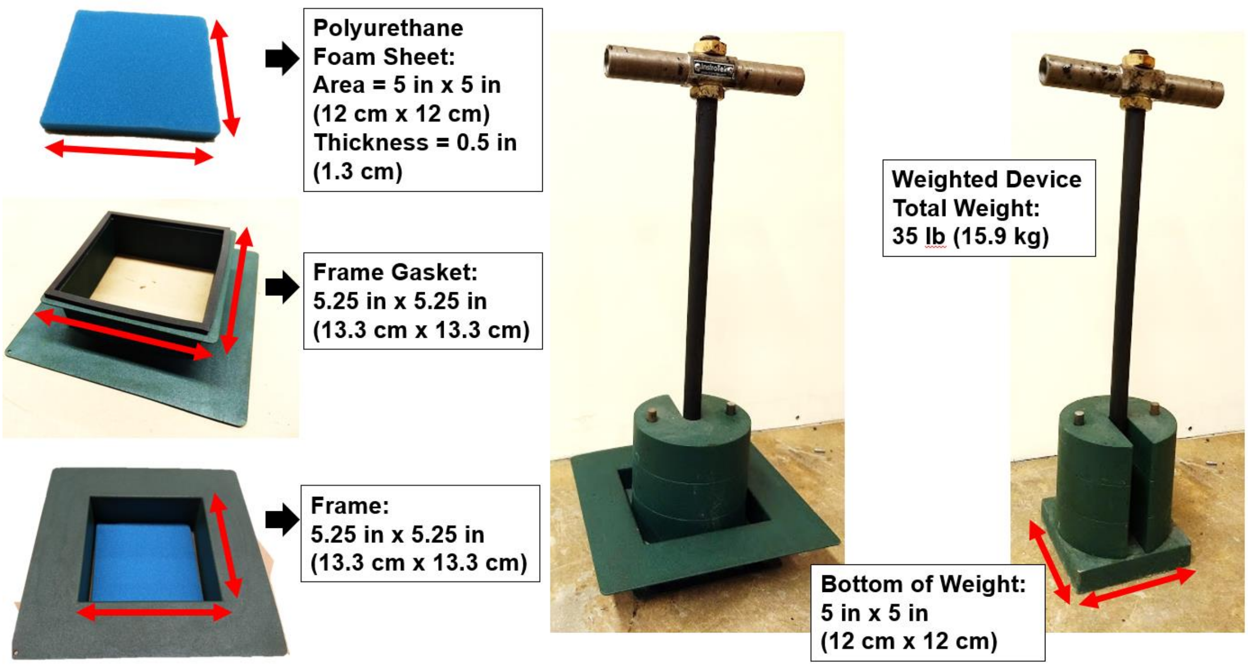

Figure 1—Tack Lifter Components

4.5 *Test Method B*:

4.5.1 *Flat plate* – comprised of steel, with an outer dimension of 8 in by 8 in and a maximum thickness of 0.25 in.

4.6 *Test Methods C and D*:

4.6.1 *Elevated Plate* – comprised of a steel pan with legs and lip. The inner dimensions of the plates are 7 in by 7 in. The height of each of the four legs, located at the plate's corners, is 0.5 in. The lip has a 3/8 in height along the plate's perimeter.

4.6.2 *Peel* – to remove the elevated plate from the paving surface while keeping the plate level. It is comprised of a flat rectangular sheet of steel that is 7 in wide and 7.5 in long with a 16 in handle. The peel also has a lip at the tip to "catch" the plate when removing it so it would not slide off the front of the peel. The lip has 1 in height. The legs of the elevated plate are 0.5 in long.

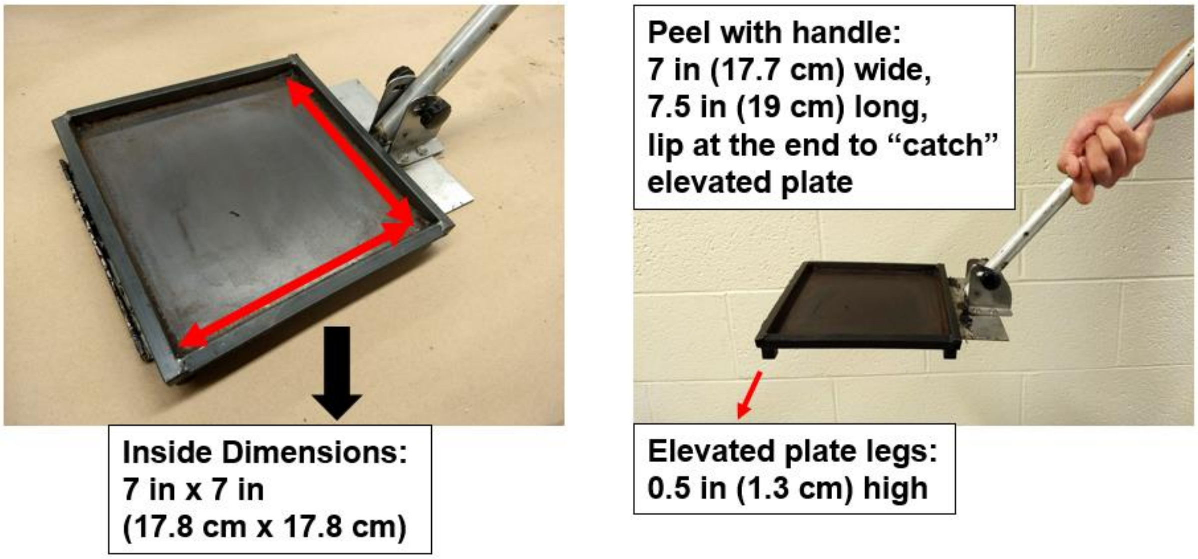

Figure 2—Elevated Plate Components

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5 PROCEDURE

5.1 *Test Method A (Assessment of Transverse EAR Variability)*:

5.1.1 Follow ASTM D 2995 Test Method B. If emulsion output from any nozzle deviates greater than 10 percent from the mean, then the nozzle should be adjusted and testing should be repeated.

5.2 *Test Method B (Assessment of Emulsion Absorption by the Existing Pavement)*:

5.2.1 Four foam sheets are needed per testing location. Obtain and record the mass of each foam sheet to the nearest 0.01 g.

5.2.2 Place two steel plates in a single wheel path on the roadway in front of the emulsion distributor. (Figure (a))

5.2.3 Within two minutes minute of emulsion application

5.2.3.1 Apply frames to each of the steel plates. In addition, place two frames on the pavement, adjacent to the plates in the wheel path. Press frames firmly to seal intrusion of emulsion from outside of the frame gasket.

5.2.3.2 Place a foam sheet into each frame. (Figure (b))

5.2.3.3 Apply the Tack Lifter weighted device to each sheet for 30 seconds. During this 30 second period, emulsion will be absorbed from the pavement or plate into the sheet. (Figure (c) and (d))

5.2.4 Remove the sheets from the frame immediately after Tack Lifter removal and transfer to a scale that is leveled and shielded from wind within one minute of removal from the roadway. (Figure (e))

5.2.5 Record the mass of each sheet to the nearest 0.01 g.

5.2.6 Remove the frames and steel plates from the pavement.

5.2.7 Repeat the procedure in the other wheel path and/or at locations where significant changes in surface conditions (e.g., roughness, color, etc.) are noted.

Figure 3 —Tack Lifter testing in the field on the surface including steps (a) placement of flat plate on in the wheel path before construction, (b) placing of frame and sheet in the frame on the surface or plate, (c) placement of Tack Lifter on the sheet (d) Tack Lifter testing and (e) weighing of Tack Lifter sheet

5.3 *Test Method C (In-situ Measurement of the Applied EAR During Construction)*

5.3.1 Two sheets should be used per testing location. Obtain and record the mass of each sheet to the nearest 0.01 g.

5.3.2 Place two elevated plates on the pavement lane center at each location of testing prior to the arrival of the emulsion distributor.

5.3.3 Locate a level area off of the roadway near the location of the elevated plate placement.

5.3.4 Within two minutes of emulsion application

5.3.4.1 Remove each plate from the pavement. To do so, place the peel under the plate (Figure (a)) and remove from the roadway (Figure (b)). Place on a level area off of the roadway (Figure (c)). Keep the plate as level as possible to prevent the flow of emulsion.

5.3.4.2 Apply a frame to each plate. Press the frame firmly to seal intrusion of emulsion from outside of the frame gasket.

5.3.4.3 Place a foam sheet into each frame.

5.3.4.4 Apply the Tack Lifter to each sheet and wait 30 seconds. During this 30 second period, emulsion will be absorbed from the plate into the sheet. (Figure (d))

5.3.5 Remove the sheets from the frame immediately after Tack Lifter removal and transfer to a scale that is leveled and shielded from wind within one minute of removal from the roadway. (Figure (e))

5.3.6 Record the mass of each sheet to the nearest 0.01 g within one minute of removal of the sheet from the plate.

5.3.7 Repeat the procedure in additional locations along the length of emulsion application to study the longitudinal variability in the applied EAR.

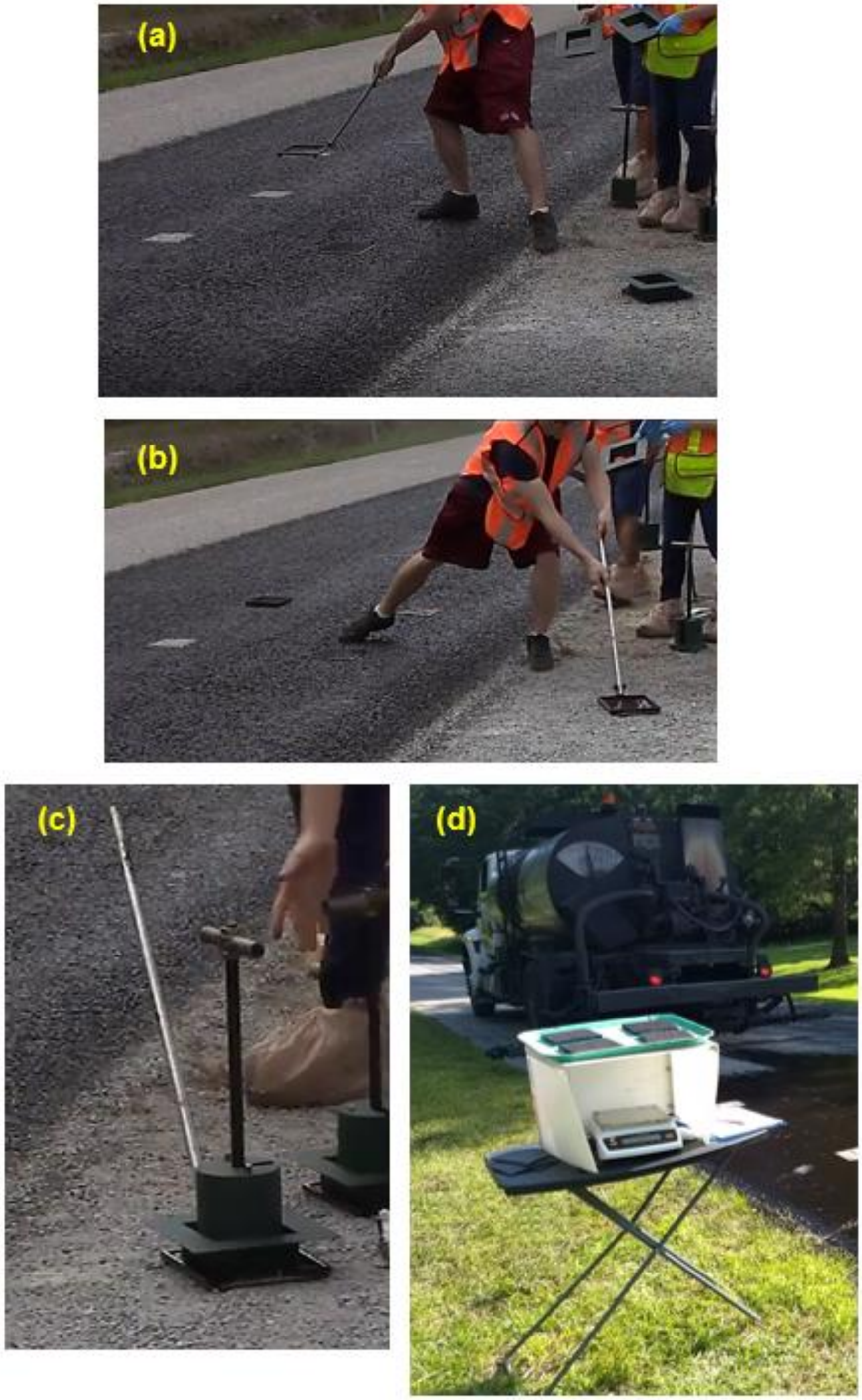

Figure 4—Tack Lifter testing in the field using elevated plates, including steps (a) placement of peel under elevated plate, (b) lifting elevated plate, (c) placement of elevated plate on level table and (d) Tack Lifter testing and (e) weighing of Tack Lifter sheet

5.4 *Test Method D (n-situ Measurement of the Residual Binder Application Rates During Construction)*

5.4.1 Follow steps 5.3.1 to 5.3.4, outlined in Test Method C.

5.4.2 Remove the sheets from the frame immediately after Tack Lifter removal and store on a level surface.

5.4.3 Repeat the procedure in additional locations along the length of emulsion application to study the longitudinal variability in the applied EAR.

5.4.4 Allow each sheet to cure for a minimum of 24 hours under ambient conditions.

5.4.5 Record the mass of each sheet to the nearest 0.01 g.

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6 CALCULATIONS

6.1 *Test Method A*:

6.1.1 Follow the procedure detailed in ASTM D 2995 Test Method B.

6.2 *Test Method B*:

6.2.1 Subtract the tare mass of each sheet from the mass of each emulsion saturated sheet.

6.2.2 Determine the EAR of emulsion contained on each sheet in gal/yd^2 as follows:

$$EAR, {}^{gal}\!/_{yd^2} = \frac{A}{26.01 in^2 \times G_s} \times 0.000264\, {}^{gal}\!/_{cc} \times 1296\, {}^{in^2}\!/_{yd^2}$$

Where:

A = net mass of emulsion absorbed by the sheet, g.
G_s = specific gravity of asphalt emulsion at spray temperature.

6.2.3 EAR values corresponding to sheets applied to plates can be regarded as the total applied EAR. If the measured applied EAR deviates more than ± 0.03 gal/yd^2 from the target application rate, results should be regarded and invalid. The distributor should be re-calibrated and testing should be repeated.

6.2.4 Determine the rate by which emulsion is absorbed by the pavement in gal/yd^2 by subtracting the EAR values corresponding to the sheets placed on the pavement from the EAR values corresponding to sheets placed on plates.

6.2.5 The absorbed emulsion rate represents the rate of applied emulsion which will be absorbed by the paving surface. Absorbed emulsion will not be available to bond with material placed on top of the emulsion. The target EAR can hence, be increased by the calculated absorption rate.

6.3 *Test Method C*:

6.3.1 Follow the same procedure as 6.2.1 and 6.2.2.

6.3.2 Comparison between the EARs measured at different locations along the length of paving can be used to assess longitudinal variability in emulsion application.

6.4 *Test Method D:*

6.4.1 Subtract the tare mass of each sheet from the mass of each binder saturated sheet.
6.4.2 Determine the residual binder application rate as follows:

$$EAR_{\text{Residual}}, \,{}^{gal}\!/_{yd^2} = \frac{R}{26.01in^2 \times G_s} \times 0.000264\,{}^{gal}\!/_{cc} \times 1296\,{}^{in^2}\!/_{yd^2}$$

Where:
R = net mass of residual binder, g;
G_s = specific gravity of the residual binder at ambient temperature.

6.4.3. The corresponding applied EAR in the field can be obtained using the residual binder rate and emulsion water content as follows:

$$EAR_{Applied}, \,{}^{gal}\!/_{yd^2} = EAR_{\text{Residual}} \times \frac{100}{WC}$$

Where:
WC = water content in emulsion sample, %.

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7 REPORT

7.1 *Test Method A*:

7.1.1 Follow reporting requirements of ASTM D 2995 Test Method B.

7.2 *Test Method B*:

7.2.1 Location of measurements.

7.2.2 Visual observation of paving surface at locations of EAR measurements (e.g., rough, bled, etc.).

7.2.3 Calculated rate by which the pavement absorbs emulsion (gal/yd^2).

7.3 *Test Method C*:

7.3.1 Locations of EAR measurements.

7.3.2 Measured EAR at each location of testing (gal/yd^2)

7.4 *Test Method D*:

7.4.1 Locations of residual binder rate measurements.

7.4.2 Measured residual binder application rate at each location of testing (gal/yd^2)

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4 PRECISION AND BIAS

8.1 Precision and bias have yet to be established for this procedure.

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5 KEYWORDS

Emulsion application rate, quality control, chip seal

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6 REFERENCES

ASTM D2995. “Standard Practice for Estimating Application Rate of Bituminous Distributors,” ASTM, 2009.

APPENDIX C: PROPOSED PRACTICE FOR MEASUREMENT OF APPLICATION RATES IN TACK COATS

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1. SCOPE

1.1 This practice covers the measurement of application rates in tack coats. The measurements include: (A) measurement of transverse variability, (B) adjustment of target EAR to account for emulsion absorbed by the existing pavement, (C) in-situ measurements of the EAR during construction, and (D) measurements of the residual binder application rate during construction.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in inch-pound units are to be regarded as the standard.

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2. REFERENCED DOCUMENTS

2.1 *ASTM Standards*:

- D 2995-15, Standard Practice for Estimating Application Rate of Bituminous Distributors

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3. SUMMARY OF PRACTICE

3.1 *Test Method A*:

3.1.1 This test method follows ASTM D 2995 Test Method B. Elliptical containers are placed under each nozzle of an emulsion distributor. Emulsion is sprayed into the containers for a specified time. The volume of emulsion in each container is then measured. Comparison between the quantities of emulsion deposited into each container allows for assessment of transverse variability in emulsion application. If the emulsion output of any nozzle deviates more than 10 percent from the mean, adjustment is required to correct the problem and testing should be repeated.

3.2 *Test Method B*:

3.2.1 Two pre-weighed steel plates are placed on the pavement in front of the emulsion distributor in a single wheel path. The emulsion distributor is driven over the steel plates while spraying asphalt emulsion. Within one minute of emulsion application, the steel plates are removed from the pavement and re-weighed. The mass of emulsion applied to each plate is determined by subtraction and converted to EAR using the known plate area. Frames are placed on the pavement within the wheel path, adjacent to the location of the steel plate placement. Pre-weighed foam sheets are placed into each frame. A weighted device is placed onto each foam sheet for 30 seconds. The foam sheets are removed from the frames and re-weighed within one minute of emulsion application. The mass of emulsion absorbed by each sheet is determined by subtraction and converted to the EAR using the known sheet area. The difference between the average EAR measurements corresponding to plates and the sheets is calculated and reported as the absorption rate. Absorbed emulsion is not available for bonding to material placed on top of the emulsion. Therefore, the target application EAR can be increased by the measured absorption rate in order to improve quality.

3.3 *Test Method C*:

3.3.1 Two pre-weighed steel plates are placed on the pavement in front of the emulsion distributor in the same transverse location. The emulsion distributor is driven over the plates while spraying asphalt emulsion. The plates are removed from the roadway and re-weighed within one minute of emulsion application. The mass of emulsion applied to each plate is determined by subtraction and converted to EAR using the known plate area. The measurement can be repeated at multiple locations along the length of construction. Differences in EAR values measured along the length of construction can be used to infer longitudinal variability.

3.4 *Test Method D*:

3.4.1 Two pre-weighed steel plates are placed on the pavement in front of the emulsion distributor in the same transverse location. The emulsion distributor is driven over the plates while spraying asphalt emulsion. The plates are removed from the roadway and securely transported to a laboratory. After 24 hours, the plates are re-weighed. The residual binder absorbed by each plate is determined by subtraction and converted to the residual binder application using the known plate area. The measurement can be repeated at multiple locations along the length of construction. Differences in residual binder application rate values measured along the length of construction can be used to infer longitudinal variability. Note that the use of Test Method D as opposed to Test Method C negates the time constraints and challenges associated with leveling and shielding a scale from wind in the field.

4. APPARATUS

4.1 *Test Methods A, B, C, and D*:

4.1.1 *Scale* – with resolution of 0.01 g and leveling bubble

4.2 *Test Methods A, B, and C*

4.2.1 *Wind Shield* – to protect scale from wind when used at the project site

4.3 *Test Method A*:

4.3.1 *Elliptical Containers* – containers measuring approximately 3.5 in along the short axis and 9 in along the long axis of the ellipse with 8 in height with approximately one gallon capacity.

4.3.2 *Rubber Bands* – used to hold the plastic bags in place around the elliptical containers.

4.3.3 *Stopwatch* – capable of recording to the nearest 0.1s.

4.3.4 *Plastic Bags* – capable of fitting inside elliptical containers but of a sufficiently larger dimension to allow folding over the edge of the container once placed inside.

4.4 *Test Methods B, C, and D:*

4.4.1 *Tack Lifter* – consisting of a weighted device including a base and handle, weighing 35 lb. The device has a square base that measures 5 in by 5 in. A 2 ft. long handle is attached through the center of the weights.

4.4.2 *Sheet* – consisting of a 5 in by 5 in super-absorbent, polyurethane foam with density of 1.8 lb/ft^3, firmness of 0.6 psi. Sheets can be purchased from McMaster Carr.

4.4.3 *Frame* – consisting of a steel with a rubber, pliable gasket along its bottom edges. The gasket conforms to the surface texture, sealing the area of interest from intrusion of additional emulsion. The inner dimensions of the gasket are 5.25 in by 5.25 in. The out dimensions of the gasket are 5.75 in by 5.75 in.

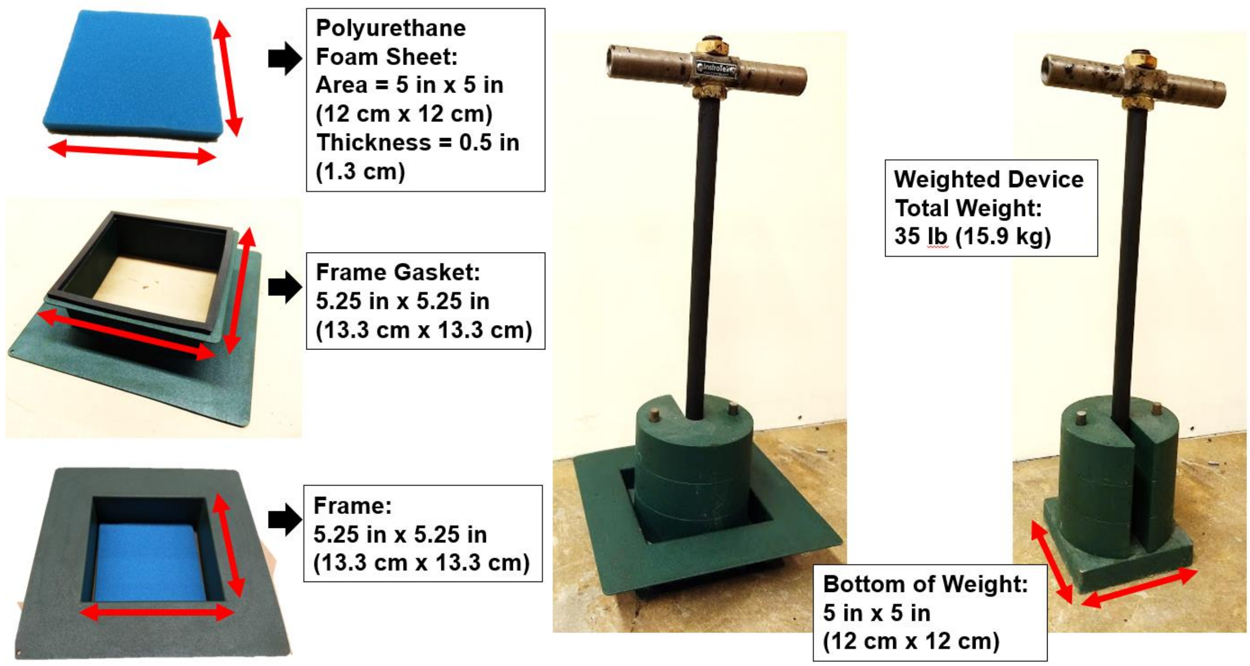

Figure 1—Tack Lifter Components

4.5 *Test Methods B, C, and D:*

4.5.1 *Steel plate* – comprised of steel, with an outer dimension of 8 in by 8 in and a maximum thickness of 0.25 in.

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5 PROCEDURE

5.1 *Test Method A (Assessment of Transverse EAR Variability)*:

5.1.1 Follow ASTM D 2995 Test Method B. If emulsion output from any nozzle deviates greater than 10 percent from the mean, then the nozzle should be adjusted and testing should be repeated.

5.2 *Test Method B (Assessment of Emulsion Absorption by the Existing Pavement)*:

5.2.1 Two foam sheets and two steel plates are needed per testing location. Obtain and record the mass of each foam sheet and plate to the nearest 0.01 g.

5.2.2 Place two steel plates in a single wheel path on the roadway in front of the emulsion distributor. (Figure (a))

5.2.3 Remove the steel plates from the pavement and transfer to a scale that is leveled and shielded from wind within one minute of removal from the roadway.

5.2.4 Record the mass of each plate with the applied emulsion to the nearest 0.01 g.

5.2.5 Also within one minute of emulsion application,

5.2.5.1 Apply two frames to pavement, adjacent to the location of plate placement in the wheel path. Press frames firmly to seal intrusion of emulsion from outside of the frame gasket.

5.2.5.2 Place a foam sheet into each frame. (Figure (b))

5.2.5.3 Apply the Tack Lifter weighted device to each sheet for 30 seconds. During this 30 second period, emulsion will be absorbed from the pavement or plate into the sheet. (Figure (c) and (d))

5.2.6 Remove the sheets from the frame immediately after Tack Lifter removal and transfer to a scale that is leveled and shielded from wind within one minute of removal from the roadway. (Figure (e))

5.2.7 Record the mass of each sheet to the nearest 0.01 g.

5.2.8 Remove the frames and steel plates from the pavement.

5.2.9 Repeat the procedure in the other wheel path and/or at locations where significant changes in surface conditions (e.g., roughness, color, etc.) are noted.

Figure 3 —Tack Lifter testing in the field on the surface including steps (a) placement of flat plate on in the wheel path before construction, (b) placing of frame and sheet in the frame on the surface or plate, (c) placement of Tack Lifter on the sheet (d) Tack Lifter testing and (e) weighing of Tack Lifter sheet

5.3 *Test Method C (In-situ Measurement of the Applied EAR During Construction)*

5.3.1 Two steel plates should be used per testing location. Obtain and record the mass of each plate to the nearest 0.01 g.

5.3.2 Place the two steel plates on the pavement in the same transverse location prior to the arrival of the emulsion distributor.

5.3.3 Within one minute of emulsion application, remove the steel plates from the pavement and transfer to a scale that is leveled and shielded from wind.

5.3.4 Record the mass of each plate with the applied emulsion to the nearest 0.01 g.

5.3.5 Repeat the procedure in additional locations along the length of emulsion application to study the longitudinal variability in the applied EAR.

5.4 *Test Method D (In-situ Measurement of the Residual Binder Application Rates During Construction)*

5.4.1 Follow steps 5.3.1 to 5.3.2, outlined in Test Method C.

5.4.2 Remove the plates from the pavement and store on a level surface.

5.4.3 Repeat the procedure in additional locations along the length of emulsion application to study the longitudinal variability in the applied EAR.

5.4.4 Allow each plate to cure for a minimum of 24 hours under ambient conditions.

5.4.5 Record the mass of each plate to the nearest 0.01 g.

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6 CALCULATIONS

6.1 *Test Method A*:

6.1.1 Follow the procedure detailed in ASTM D 2995 Test Method B.

6.2 *Test Method B*:

6.2.1 Subtract the tare mass of each plate from the mass of the plate with emulsion after emulsion application.

6.2.2 Determine the EAR of emulsion contained on each plate in gal/yd^2 as follows:

$$EAR_{Applied},\ {}^{gal}\!/_{yd^2} = \frac{A}{Area \times G_s} \times 0.000264\ {}^{gal}\!/_{cc} \times 1296\ {}^{in^2}\!/_{yd^2}$$

Where:
A = net mass of emulsion applied (mass of plate after emulsion application – mass of plate before emulsion application), g.
Area = area of the flat steel plate, in^2.
G_s = specific gravity of the asphalt emulsion at the spray temperature.

6.2.3 Subtract the tare mass of each sheet from the mass of each emulsion saturated sheet.

6.2.4 Determine the EAR of emulsion contained on each sheet in gal/yd^2 as follows:

$$EAR, gal/yd^2 = \frac{A}{26.01in^2 \times G_s} \times 0.000264\, gal/cc \times 1296\, in^2/yd^2$$

Where:
A = net mass of emulsion absorbed by the sheet, g.

6.2.5 EAR values corresponding to the plates can be regarded as the total applied EAR. If the measured applied EAR deviates more than ± 0.01 gal/yd^2 from the target application rate, results should be regarded and invalid. The distributor should be re-calibrated and testing should be repeated.

6.2.6 Determine the rate by which emulsion is absorbed by the pavement in gal/yd^2 by subtracting the EAR values corresponding to the sheets placed on the pavement from the EAR values corresponding to the plates.

6.2.7 The absorbed emulsion rate represents the rate of applied emulsion which will be absorbed by the paving surface. Absorbed emulsion will not be available to bond with material placed on top of the emulsion. The target EAR can hence, be increased by the calculated absorption rate.

6.3 *Test Method C*:

6.3.1 Follow the same procedure as 6.2.1 and 6.2.2.

6.3.2 Comparison between the EARs measured at different locations along the length of paving can be used to assess longitudinal variability in emulsion application.

6.4 *Test Method D:*

6.4.1 Subtract the tare mass of each sheet from the mass of each binder saturated sheet.

6.4.2 Determine the residual binder application rate as follows:

$$EAR_{\text{Residual}}, gal/yd^2 = \frac{R}{Area \times G_s} \times 0.000264\, gal/cc \times 1296\, in^2/yd^2$$

Where:
R = net mass of residual binder (mass of plate after emulsion application and curing – mass of plate before emulsion application), g.
Area = area of the steel plate, in^2.
G_s = specific gravity of the residual binder at ambient temperature.

6.4.3 The corresponding applied EAR in the field can be obtained using the residual binder rate and emulsion water content as follows:

$$EAR_{Applied}, \frac{gal}{yd^2} = EAR_{\text{Residual}} \times \frac{100}{WC}$$

Where:
WC = water content in emulsion sample, %.

7 REPORT

7.1 *Test Method A*:

7.1.1 Follow reporting requirements of ASTM D 2995 Test Method B.

7.2 *Test Method B*:

7.2.1 Location of measurements.

7.2.2 Visual observation of paving surface at locations of EAR measurements (e.g., rough, bled, etc.).

7.2.3 Calculated rate by which the pavement absorbs emulsion (gal/yd^2).

7.3 *Test Method C*:

7.3.1 Locations of EAR measurements.

7.3.2 Measured EAR at each location of testing (gal/yd^2)

7.4 *Test Method D*:

7.4.1 Locations of residual binder rate measurements.

7.4.2 Measured residual binder application rate at each location of testing (gal/yd^2)

2 PRECISION AND BIAS

8.1 Precision and bias have yet to be established for this procedure.

3 KEYWORDS

Emulsion application rate, quality control, tack coat

4 REFERENCES

ASTM D2995. "Standard Practice for Estimating Application Rate of Bituminous Distributors," ASTM, 2009.