Section 406

Construction Guide Specification for Emulsified Asphalt Chip Seal

406.1. DESCRIPTION

This guide specification 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 guide specification 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 the construction of emulsified asphalt chip seals applied in one layer. All units of measurement are expressed in English units which are the normal units used in the United States

Commentaries are included in this Guide specification 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 guide specification 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

406.2.1. *AASHTO Standards*

- M 140, Emulsified Asphalt
- M 208, Cationic Emulsified Asphalt
- M 316, Polymer-Modified Cationic Emulsified Asphalt
- MP 27, Standard Specification for Materials for Emulsified Asphalt Chip Seals
- PP 82, Emulsion Emulsified Chip Seal Design
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 49, Penetration of Bituminous Materials
- T 50, Float Test for Bituminous Materials
- T 59, Emulsified Asphalts
- T 96, Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- T 301, Elastic Recovery Test of Asphalt Materials by Means of a Ductilometer
- T 335, Standard Method of Test for Determining the Percentage of Fracture in Coarse Aggregate

406.2.2. *ASTM Standard*

- D 5624, Standard Practice for Determining the Transverse-Aggregate Spread Rate for Surface Treatment Applications

406.2.3. *Other Documents*

- The Asphalt Institute, *Manual Series 19, A Basic Asphalt Emulsion Manual*, 4th ed.
- Federal Lands Highway, FLH T508, Flakiness Index Value
- 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.
- Shuler, S., A. Epps-Martin, T. Lord, and D. Hoyt. *National Cooperative Highway Research Program Report 680: Manual for Emulsion-Based Chip Seals for Pavement Preservation*. National Cooperative Highway Research Program, Transportation Research Board, Washington, DC, 2011.

406.3. TERMINOLOGY

406.3.1. *CRS-2, polymer modified*—a cationic rapid 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.

406.3.2. *CRS-2*—a cationic emulsified asphalt without a polymer that is rapid setting.

406.3.3. *RS-2, polymer modified*—an anionic rapid 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.

406.3.4. *RS-2*—an anionic emulsified asphalt without a polymer that is rapid setting.

406.3.5. *HFRS-2, polymer modified*—an anionic high float rapid 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.

406.3.6. *HFRS-2*—an anionic high float emulsified asphalt without a polymer that is rapid setting.

406.3.7. *CHFRS-2, polymer modified*—a cationic high float rapid 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.

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

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

406.4. MATERIALS

406.4.1. *Emulsified Asphalt*—Emulsified asphalt for chip seal shall meet the requirements of MP 27, M 140, M 208, or M 316.

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

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

406.5. CONSTRUCTION

406.5.1. *Equipment*:

406.5.1.1. *Pressure Distributor*—The pressure 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 pressure 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 using the wrench supplied by the distributor manufacturer. Each pressure distributor shall be capable of maintaining the specified application rate within ±0.015 gal/yd^2 for each load.

Commentary

Obtaining a triple overlap from the spray bar is the most desirable arrangement because the emulsion 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

406.5.1.2. *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.

406.5.1.3. *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 to achieve a minimum contact pressure of 80 lb/in.^{2} shall be used. The alignment of the axles shall be such the rear axle tires, when inflated to the proper pressure, can compact the voids untouched by the front-axle tire. All tires shall be as supplied by the roller manufacturer. Width of the rollers shall exceed 60 in.

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 snow plow 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. Vibration shall not be used if the rollers are so equipped.

406.5.1.4. *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 chip sealing.

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.

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

406.5.2. *Equipment Calibration*

The contractor shall provide proof of calibration of the pressure distributor and the aggregate spreader. Calibration shall be repeated once per week or after every five full days of chip seal operations. The contractor shall submit the results of the calibration procedure to the Engineer.

Flow from each nozzle in the pressure distributor must be within ±10 percent of the average flow of all nozzles as measured by the procedure described below.

Uniformity of the aggregate applied transverse to the pavement centerline 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 emulsion and chips applied to the pavement are correct. Although many modern asphalt distributors and aggregate spreaders are computer controlled, calibration is required to tell the computer how much emulsion is being applied. This quantity must be checked prior to spraying emulsion and spreading chips and checked against the quantity the computer (if the distributor is so equipped) indicates is being applied.

406.5.2.1. *Pressure 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.

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

Commentary

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

406.5.2.1.1. *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 spray bar manufacturers' recommendation. All nozzles shall spray a full fan except for the right and left edge nozzles. The right and left edge nozzle shall be adjusted to a half fan such that the spray stays to the inside of the spray bar.

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 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.

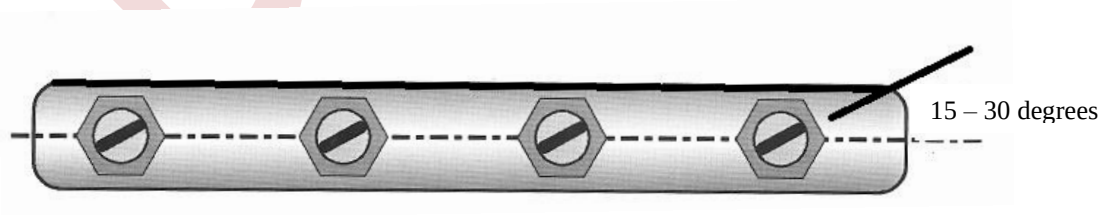

Figure 1—Spray Bar Nozzle Orientation in Spray Bar

The angle at which the nozzles are positioned shall be adjusted using the wrench supplied with the distributor.

However, in cases where this wrench is unavailable, a wrench that fits the hexagonal nozzle will suffice but the angle must be judged visually.

All nozzles fitted to the spray bar shall be full fan nozzles except for the right and left edge nozzles. These nozzles shall be half fan nozzles adjusted so the spray from the nozzle remains to the inside of the spray bar.

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

Commentary

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

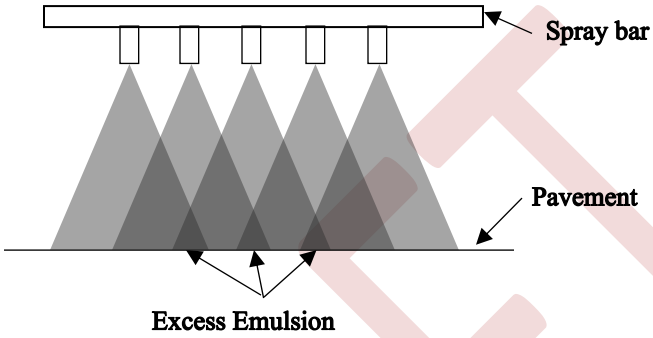

Figure 2—Streaks with Spray Bar Too High for Double Overlap

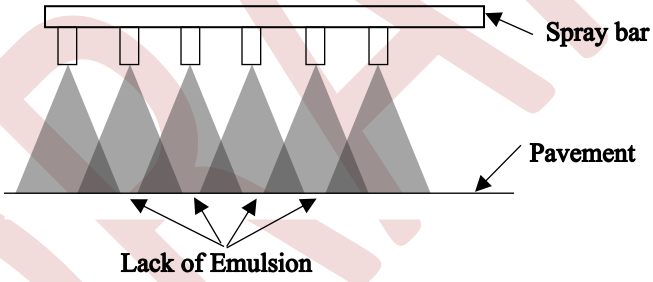

Figure 3—Streaks with Spray Bar Too Low for Double Overlap

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 4 and 5.

406.5.2.1.3. *Bar Height Adjustment to Achieve Double Lap*

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

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

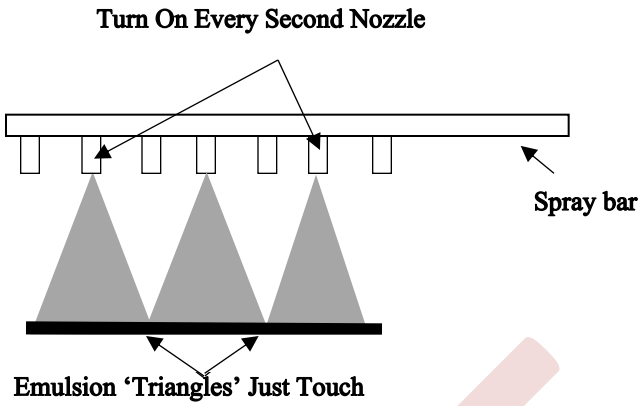

Figure 4—Adjustment of Spray Bar Height for Double Overlap

406.5.2.1.4. *Triple Lap Application Bar Height Adjustment*

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

Once it is confirmed the bar height is correct, the nozzles that were turned off can be turned back on and a double application of emulsion 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.

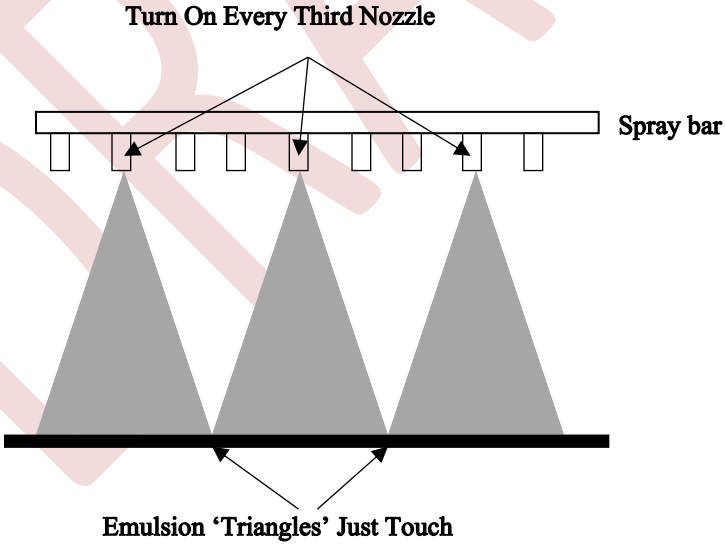

Figure 5—Adjustment of Spray Bar Height for Triple Overlap

406.5.2.1.5. *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

This is done 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. This apparatus consists of a pipe to which each nozzle can be fitted, in turn, on one end and a water source can be fitted to the other end. The flow of water through each nozzle shall be measured by filling a 1-gal container in a measured period. This shall be done for each nozzle to be used on the project. If the flow rate of any of the nozzles is greater than 10 percent of the average of all the nozzles to be used these nozzles 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 emulsion in containers placed under each nozzle. This process is practical using standard 6-in. by 12-in. concrete cylinder molds lined with one-gallon zip-lock freezer bags. The cylinder molds can be reused and the zip lock bags discarded appropriately with the contents.

406.5.2.1.6. *Longitudinal Flow Rate*—The longitudinal spray rate shall be accomplished by measuring the volume of emulsion in the distributor before and after spraying enough emulsion to reduce the volume of emulsion 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 dip stick supplied with the distributor must be used. This dip stick is usually carried on the top of the tank near the inspection hatch. Prior to shooting emulsion, take a volume reading with the dip stick.

Pay attention to how the dipstick is used. Many dipsticks are not intended to be submerged in the emulsion, but instead, are inserted into the top of the tank only until the tip of the dipstick touches the surface of the emulsion. 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 emulsion and shoot a minimum of 3000 feet by 12 feet of emulsion 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 dip stick reading. Record this reading as 'ending volume'. Subtract 'ending volume' from 'beginning volume' and record this as 'volume used'. Determine the area of emulsion sprayed. Divide 'volume used' by the area sprayed in square yards. This is the gallons per square yard 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.

An example of this calibration is presented below:

Given:

1800-gal capacity asphalt distributor

12-ft wide spray width

Trial spray distance = 3630 ft

0.32 gal/yd^2 design spray rate

Dipstick reading beginning of shot = 1765 gal

Dipstick reading end of shot = 265 gal

Calculations:

1. *Check to see if enough volume shot. 1765 – 265=1500 gal*
2. *1500/1765 = 85 percent >70 percent and <90 percent. OK, enough applied to be valid*

3. Calculate spray rate = 1500 gal / (12 × 3630/3) = 0.31 gal/yd^2

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

406.5.2.2. *Aggregate Chip Spreader*

406.5.2.2.1. *Transverse Spread Rate*

Commentary

Various methods of calibrating this equipment have been used and the ASTM D5624 procedure can be effective. However, 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 uniform 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 chips indicates variation in application rate. More light means a lack of chips. 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 chips being deposited, ASTM D5624 is a good procedure to use.

406.5.2.2.2. *Longitudinal Spread Rate*

Commentary

Once the transverse spread rate is adjusted the longitudinal rate can be adjusted. This is also done visually, at first. Begin spreading chips into the fresh emulsion when a few chips cast by hand stick to the emulsion and do not roll over. This shall be done well before the emulsion begins to 'break' or 'set', but not immediately after spraying unless temperature, wind, or high demulsibility demand it.

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 emulsion 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. Emulsion should be visible between the chips upon dropping the chips and before rolling. If all emulsion 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.

Evaluating the quantity of chips 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 chip spreader before and after applying the chips and calculating the spread rate based on the area covered. This is often not practical. Therefore, a suitable alternative includes estimating the quantity of chips spread over a known area by knowing the weight of each transport truck supplying the spreader and dividing the estimated weight of chips spread by the area covered for that load.

An example follows:

Given:

Trucks loading the chip spreader are 12-ton capacity tandem dumps

12-ft wide pavement

28 lb/yd^2 design spread rate

Calculations:

1. Check Truck No. 1

a. Load = 23,803 lb

b. Spreader distance = 213 ft

*c. Rate = 23,803 / 213 **x** 12 / 3 = 27.9 lb/yd^2*

2. Check Truck No. 2

a. Load = 23,921 lb

b. Spreader distance = 211 ft

c. Rate = 23,921 / 211 × 12 / 3 = 28.3 lb/yd^2

3. Check Truck No. 3

a. Load = 23,848 lb

b. Spreader distance = 213 ft

c. Rate = 23,848 / 213 × 12 / 3 = 28.0 lb/yd^2

4. Average Rate = (27.9 + 28.3 + 28.0) / 3 = 28.1 lb/yd^2

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

Compensation for moisture on chips must be considered when calibrating chip spreaders. The above example indicates no adjustment is needed since the measured spread rate is within 0.10 lb/yd^2 of the design spread rate. However, if the chips above had contained as much as 1.02 percent moisture that was unaccounted for, the application rate would have been too low.

406.5.3. *Preconstruction Meeting*—Coordinate a preconstruction meeting prior to construction with the engineer to discuss the following topics:

- construction process
- quality control plan, required to be submitted
- mix design, required to be submitted
- materials control
- materials measurement
- equipment calibration, required to be submitted
- traffic control plan
- equipment/process overview
- inspection
- test strip
- unique project conditions
- project documentation
- expectations

406.5.4. *Road Surface Preparations*

406.5.4.1. *Cleaning Pavement*—Clean the roadway surface by sweeping no more than 30 minutes prior to application of the asphalt emulsion and chips. However, this 30-minute 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 broom with a hand broom. Clean the outer edges of the pavement to be sealed including an adjacent paved shoulder.

406.5.4.2. *Protecting Accessories*—Cover utility castings (manholes, gate valve covers, catch basins, sensors, etc.) 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.

406.5.4.3. *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.

406.5.5. *Application*

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

- Ambient and pavement surface temperatures shall be 50°F and rising.
- Application of the chip seal shall be only during daylight hours.
- Suspend chip sealing if the pavement surface temperature exceeds 140°F.
- The road surface shall be dry to damp.

406.5.5.2. *Test Strip*—A test strip shall be constructed 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 300 feet 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.

406.5.5.3. *Application of Emulsified Asphalt*

Apply the asphalt emulsion 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.

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

Commentary

If the temperature is lower than 120°F, 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 at the outside edge of shoulder. There shall be no overlap of the longitudinal construction joint for a single application chip seal.

406.5.5.4. *Application of Cover Aggregate*—Provide uniformly moistened aggregates, which are damp at the time of placement. Damp chips 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 mat or satin finish, using a painting analogy, and not glossy. A damp chip draws emulsion into the pores of the chip thus providing better adhesion once the emulsion has set.

Immediately (within 1 min) after the emulsified asphalt has been sprayed, apply the aggregates. 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 chip application rate, adjustments are almost always needed in the field. This should be done during the first day of construction to make sure the chip quantity is correct. This is best done by observing the appearance of the chips

after they have been dropped into the emulsion, but before rolling. Some emulsion should be visible between many of the chips. If emulsion cannot be seen between the chips, the chip rate is too high. Conversely, too much emulsion showing through between the chips will cause pickup on rubber tires.

406.5.5.5. *Transverse Paper Joints*—When beginning a new application of the chip seal transversely abutting the previously placed chip seal a transverse paper joint shall be used so excess asphalt and chips are not placed at the joint. The transverse paper joint shall be formed by placing 36-in. 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 asphalt emulsion by starting the application on top of the Kraft paper. After the 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 emulsion and chip quantity at the joint. The placement of the paper is calculated based on the emulsion shot rate and the quantity of emulsion in the distributor. The distance the 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 emulsion applied than desired at the end of the shot.

406.5.5.6. *Rolling Operations*—Complete the first roller pass as soon as possible but not longer than two minutes after applying the aggregate. Proceed in a longitudinal direction at a speed less than or equal to 3 mph. 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 emulsion 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.

406.5.5.7. *Sweeping*

Excess chips shall be swept off the new surface in accordance with Table 1.

Table 1—Sweeping Sequence

Chip Seal Class[a]		
I	II	II
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 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 asphalt emulsion. Moisture content shall be determined by the procedure reported in *NCHRP Report 680* (Shuler et al., 2011). Re-sweep 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 within tolerances.

406.5.5.8. *Traffic Control*

Traffic may be allowed onto the fresh chip seal after rolling is completed and before sweeping in accordance with Table 2.

Table 2—Timing for Traffic

Chip Seal Class[a]		
I	II	II
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.

406.5.5.9. *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.

406.5.5.10. *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 hours after final rolling. Refer to the AASHTO Construction Guide Specification for Fog Seals in the section for application over chip seals for specific requirements.

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 emulsion from being absorbed into the substrate unevenly.

406.5.5.11. *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 chips 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.

The permanent pavement markings shall not be placed for three days after placing the fog seal, if used, for water borne pavement marking or ten days for other types.

Commentary

The chip seal will usually cure within 24 h under dry conditions and temperatures above 60°F. 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. Interim pavement markings can be placed after the fog seal cures.

406.5.6. *Quality Control*

406.5.6.1. *General*

The Contractor is responsible for quality control (QC) sampling and testing and shall submit a QC plan including materials and procedures for verifying the quality of the chip seal aggregates and emulsified asphalt(s). The Contractor's QC plan shall include but is not limited to sampling, testing, inspection, monitoring, documentation, and corrective action procedures during transport, stockpiling, and placement operations.

A written Quality Control Plan (QCP) shall be developed that details the Contractor's QC program that meets the requirements of these specifications. The QCP shall be contract-specific and signed by the Contractor's representative. Chip seal construction shall not proceed without Agency approval of the QCP and QC personnel present on the project. Failure to comply with these provisions will result in shutdown of the operations until such time as the Contractor's operations are in compliance.

406.5.6.2. *Personnel*—The QC staff shall include the following as a minimum:

a) *QCP Administrator*—Person with overall responsibility for the QCP.

b) *QCP Manager*—Person responsible for the execution of the QCP and liaison with the Agency. This person shall be on the project and have the authority to stop or suspend construction operations.

c) *QC Technicians*—Person(s) responsible for conducting QC tests and inspection to implement the QCP. QC technicians shall have Level 2 Aggregate Testing Certification from the American Concrete Institute (ACI) or other accrediting body approved by the Agency.

d) *Certified Crew Members*—Three crew members (job foreman, aggregate spreader operator, and asphalt distributor operator), at a minimum, shall possess a valid chip seal certification and be on the project at all times the chip seal is being constructed. Chip seal certification is administered by the National Center for Pavement Preservation (NCPP) on behalf of AASHTO TSP2 (Transportation Services Preservation Program).

406.5.6.3. *Testing Facilities and Equipment*—The Contractor shall provide the name of the laboratory conducting QC tests. The laboratory shall maintain accreditation by the AASHTO Accreditation Program (AAP) for all tests within the relevant scope of testing, or other accrediting body approved by the agency. Sampling, testing, and measuring devices shall meet the requirements of the specified standards and test methods. The laboratory shall maintain records of the calibration and maintenance of all sampling, testing, and measuring equipment.

406.5.6.4. *Materials Testing*—Chip seal aggregates and asphalt emulsion shall be tested for compliance with the specifications as follows:

406.5.6.4.1. *Chip Seal Aggregate*

406.5.6.4.1.1. *Stockpile*—Test the aggregate gradation a minimum of once per day, or every 1500 tons, whichever is less in accordance with T 27 to determine compliance with Table 1 requirements. If the material is hauled from the production site to a temporary stockpile, test at the temporary stockpile.

406.5.6.4.1.2. *Construction*—Test the aggregate gradation from the hopper of the chip spreader a minimum of once per day, or every 1500 tons, whichever is greater in accordance with T 27 to determine compliance with Table 1 requirements. The testing rate for quality values in Table 2 shall be once per source.

406.5.6.4.2. *Emulsified Asphalt*

Only emulsified asphalt from certified or approved sources is allowed for use. Verify the emulsion(s) meet the specifications by obtaining certificates of compliance from the supplier.

Verify the application rate of the emulsified asphalt by dividing the volume of emulsified asphalt used by the area chip sealed each day. Allowable variation is ±5 percent of the application rate adjusted from the design quantity. Provide material certification and quality control test results for each batch of emulsified asphalt used on the project. Include the supplier name, plant location, emulsion grade, and batch number on all reports.

406.5.6.5. *Calibration of Equipment and Workmanship*—Describe the equipment and methods used to calibrate the chip spreader and asphalt distributor and workmanship items including:

- Longitudinal application rates
- Transverse application rates
- Asphalt transverse application uniformity
- Transverse joint construction technique
- Monitoring method for application rates
- Rolling operations detailing the roller pattern and number of passes and coverages
- Sweeping operations and schedule
- Method of controlling traffic

406.5.6.6. *Documentation and Records*

Describe the documentation and reporting procedures for all QC activities. Include samples of all QC test forms, inspection reports, and test reports.

The Contractor shall maintain complete records of all QC tests and inspections.

All QC test results shall be submitted to the Agency at the end of the contract. A material certification shall be submitted from each supplier for each batch of material delivered to the project, including test results.

The QC records shall contain all test and inspection reports, forms and checklists, equipment calibrations, supplier material certificates, and non-conformance and corrective action reports. The QC records shall indicate the nature and number of observations made, the number and type of deficiencies found, the quantities conforming and non-conforming, and the nature of corrective action taken as appropriate for materials as well as workmanship. The QC records shall be available to the Agency at all times and shall be retained by the contractor for the life of the contract. The Contractor's documentation procedures will be subject to approval by the Agency prior to the start of work, and to compliance checks by the Agency during the progress of the work.

406.5.6.7. *Compliance with Specifications*—The Contractor shall attest in writing to the Agency that the chip seal has been constructed in accordance with and meets the requirements of the specifications at the conclusion of the project.

406.5.7. *Agency Acceptance*

406.5.7.1. *General*—The Agency will conduct acceptance sampling, testing, and inspection activities to ensure material quality, correct application rates, rolling, sweeping, and traffic control are within specification requirements. These activities will be done randomly by the Agency.

406.5.7.2. *Acceptance Activities*

406.5.7.3. *Materials Testing*

406.5.7.3.1. *Aggregate*—Sample aggregate taken from the chip spreader hopper once per day. Samples will be stored and tested for gradation at the discretion of the Agency. If the results vary from the requirements of Tables 1 and 2, a price reduction will be applied per the Schedule of Price Reduction prepared by the owner agency.

406.5.7.3.2. *Emulsified Asphalt*—Sample the first shipment and provide one sample for every 50,000 gal (approximately 200 tons) thereafter. Testing of emulsions shall be in accordance with M 140, M 208, or M 316.

406.5.7.4. *Equipment*—All equipment to be used on the project shall be evaluated by the Agency to assure it is in acceptable operating condition, calibrated correctly and will provide the quantities of material specified.

406.5.7.5. *Final Inspection*—A final inspection will be done to assure that no bleeding or flushing, excessive chip loss or crushed aggregate has occurred. Longitudinal and transverse joints will be inspected to assure that no excessive overlap has occurred.

406.6. MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.01 of the *AASHTO Construction Guide Specifications* and as follows:

406.6.1. *Emulsified Asphalt*—Measure the emulsified asphalt for chip seal by volume, at 60°F.

406.6.2. *Aggregate Chips*—Aggregate chips will be measured based on the area of pavement surfaced.

Commentary

Chips can be paid for by the ton, as well. This is easier to verify but results in an incentive to place more chips than necessary. Applying too many chips is poor practice and results in dislodgement of embedded chips.

406.7. PAYMENT

Payment for chip seals can be done by either paying for the materials in unit costs, or for the completed chip seal by area of pavement sealed.

Commentary

The advantage of payment by the square yard for a completed chip seal is simplicity if the area is easily defined. The disadvantage is that an incentive is created to reduce material quantities. Reduced asphalt emulsion quantities can lead to chip loss and vehicle damage.

406.7.1. *Payment by Unit Price*—The Agency will pay for accepted quantities at the contract price as follows:

1. Payment for the accepted quantity of emulsified asphalt and aggregate for chip seal (including any required additives) at the contract bid price of measure is compensation in full for all costs of furnishing and applying the material as specified.
2. Payment will be made in accordance with the schedule set forth below at the Contract bid price for the specified unit of measure.

Item No.	Item	Unit
State ##	Emulsified asphalt for chip seal	gal
State ##	Aggregate for chip seal	tons
State ##	Diluted emulsion for fog seal, if used	gal

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

406.7.2. *Payment for Completed Chip Seal*

406.7.2.1. Payment for the accepted quantity of the chip seal at the Contract bid unit price of measure is compensation in full for all costs of furnishing and applying the material as specified, including cleaning the existing pavement, stationing, purchase of aggregate, delivery of aggregate, all labor, equipment, and materials necessary for the placement of the chip seal for full lane coverage, sweeping of any loose aggregate after construction and other requirements as specified.

406.7.2.2. Payment will be made in accordance with the schedule set forth below at the Contract bid price for the specified unit of measure.

Item No.	Item	Unit
State ##	Chip seal	yd^2
State ##	Diluted emulsion for fog seal, if used	gal

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