American Association of State Highway and Transportation Officials

AASHTO

Guide Specifications for **Highway Construction**

2020

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2022 Interim Revisions

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Notes for SI version and conversions: Mg (megagram) and MT (metric ton) are equivalent and Mg will be used throughout this publication to denote the quantity. Conversions in [brackets] are soft conversions.

E. *Applying Blotter Sand*. Apply blotter sand to absorb excess asphalt if required to open roadway to traffic before complete penetration and cure.

405.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure prime coat by the amount of residual asphalt.

405.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Asphalt binder for prime coat	ton (Mg), gal (L)
(B) Cutback asphalt for prime coat	ton (Mg), gal (L)
(C) Emulsified asphalt for prime coat	ton (Mg), gal (L)
(D) Blotter sand	ton (Mg), yd^3 (m^3)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 406
EMULSIFIED ASPHALT CHIP SEAL (REVISED)

406.1 DESCRIPTION

Construct a single-application chip seal on a prepared existing surface. Emulsion chip seal is an application of an emulsified asphalt binder covered with an application of clean graded aggregate to an existing asphalt surface. The emulsified asphalt binders may be modified with various polymers such as latex, tire, and natural rubbers. Aggregate must be durable, consisting of crushed stone, gravels, or manufactured aggregates varying in size from $^5/_8$ in. (16 mm) to a minimum of $^1/_4$ in. (6 mm).

This Section is intended to provide information needed for Owners or Contractors to construct emulsified asphalt chip seals. An emulsified asphalt chip seal is the application of emulsified asphalt, followed immediately by a single layer of aggregate chips to a prepared surface.

This Section refers to quality requirements for materials and a design method for chip seals available in other AASHTO documents. However, the main purpose is to provide guidance for

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the construction of emulsified asphalt chip seals applied in one layer. All units of measurement are expressed in inch-pound units, which are the normal units used in the United States, with SI units in parentheses.

Commentaries are included in this Section to 1) emphasize and further explain the section, 2) present options to be considered by the user, or 3) provide sources of additional information. An example of these commentaries is shown below:

Commentary

This Section covers construction of single-application chip seals. If this process is repeated with another application of emulsified asphalt and another layer of cover aggregate, the process is known as a double chip seal. A triple chip seal would require yet another application of emulsified asphalt and cover aggregate. Other terms have been used referring to chip seals such as "seal coat," "surface treatment," "surface seal," "surface dressing," "sprayed seal," and others. Sometimes, a fog seal is applied over the completed chip seal.

406.2 REFERENCED DOCUMENTS

A. *AASHTO Standards:*

- M 140, Emulsified Asphalt
- M 208, Cationic Emulsified Asphalt
- M 316, Polymer-Modified Emulsified Asphalt
- MP 27, Materials for Emulsified Asphalt Chip Seals
- R 10, Definition of Terms Related to Quality and Statistics as Used in Highway Construction
- R 66, Sampling Asphalt Materials
- R 78, Recovering Residue from Emulsified Asphalt Using Low-Temperature Evaporative Techniques
- R 90, Sampling Aggregate Products
- PP 82, Emulsified Asphalt Chip Seal Design
- T 11, Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
- T 19M/T 19, Bulk Density ("Unit Weight") and Voids in Aggregate
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 44, Solubility of Bituminous Materials
- T 49, Penetration of Bituminous Materials
- T 51, Ductility of Asphalt Materials
- T 59, Emulsified Asphalts
- T 85, Specific Gravity and Absorption of Coarse Aggregate

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- T 96, Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- T 104, Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate
- T 111, Mineral Matter or Ash in Asphalt Materials
- T 112, Clay Lumps and Friable Particles in Aggregate
- T 301, Elastic Recovery Test of Asphalt Materials by Means of a Ductilometer
- T 335, Determining the Percentage of Fracture in Coarse Aggregate
- T 350, Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
- T 382, Determining the Viscosity of Emulsified Asphalt by a Rotational Paddle Viscometer

B. *ASTM Standard:*

- D5624, Standard Practice for Determining the Transverse-Aggregate Spread Rate for Surface Treatment Applications

C. *Federal Highway Administration:*

- FHWA-HIF-12-001, Independent Assurance Programs (2011)
- FHWA-HIF-19-029, Chip Seal Checklist (2019)

D. *Federal Lands Highway Standard:*

- FLH T 508, Flakiness Index Value.

E. *Other Documents:*

- Martin, R. S., Jr. Chip Seal Practice. In *Proc., 26th Paving and Transportation Conference*, Department of Civil Engineering, University of New Mexico, Albuquerque, New Mexico, January, 1989.
- Shuler, S. High Traffic Chip-Seal Construction: The Tulsa Test Road. In *Transportation Research Record No. 1300*. Transportation Research Board, National Research Council, 1991, pp. 116–124.

406.3 TERMINOLOGY

A. *CRS-2P, Polymer Modified.* A cationic rapid-setting emulsified asphalt that includes a polymer modifier typically in the form of a styrene–butadiene latex rubber or a styrene–butadiene or styrene–butadiene–styrene block copolymer-modified base asphalt binder and meets AASHTO MP 27 for emulsified asphalt chip seals.

B. *CRS-2.* A cationic rapid-setting emulsified asphalt without a polymer.

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C. *RS-2P, polymer modified.* An anionic rapid-setting emulsified asphalt that includes a polymer modifier typically in the form of a styrene–butadiene latex rubber or a styrene–butadiene or styrene–butadiene–styrene block copolymer-modified base asphalt binder and meets AASHTO MP 27 for emulsified asphalt chip seals.

D. *RS-2.* An anionic rapid-setting emulsified asphalt without a polymer.

E. *HFRS-2P, Polymer Modified.* An anionic high-float rapid-setting emulsified asphalt that includes a polymer modifier typically in the form of a styrene–butadiene latex rubber or a styrene–butadiene or styrene–butadiene–styrene block copolymer-modified base asphalt binder.

F. *HFRS-2.* An anionic high-float rapid-setting emulsified asphalt without a polymer.

G. *CHFRS-2P, Polymer Modified.* A cationic high-float rapid-setting emulsified asphalt that includes a polymer modifier typically in the form of a styrene–butadiene latex rubber or a styrene–butadiene or styrene–butadiene–styrene block copolymer-modified base asphalt binder.

H. *CSS-1h.* A cationic emulsified asphalt that is slow setting and has a hard penetration residual binder residue.

I. *SS-1h.* An anionic emulsified asphalt that is slow setting and has a hard penetration residual binder residue.

406.4 MATERIALS

Provide materials as specified below:

A. *Emulsified Asphalt.* Emulsified asphalt for chip seal shall meet the requirements of AASHTO M 140, M 208, or M 316.

B. *Aggregate.* Chip seal aggregate shall conform to the requirements specified in AASHTO MP 27, Section 6.1, Tables 1 and 2.

C. *Mix Design.* Design the chip seal to determine aggregate spread rate and emulsified asphalt application rate using a design method such as that described by AASHTO PP 82.

406.5 CONSTRUCTION

A. *Equipment.* Furnish the following equipment or equivalent:

1. *Asphalt Distributor.* The asphalt distributor shall be self-propelled with a ground speed control device interconnected with the emulsified asphalt pump such that the specified application rate will be supplied at any speed. The asphalt distributor shall be capable of maintaining the emulsified asphalt at the specified temperature. The spray bar nozzles shall produce a uniform double or triple lap application fan spray, and the shutoff shall be instantaneous, with no dripping. All nozzles shall be oriented at the same angle between 15 and 30 degrees using the wrench supplied by the distributor manufacturer. Each

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asphalt distributor shall be capable of maintaining the specified application rate within ±0.015 gal/yd^2 [0.068 L/m^2] for each load.

Commentary

Obtaining a triple overlap from the spray bar is the most desirable arrangement because the emulsified asphalt application will generally be more uniform than with double overlap. However, when equipment is calibrated and set up properly, very acceptable results have been obtained with double overlap.

2. *Aggregate Spreader.* A self-propelled mechanical-type aggregate spreader with a computerized spread control, capable of distributing the aggregate uniformly to the required width and at the designed rate shall be used.

3. *Pneumatic-Tire Rollers.* A minimum of three self-propelled pneumatic-tire rollers capable of ballast loading, either with water or sand, to allow the weight of the machine to be varied from 6 to 8 tons [5.4 to 7.2 Mg] to achieve a minimum contact pressure of 80 lb/in.^{2} (550 kPa) shall be used. The alignment of the axles shall be such that the rear-axle tires, when inflated to the proper pressure, can compact the voids untouched by the front-axle tires. All tires shall be as supplied by the roller manufacturer. Width of the rollers shall exceed 60 in. (1.5 m).

Commentary

Steel-wheel rollers have been used as the final roller on some chip seals with success. The advantage is a more even final elevation. This produces fewer prominent chip edges extruding above the surface, which can be susceptible to snowplow damage. The disadvantage of steel-wheel rollers is the potential for crushing of aggregate chips that cannot withstand the high stress imparted at the steel roll–chip interface. Therefore, if used, steel rollers should be limited to 5 tons [4.5 Mg]. Vibration shall not be used if the rollers are so equipped.

4. *Brooms.* Motorized brooms with a positive means of controlling vertical pressure shall be used to clean the road surface prior to spraying emulsified asphalt. Plastic bristle brooms are required to remove loose aggregate after rolling.

Commentary

Vacuum brooms are preferred in urban or residential areas, but push brooms are acceptable in rural areas where chips being scattered off the roadway do not pose a hazard to pedestrians or vehicles.

5. *Trucks.* Unless otherwise approved, use trucks of uniform capacity to deliver the aggregate. Provide documentation showing measurements and calculation in cubic yards (cubic meters). Clearly mark the calibrated level. Truck size may be limited when shown on the plans.

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B. *Equipment Calibration:*

Provide proof of calibration of the asphalt distributor and the aggregate spreader. Conduct calibration no earlier than five days prior to chip seal operations. Submit the results of the calibration procedure to the Engineer.

Flow from each nozzle in the asphalt distributor must be within ±10 percent of the average flow of all nozzles as measured by the procedure as described in NCHRP Report 680, Chapter 7 (Shuler et al., 2011).

Uniformity of the aggregate applied transverse to the pavement centerline shall be in accordance with ASTM D5624. Tolerance for each pad tested for transverse spread rate shall be ±10 percent of the average of the total transverse rate.

Commentary

Calibration is very important to assure the quantity of emulsified asphalt and aggregate applied to the pavement is correct. Although many modern asphalt distributors and aggregate spreaders are computer controlled, calibration is required to tell the computer how much emulsified asphalt is being applied. This quantity must be checked prior to spraying emulsified asphalt and spreading aggregates and checked against the quantity the computer (if the distributor is so equipped) indicates is being applied.

1. *Asphalt Distributor:*

All nozzles shall be the same size, provide the same flow rate, be oriented in the same direction, and be the same distance above the pavement.

Commentary

The distributor truck applies emulsified asphalt to the pavement surface. This application must be done uniformly both transverse and longitudinal to the centerline of the pavement to provide the proper emulsified asphalt layer necessary for proper aggregate chip adhesion.

When lower application rates are determined necessary or shown in the plans, smaller nozzles shall be inserted in the spray bar where the emulsified asphalt rate is reduced.

Commentary

Due to minor rutting or heavy truck traffic, it may be desirable to reduce the emulsified asphalt application rate in the wheel paths.

a. *Nozzle Angle:*

Nozzles shall be positioned at an angle of 15 to 30 degrees from the horizontal of the spray bar in accordance with the manufacturer's recommendation. All nozzles shall spray a full fan except for the right and left edge nozzles. The right and left edge nozzles shall be adjusted to a half fan such that the spray stays to the inside of the spray bar.

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Commentary

The next step in calibrating the distributor is adjustment of the spray bar nozzle angles. Each nozzle has a slot cut across the face of the nozzle. When the nozzle is threaded into the spray bar, the slot should all be positioned at an angle of 15 to 30 degrees to the direction of the spray bar as shown in Figure 406.5-1. This angle provides the best position for achieving uniformity in the spray and the triple overlap coverage. The angle should be adjusted using the wrench supplied with the distributor. This wrench is designed, when used properly, to set the correct angles for each nozzle. Any wrench that fits the hexagonal nozzle can adjust the nozzle angle, but correctness of the angle would have to be visually verified.

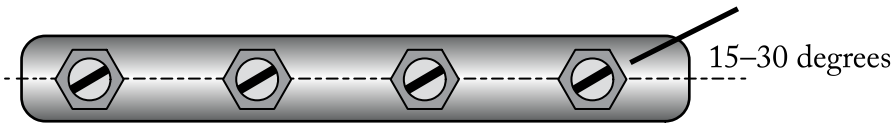

Figure 406.5-1. Spray Bar Nozzle Orientation in Spray Bar

b. *Spray Bar Height*. The spray bar height must be adjusted so that the emulsified asphalt provides exactly two or three overlaps across the entire spray width.

Commentary

Streaking of the emulsified asphalt will occur if the spray bar is set too high or too low as shown in Figures 406.5-2 and 406.5-3.

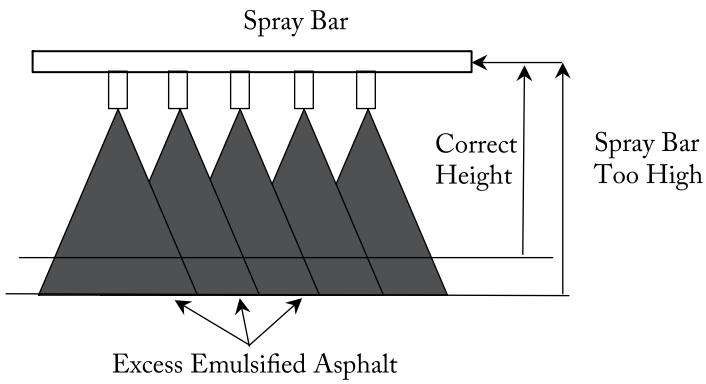

Figure 406.5-2. Streaks with Spray Bar Too High for Double Overlap

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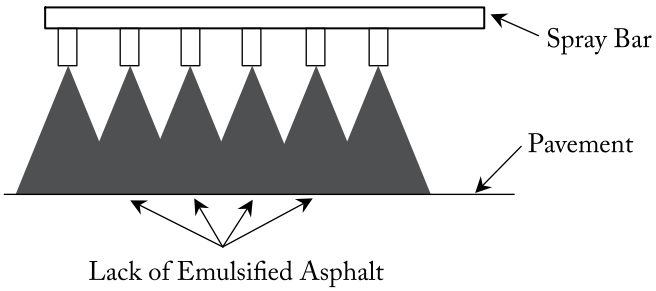

Figure 406.5-3. Streaks with Spray Bar Too Low for Double Overlap

To avoid this streaking, the bar must be adjusted to the correct height. This adjustment process is accomplished by shutting off nozzles to determine where the spray pattern contacts the pavement as shown in Figures 406.5-4 and 406.5-5.

c. *Bar Height Adjustment to Achieve Double Lap*

Every other nozzle shall be turned off when a double lap application is desired, as shown in Figure 406.5-4. The distributor operator shall spray emulsified asphalt onto the pavement surface for as short an interval as possible while an observer watches where the emulsified asphalt hits the pavement from each nozzle left open. If there is overlap of emulsified asphalt from adjacent nozzles, the bar is too high. If there is a lack of emulsified asphalt from adjacent nozzles, the bar is too low.

Once it is confirmed the bar height is correct, the nozzles that were turned off should be turned back on and a double application of emulsified asphalt will result when spraying resumes.

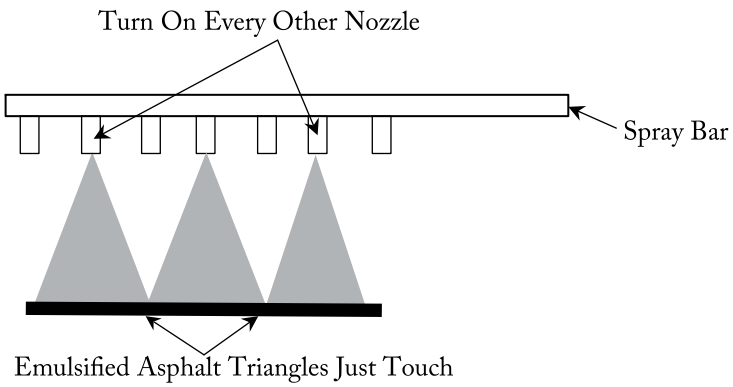

Figure 406.5-4. Adjustment of Spray Bar Height for Double Overlap

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d. *Triple Lap Application Bar Height Adjustment*

Every third nozzle shall be turned off when a triple lap application is desired, as shown in Figure 406.5-5. The distributor operator shall spray emulsified asphalt onto the pavement surface for as short an interval as possible while an observer watches where the emulsified asphalt hits the pavement from each nozzle left open. If there is overlap of emulsified asphalt from adjacent nozzles, the bar is too low. If there is a lack of emulsified asphalt from adjacent nozzles, the bar is too high.

Once it is confirmed the bar height is correct, the nozzles that were turned off should be turned back on and a triple application of emulsified asphalt will result when spraying resumes.

As the distributor empties during spraying, the bar height will rise. However, this is not usually enough to cause significant streaking worth adjustment of the spray bar.

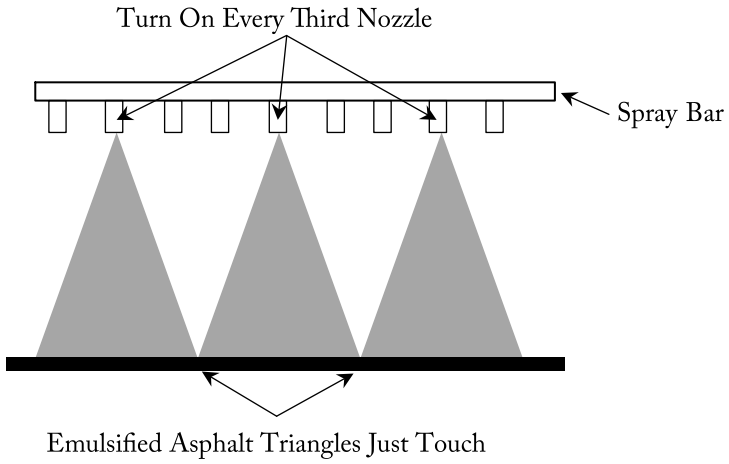

Figure 406.5-5. Adjustment of Spray Bar Height for Triple Overlap

e. *Transverse Flow Rate.* The flow rate across the spray bar shall be uniform, with each nozzle spraying within ±10 percent of the average flow rate.

Commentary

A uniform flow rate is achieved by measuring the width of the slot in the nozzle and by measuring the orifice diameter. Also, some nozzles are labeled by the manufacturer. Manufacturers supply a list of nozzles in the owner's document describing which nozzles shall be used for various application rates or on a placard mounted on the equipment.

However, nozzles of the same apparent size have been measured with different flow rates. Therefore, it is recommended that all nozzles be checked for flow rate before chip seal operations begin. This is easily accomplished by fabricating a flow apparatus (Martin, 1989). This apparatus consists of a pipe to which each nozzle, in turn, can be fitted on one end and a water

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source can be fitted on the other end. The flow of water through each nozzle shall be measured by the volume captured in a 1-gal (4-L) container within a set time period. This shall be done for each nozzle to be used on the project. If the flow rate of any nozzle is greater than ±10 percent of the average of all the nozzles to be used, such nozzle shall be discarded or modified to flow within the 10 percent tolerance.

Determination of uniform lateral flow from the spray bar is determined by collecting a measured volume of emulsified asphalt in containers placed under each nozzle. This process is practical using standard 6-in. by 12-in. (150-mm by 300-mm) concrete cylinder molds lined with 1 gal (4 L) resealable freezer bags. The cylinder molds can be reused and the freezer bags discarded appropriately with the contents.

f. *Longitudinal Flow Rate.* The longitudinal flow rate shall be accomplished by measuring the volume of emulsified asphalt in the distributor before and after spraying enough emulsified asphalt to reduce the volume of emulsified asphalt in the distributor by 70 to 90 percent.

Commentary

The longitudinal flow rate must be measured with all nozzles inserted in the distributor bar. First, the quantity of emulsified asphalt in the truck must be determined. Although there is a volume indicator on the rear of most modern distributors, these are not calibrated in small enough increments to be of use for longitudinal flow rate calibration and shall not be used for this purpose. Instead, the dipstick supplied with the distributor must be used. This dipstick is usually carried on the top of the tank near the inspection hatch. Prior to shooting emulsified asphalt, take a volume reading with the dipstick.

Pay attention to how the dipstick is used. Many dipsticks are not intended to be submerged in the emulsified asphalt but instead are inserted into the top of the tank only until the tip of the dipstick touches the surface of the emulsified asphalt. Then, the volume in the tank is read by indexing the top of the inspection cover to the reading on the dipstick.

Record this volume as "beginning volume." Set up the truck to shoot emulsified asphalt and shoot a minimum of 3000 ft by 12 ft (1000 m by 3.6 m) of emulsified asphalt at the design rate using the gallon per minute pump flow volume and truck speed required by the manufacturer to attain this flow rate. Take a second dipstick reading. Record this reading as "ending volume." Subtract ending volume from beginning volume and record this as "volume used." Determine the area of emulsified asphalt sprayed. Divide volume used by the area sprayed in square yards (square meters). This is the gallons per square yard (liters per square meter) applied to the pavement. This value shall then be compared to the distributor computer, if equipped, to evaluate the accuracy of the computer. A correction factor may then be applied to the computer output, if needed, and used for the remainder of the day. This calibration shall be accomplished each day.

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An example of this calibration is presented below:

Given:

1800-gal (6800-L) capacity asphalt distributor

12-ft (3.6-m) wide spray width

Trial spray distance = 3630 ft (1100 m)

0.32 gal/yd^2 (1.45 L/m^2) design spray rate

Dipstick reading beginning volume = 1765 gal (6584 L)

Dipstick reading ending volume = 265 gal (1003 L)

Calculations:

Check to see if enough volume shot. 1765–265 = 1500 gal (6584–1003 = 5581 L)

1500/1765 (5581/6581)= 85 percent > 70 percent and < 90 percent.
OK; enough applied to be valid

Calculate spray rate = 1500 gal / (12 × 3630/9) = 0.31 gal/yd^2
5581 L / (3.6 m × 1100 m) = 1.41 L/m^2

Therefore, decrease distributor speed, or recalibrate computer and recheck.

2. *Aggregate Spreader*

   a. *Transverse Spread Rate:*

   The aggregate spread shall be uniform across the veil and within ±10 percent of the average spread rate. Various methods of calibrating this equipment have been used and the ASTM D5624 procedure can be effective.

   Commentary

   A visual assessment of the lateral distribution of chips is a good place to start the process since non-uniform distribution can easily be seen. The veil of chips deposited on the pavement from the spreader box can be viewed from behind, with the spreader moving away from the observer, or from the front. Either position for the observer is adequate for viewing how uniformly the veil of chips is falling out of the spreader box. However, viewing from either front quarter affords the observer a better view of the entire spreader width and is, of course, safer than directly in front of the spreader. Any variation in light passing through the veil of aggregate indicates variation in application rate. More light means a lack of aggregate. Variation in light means the machine shall be stopped, the gates on the spreader contributing to the non-uniformity adjusted, and the trial rerun. This procedure provides adjustment to the transverse spread rate. Then, to obtain an objective means of measuring the amount of aggregate being deposited, ASTM D5624 is a good procedure to use.

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b. *Longitudinal Spread Rate.* The longitudinal spread rate shall be uniform and be within ±10 percent of the design spread rate.

Commentary

Once the transverse spread rate is adjusted, the longitudinal rate can be adjusted. This is also done visually, at first.

Evaluating the quantity of aggregates being placed is important after the rate is established. This provides a quantitative baseline for future work. The best method to accomplish this evaluation is by weighing the aggregate spreader before and after applying the aggregate and calculating the spread rate based on the area covered. This is often not practical. Therefore, a suitable alternative is estimating the quantity of aggregates spread over a known area by knowing the weight of each transport truck supplying the spreader and dividing the estimated weight of aggregate spread by the area covered for that load.

An example follows:

Given:

Trucks loading the aggregate spreader are 12-ton (11 Mg) capacity tandem dumps

12-ft (3.6-m) wide pavement

28 lb/yd^2 (15.42 kg/m^2) design spread rate

Calculations:

Check Truck No. 1

Load = 23,803 lb (10,806 kg)

Spreader distance = 640 ft (195.2 m)

Rate = 23,803/(640 × 12/9) = 27.9 lb/yd^2
(10,806/(195.2 × 3.6) = 15.38 kg/m^2)

Check Truck No. 2

Load = 23,921 lb (10,860 kg)

Spreader distance = 634 ft (193.4 m)

Rate = 23,921/(634 × 12/9) = 28.3 lb/yd^2
(10,860/(193.4 × 3.6) = 15.60 kg/m^2)

Check Truck No. 3

Load = 23,848 lb (10,826 kg)

Spreader distance = 639 ft (194.9 m)

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Rate = 23,848/(639 × 12/9) = 28.0 lb/yd²
(10,826/(194.9 × 3.6) = 15.43 kg/m²)

Average Rate = (27.9 + 28.3 + 28.0) / 3 = 28.1 lb/yd²
((15.38 + 15.60 + 15.43) / 3 = 15.47 kg/m²)

No adjustment needed since measured rate is within 1 percent of design.

Compensation for moisture on the aggregate must be considered when calibrating spreaders. The above example indicates no adjustment is needed since the measured spread rate is within 0.10 lb/yd² (0.05 kg/m²) of the design spread rate. However, if the aggregate above had contained as much as 1.02 percent moisture that was unaccounted for, the application rate would have been too low.

C. *Preconstruction Meeting.* Coordinate a preconstruction meeting prior to construction with the Engineer to discuss the following topics:

1. Construction process;
2. Quality control plan; required to be submitted;
3. Mix design; required to be submitted;
4. Materials control;
5. Materials measurement;
6. Equipment calibration; required to be submitted;
7. Traffic control plan;
8. Equipment/process overview;
9. Inspection;
10. Test strip;
11. Unique project conditions;
12. Project documentation; and
13. Expectations.

D. *Road Surface Preparations:*

1. *Cleaning Pavement.* Clean the roadway surface by sweeping no more than 30 min prior to application of the emulsified asphalt and aggregate. However, this 30-min window may be extended if authorized by the Engineer in cases where extending the time does not jeopardize a clean surface prior to chip seal operations. Sweep the pavement with a motorized broom to remove loose material. Clean depressions not reached by the motorized

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broom with a hand broom. Clean the outer edges of the pavement to be sealed including an adjacent paved shoulder.

2. *Protecting Accessories.* Cover utility castings (e.g. manholes, gate valve covers, catch basins, sensors) to prevent coating with emulsified asphalt. Suitable covering includes plywood disks, kraft paper, roofing felt, or other approved methods. Remove the protective coverings before opening the road to traffic.

3. *Stripe Removal.* Thermoplastic pavement markings shall be removed by grinding or other approved methods prior to chip seal operations. Other pavement markings may be left in place.

   Commentary

   If the edge stripes and center lane stripes are worn, removal may not be necessary or, if in doubt, applying a fog seal to the stripes prior to chip sealing has been demonstrated as effective for maintaining good chip seal adhesion. Stop bars and turn arrows should always be removed.

E. *Application:*

1. *Weather Limitations.* Construct chip seal per the following conditions:

   a. Ambient and pavement surface temperatures shall be 50°F (10°C) and rising.

   b. Application of the chip seal shall be only during daylight hours.

   c. Suspend chip sealing if the pavement surface temperature exceeds 140°F (60°C).

   d. The road surface shall be dry to damp.

2. *Test Strip.* Construct a test strip on or near the project site. Construct the test strip under similar placement conditions of time of day, temperature, and humidity as expected for the duration of the project. The test strip shall be a minimum of 500 ft (150 m) in length and shall be constructed with the job mix proportions, materials, and equipment to be used on the project. Adjustments to the mixture formula shall be permitted provided they do not exceed the values stated in the mix design. The Agency shall evaluate the test strip to determine whether project specifications are met. If specifications are not met, additional test strips will be constructed until specifications are met, at no additional cost to the Agency.

3. *Application of Emulsified Asphalt:*

   Apply the emulsified asphalt at the rate determined by the design. This rate shall be within ±5 percent of the chip seal design rate. After applying the emulsified asphalt, place the cover aggregate at the design application rate. Adjust the rate of application, if necessary, so that some emulsified asphalt can be seen between the aggregate chips, but not so much that aggregate chips adhere to the pneumatic rollers. Inspect the aggregate in the wheel paths for proper embedment. Embedment shall be 50 to 60 percent after rolling. Make additional adjustments to the rate of application during the project, if needed.

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The temperature of the emulsified asphalt at the time of application shall be above 120°F (50°C).

Commentary

If the temperature is lower than 120°F (50°C), there is risk of less material being applied than desired due to high viscosity.

The longitudinal construction joint for a single-course chip seal must coincide with the painted lane line or the outside edge of the shoulder. There shall be no overlap of the longitudinal construction joint for a single-application chip seal.

4. *Application of Cover Aggregate.* Provide uniformly moistened aggregates that are damp at the time of placement. Damp aggregates shall be saturated but surface dry with approximate moisture content between 1 and 3 percent depending on the aggregate absorption capacity.

Commentary

This moisture content makes the chips appear as though they have a matte or satin finish, and not glossy, using a painting analogy. A damp aggregate draws emulsified asphalt into the aggregate pores, thus providing better adhesion once the emulsified asphalt has set.

For non-modified emulsified asphalts like RS-2 or CRS-2, begin spreading chips into the fresh emulsified asphalt when a few chips cast by hand stick to the emulsified asphalt and do not roll over. This shall be done well before the emulsified asphalt begins to break or set, but not immediately after spraying unless temperature, wind, or high demulsibility demand it. This practice may not be necessary for emulsified asphalts that are polymer modified. Polymer-modified emulsified asphalts are highly adhesive immediately after spraying and chips do not tend to roll over after spreading. Therefore, for polymer-modified emulsified asphalts, chips should be spread immediately after spraying the emulsified asphalt.

The application rate of the chips shall be similar to the design rate. This is a rate where immediately upon dropping the chips, the appearance of the surface has some emulsified asphalt showing between the chips. In fact, the chip quantity should seem somewhat inadequate. The chip spread rate should not be low enough to cause pickup problems on rubber-tire rollers. However, the rate should be such that a small decrease in rate would cause pickup. Emulsified asphalt should be visible between the aggregates upon dropping them and before rolling. If all emulsified asphalt is covered before rolling, there is an excess of chips and the rate shall be reduced. It is the responsibility of the construction superintendent to achieve this application rate.

The speed of the spreader shall be restricted to prevent the aggregates from rolling over. Starting and stopping of the spreader should be minimized. The edges of the aggregate applications shall be sharply defined. Previously used aggregates from sweeping may not be returned to the stockpile or the spreader for reuse.

Commentary

Although a design was done in the laboratory to determine the aggregate application rate, adjustments are almost always needed in the field. This should be done during the first day of construction

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to make sure the aggregate quantity is correct. This is best done by observing the appearance of the aggregates after they have been dropped into the emulsified asphalt, but before rolling. Some emulsified asphalt should be visible between most of the aggregates. If emulsified asphalt cannot be seen between the aggregates, the rate is too high. Conversely, too much emulsified asphalt showing through between the aggregate will cause pickup on rubber tires.

5. *Transverse Paper Joints.* When beginning a new application of the chip seal transversely abutting the previously placed chip seal, use a transverse paper joint so excess asphalt and chips are not placed at the joint. The transverse paper joint shall be formed by placing 36-in. (1-m) wide kraft paper on top of the previously applied chip seal so the edge of the paper aligns with the joint that will be formed when the previously placed chip seal meets the newly applied chip seal. The asphalt distributor shall begin applying emulsified asphalt by starting the application on top of the kraft paper. After the asphalt distributor moves forward and over the joint, the paper shall be removed.

   Commentary

   Ideally, the paper should also be placed at the end of the distributor shot as well. This creates a clean edge with the correct emulsified asphalt and aggregate quantity at the joint. The placement of the paper is calculated based on the emulsified asphalt shot rate and the quantity of emulsified asphalt in the distributor. The distance the asphalt distributor travels before encountering the paper and turning off the bar should be approximately equivalent to 80 percent of the distributor tank volume. This assures the distributor does not spray until empty which can result in less emulsified asphalt applied than desired at the end of the shot.

6. *Rolling Operations.* Complete the first roller pass as soon as possible but not longer than 2 min after applying the aggregate. Proceed in a longitudinal direction at a speed less than or equal to 3 mph (5 km/h). Three complete roller passes of the aggregate chips are required as a minimum. One pass is defined as the roller moving over the aggregates in a single direction. Ensure the rolling is completed quickly enough to embed the aggregate, before the emulsified asphalt breaks, and no longer than 15 min after the emulsified asphalt is sprayed. Position the rollers in echelon so the entire width of the pavement lane is covered in one pass of the rollers.

   Commentary

   If desired, final rolling may be accomplished using the steel-wheel roller in one pass. The asphalt distributor and aggregate spreader speed may have to be reduced if the rolling operations cannot be accomplished before the emulsified asphalt breaks.

7. *Sweeping.* Excess aggregate shall be swept off the new surface in accordance with Table 406.5-1.

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Table 406.5-1. Sweeping Sequence

Chip Seal Class[a]		
I	II	III
Within 24 h after rolling	No later than the following morning	Before traffic is allowed without traffic control

[a] Class I is less than 500 annual average daily traffic (AADT), Class II is 501 to 5000 AADT, and Class III is greater than 5000 AADT.

Do not sweep embedded aggregate until at least 85 percent of the total moisture present in the chip seal has evaporated or aggregates may become dislodged. Moisture present consists of moisture in the aggregate chips and moisture present in the emulsified asphalt. Moisture content shall be determined by the procedure reported in NCHRP Report 680 (Shuler et al., 2011). Resweep areas the day after the initial sweeping. The Contractor shall dispose of the surplus cover aggregate in a manner satisfactory to the Agency. In no case shall the excess aggregates swept from the surface exceed 10 percent of the total amount placed. If this quantity is exceeded, work shall cease until an adjustment is made to reduce the spread rate to be within tolerances.

8. *Traffic Control*

   Traffic may be allowed onto the fresh chip seal after rolling is completed and before sweeping in accordance with Table 406.5-2. Before allowing traffic on the newly placed chip seal, ensure that at least 85 percent of the total moisture present in the chip seal has evaporated or aggregates may become dislodged.

Table 406.5-2. Timing for Traffic

Chip Seal Class[a]		
I	II	III
Traffic controlled with speed limit signs	Traffic controlled with pilot cars	Traffic controlled with pilot cars

[a] Class I is less than 500 AADT, Class II is 501 to 5000 AADT, and Class III is greater than 5000 AADT.

A pilot car shall be used on two-lane roadways during construction and until the roadway and shoulders have been swept free of loose aggregate.

9. *Protection of Motor Vehicles.* The Contractor is responsible for claims of damage to vehicles until the roadways and shoulders have been swept free of loose aggregate and permanent pavement markings have been applied. If permanent pavement markings are to be applied by Agency forces, the Contractor's responsibility ends after completion of the chip seal and placement of temporary pavement markings.

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10. *Fog Seal*

If, in accordance with the plans, a fog seal is applied to the surface of the completed chip seal, spray the fog seal after sweeping and before placement of permanent pavement markings, but not sooner than 24 h after final rolling. Refer to Section 410 for specific requirements for application of fog seal over chip seals.

Commentary

Fog seals are applied to the surface of completed chip seals for two reasons: 1) The dark color provides more contrast to pavement markings, and 2) the fog seal provides a slight increase in binder residue to increase chip retention.

A fog seal may also be applied to recent hot mix asphalt patches in the pavement to be chip sealed. These fresh hot mix patches can be more absorptive than the surrounding pavement due to higher air void content. The fog seal helps prevent the new chip seal emulsified asphalt from being absorbed into the substrate unevenly.

11. *Sequence of Work:*

Construct the chip seal so that adjacent lanes are sealed on the same day when possible. If the adjacent lane(s) has not been sealed, sweep all loose aggregate from the unsealed lane(s) before traffic is allowed on the surface without traffic control.

Permanent pavement markings shall not be placed for 24 h after placing the chip seal when no fog seal is applied.

If fog seal is used, the permanent pavement markings shall not be placed before three days have elapsed for waterborne pavement marking or ten days for other types of markings.

Commentary

The chip seal will usually cure within 24 h under dry conditions and temperatures above 60°F (16°C). The fog seal can be applied after the chip seal coat is cured. The fog seal will usually cure within 2 h under dry conditions and temperatures above 60°F (16°C). Interim pavement markings can be placed after the fog seal cures. Do not allow traffic on the fog seal until cured.

F. *Quality Assurance:*

1. *General:*

a. The chip seal contractor (the Contractor) shall establish, implement, and maintain a QC program to control all equipment, materials, workmanship, and processes during chip seal construction. The Contractor's QC program shall include preconstruction activities including chip seal design, site preparation, material handling and transportation, and stockpiling. The program shall include procedures required for sampling, testing, inspection, monitoring, documentation, and corrective action procedures during transport, stockpiling, placement, and finishing operations.

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b. A written quality control plan shall be developed which details the Contractor's QC program that meets the requirements of these specifications. The QC plan shall be contract specific and signed by the Contractor's representative. Chip seal construction shall not proceed without Agency acceptance of the QC plan and QC personnel present on the job. Failure to comply with these provisions will result in shutdown of the operation until the Contractor's operation is in compliance.

2. *Definitions:*

   a. **Agency.** A state highway agency, other agency, or owner responsible for the final acceptance of the project.

   b. **Calibration.** Any calibration, standardization, check, or verification as required by the test method or standard.

   c. **Contractor.** The prime contractor who has ultimate control of the project.

   d. **Supplier.** One who produces the final product materials (i.e., aggregates and asphalt emulsion) used on the project.

   e. **Standard.** Any standard, specification, test method, practice, or other document utilized to achieve compliance with the contract.

   f. **Testing Lab.** The laboratory conducting quality control tests (Contractor or Supplier) and acceptance tests (Agency).

3. *Personnel:*

   a. *Responsibilities and Requirement of QC Staff.* At a minimum, provide the name of the person responsible for each position listed below, including their telephone number, email, and their qualifications/certifications.

      i. *QC Plan Manager.* The person responsible for the execution of the QC plan and liaison with the Agency. This person shall be on the job and have the authority to stop or suspend construction operations.

      ii. *QC Technicians.* The person(s) responsible for conducting QC tests and inspection to implement the QC plan. QC technicians shall have Level 2 aggregate testing certification from the American Concrete Institute (ACI), or other certification program approved by the Agency.

   b. *Certified Contractor Staff.* At a minimum, one crew member (project manager or other with decision-making authority) possessing a valid chip seal certification shall always be on the job while the chip seal is being constructed. The chip seal certification is administered by the National Center for Pavement Preservation (NCPP) on behalf of AASHTO TSP·2 (Transportation System Preservation Technical Services Program).

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4. *QC Testing Laboratories and Equipment:*

    a. The laboratory that performs the QC for production can be either qualified or Agency approved. The Contractor shall provide the name of the Agency-approved lab for all tests within the relevant scope of testing.

    b. Testing and sampling equipment and measuring devices shall meet the requirements of the specified standards and test methods. The lab shall maintain records of the calibration and maintenance of all sampling, testing, and measuring equipment, and all documents required by the Agency.

    c. Placement Equipment Calibration. Prior to the commencement of work, the asphalt emulsion distributor and aggregate spreader shall be calibrated in the presence of the Agency representative utilizing the materials to be used on the project. Calibration will be performed consistent with procedures in FHWA-HIF-19-029, Chip Seal Checklist (2019).

5. *QC Activities.* QC activities shall include monitoring, inspection, sampling, and testing. The Contractor's QC activities shall cover all aspects that affect the quality of the materials and workmanship of the chip seal. If there is no Agency-specific requirement, the minimum QC activities and frequencies required are listed as follows:

    a. Component materials;

    b. Transportation material handling;

    c. Mix design by a qualified lab;

    d. Test strip construction and assessment;

    e. Placement and finishing;

    f. Performance; and

    g. Review of material certifications supplied by vendors and suppliers.

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