Section 4XX

Construction Guide Specification for Sand Seals

4XX.1 DESCRIPTION

This guide specification is intended to provide information needed for owners or contractors to construct sand seals. A sand seal is the application of emulsified asphalt followed immediately by an application of a single layer of fine graded cover aggregate. The sand seal may be applied in multiple lifts depending on traffic demands and existing road surface conditions.

This guide specification refers to materials, construction, measurement, warranty, and payment used to construct sand seals. However, the main purpose is to provide guidance for the construction of a sand seal applied in one layer. For multi-layer application of sand seals, the road should remain open to traffic for 4 to 8 weeks between successive applications.

All units of measurement are expressed in US Customary units and Standard International (SI) units. Note that conversions are provided where appropriate.

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 sand seals. A sand seal is a pavement preservation treatment used to extend the life of a structurally sound low volume road with low to medium severity distresses such as bleeding, raveling, polished aggregates, and friction loss.

4XX.2 REFERENCED DOCUMENTS

4XX.2.1 AASHTO Standards

- M 140, Emulsified Asphalt
- M 208, Cationic Emulsified Asphalt
- M 344, Materials for Sand Seals
- R 106, Sand Seal Design
- T 11, Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 176, Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
- AASHTO Guide Specifications for Highway Construction, 10th Edition, 2020

4XX.2.2 ASTM Standards

- D 5624-13, Standard Practice for Determining the Transverse-Aggregate Spread Rate for Surface Treatment Applications

4XX.2.3 Other Documents

- The Asphalt Institute Manual Series 19, “A Basic Asphalt Emulsion Manual”, 4th Edition.

4XX.3 TERMINOLOGY

4XX.3.1 *rapid-setting type emulsified asphalt*—any emulsified asphalt containing the CRS, CHFRS, HFRS, or RS designation as referenced in M 140 or M 208.

4XX.3.2 *medium-setting type emulsified asphalt*—any emulsified asphalt containing the MS or HFMS designation as referenced in M 140.

4XX.3.3 *cationic slow-setting*—any emulsified asphalt containing the CSS-1 or CSS-1h designation as reference in M 208.

4XX.4 MATERIALS

Commentary

Users should reference M 344 when considering materials for sand seals. However, additional information is provided here beyond the information in M 344.

4XX.4.1 *Emulsified Asphalt* – emulsified asphalt for sand seals shall meet the requirements of rapid-setting, medium-setting, or cationic slow-setting type emulsified asphalt in M 140 or M 208.

Commentary

The hardness of the emulsified asphalt residue is determined by the owner agency utilizing regional climatic and traffic conditions. The proper emulsion should be determined by running compatibility tests between the emulsion and the aggregate to be used.

4XX.4.2 *Aggregate* – sand seal aggregate shall consist of fine granular material, composed of hard, durable particles, uniform in quality, and free from deleterious materials. Gradations are specified in Table 1 as three aggregate sizes: No. 8, No. 4, and 3/8 in. The sand equivalent test results shall be minimum 45 for all aggregate types (AASHTO M 344, 2022). The aggregate type and detailed gradation to be used will be as specified by the Owner Agency.

Table 1—Sand Seal Aggregate Types (AASHTO M 344, 2022)

Sieve Size (see T 11 or T 27)	Passing, %		
	Type I	Type II	Type III
3/8 in.	100	100	100
No. 4	100	90–100	70–90
No. 8	90–100	65–90	45–70
No. 16	65–90	45–70	28–50
No. 30	40–65	30–50	19–34
No. 50	25–42	18–30	12–25
No. 100	15–30	10–21	7–18
No. 200	10–20	5–15	5–15
Sand Equivalent Test	45 minimum for all aggregate types		

Note: Stockpile tolerances may be set by the Owner Agency.

4XX.5 CONSTRUCTION

4XX.5.1 *Weather limitations* —Construct sand seals per the following conditions:

- Ambient or pavement surface temperatures shall be 50°F (10°C) and rising.
- Seal shall not be applied if temperatures below 32°F (0°C) are anticipated in the 14 days following application
- The road surface shall be dry or moist, there shall be no standing water.
- Suspend sand seal operations when rain is expected.
- Sustained winds are less than or equal to 20 mph (32.2 kmph).
- Daylight application

Commentary

Emulsified asphalt requires exposure to daylight and a warm temperature range to undergo the processes of breaking and curing effectively. These conditions are crucial for the emulsion to transition from a liquid state to a solid form, ensuring optimal performance and longevity of the applied material.

4XX.5.2 *Preconstruction meeting*—Coordinate a preconstruction meeting prior to construction with the project manager, project engineer, inspector, material tester, representatives of prime contractor, each sub-contractor, material suppliers, and others as necessary to discuss the following topics:

- Sand seal design
- Construction process
- Materials control, sampling, and measurement
- Equipment calibration, required to be submitted
- Traffic control plan
- Stockpiling, staging area
- Project inspection
- Project documentation
- Test strip and staging area
- Temporary and permanent pavement markings
- Unique project conditions
- Expectations
- Safety procedures
- Schedule
- Public notification
- Payment
- Quality assurance plan (including quality control, quality acceptance, and independent assurance)

Commentary

The meeting can include Just-In-Time training (JITT) among the Agency, Contractor, inspectors, and other stakeholders prior to the construction.

4XX.5.3 *Road Surface Preparations*

4XX.5.3.1 *Preparing pavement*— All incompressible materials shall be removed from joints/cracks greater than 1.5 in (38.1 mm) wide; all cracks greater than 0.5 in (12.7 mm) should be sealed. Allow crack sealant material to cure for a minimum of 30 days on pavement surfaces that have been crack sealed before application of the sand seal. Waive this requirement if a compatible crack sealant is used that does not require a cure time. In addition, ensure that all patches are flush with clean edges and the entire pavement section is structurally sound and no patch is less than 30 days old.

4XX.5.3.2 *Stripe removal*— Pavement raised markers and thermoplastic pavement marking shall be removed by grinding or other approved methods prior to sand seal applications. Other pavement marking paint may be left in place.

4XX.5.3.3 *Cleaning pavement*—Clean the roadway surface by sweeping unless it is an application of the sand seal on base materials. 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.

4XX.5.3.4 *Protecting accessories*—Cover utility castings (manholes, gate valve covers, catch basins, traffic sensors, etc.) to prevent coating with sand seals. Suitable coverings include plastic sheet, Kraft paper, roofing felt, or other approved methods. Remove the protective coverings after placing the sand seal before opening the road to traffic.

4XX.5.4 *Equipment*

4XX.5.4.1 *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 overlapping application fan spray, and the shutoff shall be instantaneous, with no dripping. All nozzles, except two edge ones, shall be oriented at the same angle between 15 and 30 degrees using the wrench supplied by the distributor manufacturer. Each 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, acceptable results have been obtained with double overlap.

4XX.5.4.2 *Aggregate Spreader*—A self-propelled mechanical type aggregate spreader or a truck mounted sand spreader with a computerized spread control, capable of distributing the aggregate uniformly to the required width and at the designed rate shall be used.

Commentary

The aggregate spreader could be a chip spreader or a truck mounted sand spreader. A dump truck may not provide uniform distribution of sands to the required width and at the designed rate.

4XX.5.4.3 *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 shall be used to remove loose aggregate after rolling.

4XX.5.4.4 *Hauling equipment* —For hauling emulsified asphalt, load emulsified asphalt into a clean trailer or a trailer that last transported compatible emulsified asphalt. Do not mix anionic and cationic emulsified asphalt. Do not store emulsified asphalt in the trailer and minimize the pumping of the emulsified asphalt.

4XX.5.4.5 *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 7.3 Mg) to achieve a minimum contact pressure of 80 lb/in.^{2} (552 kPa) shall be used. 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. The minimum width of the rollers shall be 60 in (1.524 m).

4XX.5.4.6 *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.

4XX.5.5 *Equipment calibration*

The contractor shall provide proof of calibration of the asphalt distributor and the aggregate spreader. Calibration shall be conducted no earlier than 30 days prior to sand seal operations. The contractor shall submit the results of the calibration to the Engineer.

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 being applied.

4XX.5.5.1 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 adhesive layer necessary for proper aggregate 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.

4XX.5.5.1.1 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 manufacturer's 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

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.

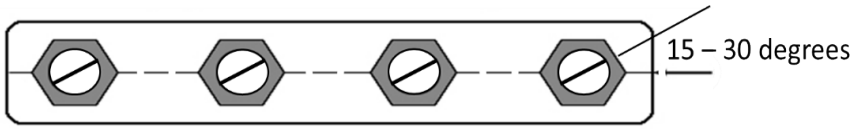

Figure 1—Spray Bar Nozzle Orientation in Spray Bar

4XX.5.5.1.2 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 2 and 3.

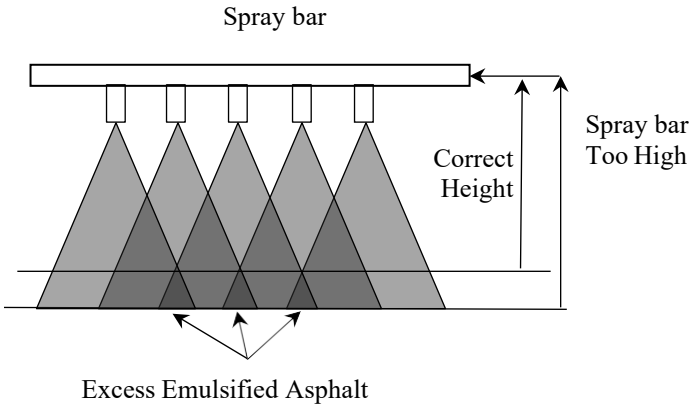

Figure 2—Streaks with Spray Bar Too High for Double Overlap

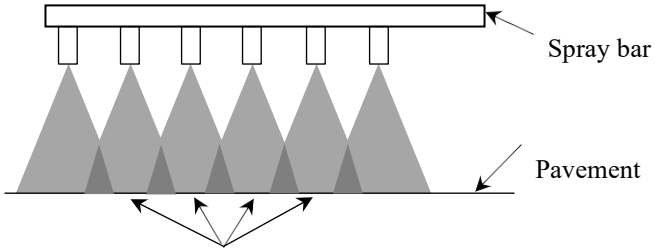

Figure 3—Streaks with Spray Bar Too Low for Double Overlap

To avoid potential improper bonding, 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.

4XX.5.5.1.2.1 Bar height adjustment to achieve double overlap

Every other nozzle shall be turned off when a double overlap application is desired as shown in Figure 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 can be turned back on and a double application of emulsified asphalt or hot applied asphalt binder will result when spraying resumes.

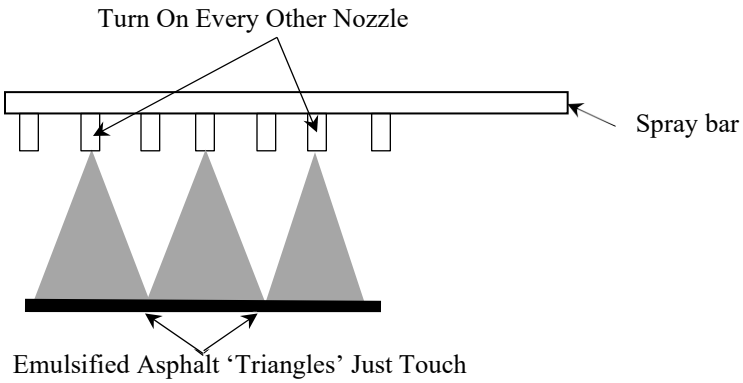

Figure 4—Adjustment of Spray Bar Height for Double Overlap

4XX.5.5.1.2.2 *Triple overlap application bar height adjustment*

Every third nozzle shall be turned off when a triple overlap application is desired as shown in Figure 5. The distributor operator shall spray emulsified asphalt onto the pavement surface for as short an interval as possible while an observer watches where it 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 that bar height is correct, the nozzles that were turned off can be turned back on and a triple application of emulsified asphalt will result when spraying resumes.

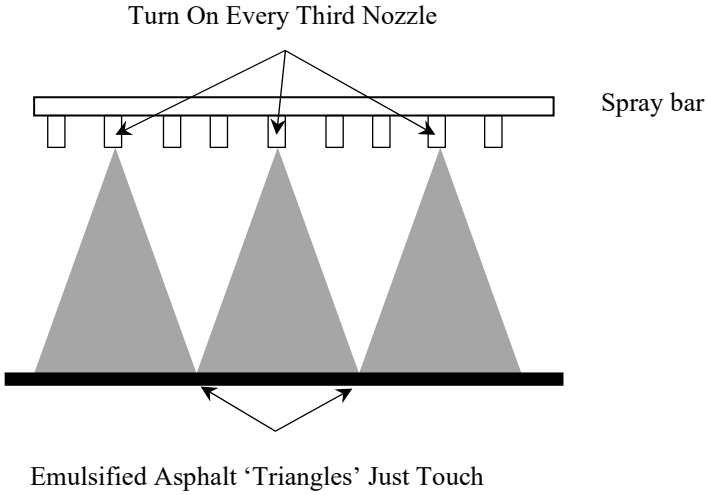

Figure 5—Adjustment of Spray Bar Height for Triple Overlap

4XX.5.5.1.3 *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

The flow rate of a nozzle can be estimated 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 sand seal operations begin.

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. (15.2 cm) by 12-in. (30.4 cm) concrete cylinder molds lined with 1-gal (4.5 L) zip-lock freezer bags. The cylinder molds can be reused, and the zip-lock bags discarded appropriately with the contents.

4XX.5.5.1.4 Longitudinal flow rate

The longitudinal spray rate shall be accomplished by measuring the volume of emulsified asphalt in the tank before and after spraying enough emulsified asphalt to reduce the volume of liquid in the tank 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 tank 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. NOTE – carefully follow all safety protocol when taking a dipstick reading for either emulsified asphalt.

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 distributor to shoot emulsified asphalt and shoot a minimum of 3000 ft (914 m) by 12 ft (3.66 m) of emulsified asphalt at the design rate using the gallon per minute pump flow volume and distributor 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 emulsified asphalt 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 = 4500 ft

0.25 gal/yd^2 design spray rate

Dipstick reading beginning of shot = 1765 gal

Dipstick reading end of shot = 265 gal

NOTE: 1 gal = 3.785 L, 1 ft = 0.30 m, 1 gal/yd^2 = 4.53 L/m^2

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 × 4500/9) = 0.25 gal/yd^2*

Therefore, distributor is set up correctly.

4XX.5.5.2 Aggregate Spreader

4XX.5.5.2.1 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, Standard Practice for Determining the Transverse-Aggregate Spread Rate for Surface Treatment Applications, procedure can be effective.

Commentary

A visual assessment of the lateral distribution of aggregates is a good place to start the process since non-uniform distribution can easily be seen. The veil of aggregates 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 aggregates is falling out of the spreader box. However, viewing from either front sides 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.

4XX.5.5.2.2 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 includes 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 aggregates spread by the area covered for that load.

An example is shown as follows:

Given:

Trucks loading the aggregate spreader are 12-ton capacity tandem dumps12-ft wide pavement

15 lb/yd^2 design spread rate

Calculations:

1. *Check Truck No. 1*
   a. *Load = 23,803 lb*
   b. *Spreader distance = 1200 ft*
   c. *Rate = 23,803/(1200x12/9) = 14.9 lb/yd²*
2. *Check Truck No. 2*
   a. *Load = 23,921 lb*
   b. *Spreader distance = 1205 ft*
   c. *Rate = 23,921/(1205 × 12/9) = 14.9 lb/yd²*
3. *Check Truck No. 3*
   a. *Load = 23,848 lb*
   b. *Spreader distance = 1180 ft*
   c. *Rate = 23,848/(1180 × 12/9) = 15.2 lb/yd²*
4. *Average Rate = (14.9 + 14.9 + 15.2) / 3 = 15 lb/yd²*
5. *No adjustment needed since measured rate is within 1 percent of design.*

Commentary

Note: This example uses US Customary units. For SI units, use 1 ft = 0.305 m, 1 yd = 0.914 m, 1 lb = 0.454 kg, 1 lb/yd² = 0.542 kg/m², and 1 ton = 0.907 Mg.

Compensation for moisture on the aggregates 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 1.5 percent moisture that was unaccounted for, the application rate would have been too low.

4XX.5.6 *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 500 feet (150 m) in length and shall be constructed with the design application rates, materials, and equipment to be used on the project.

4XX.5.6.1 *Verify on application rates*

The general application rate for emulsified asphalt shall be between 0.20 gal/yd² (0.91 L/m²) to 0.30 gal/yd² (1.36 L/m²). A summary of recommended emulsified asphalt application rate adjustments is shown in Table 2. Cover aggregate shall be spread in the range of 12 lb/yd² (6.51 kg/m²) to 25 lb/yd² (13.6 kg/m²). The actual rates used for a specific pavement shall be determined using a test strip.

Table 2—Emulsified Asphalt Application Rate Adjustment for Substrate Surface Condition (AASHTO R106, 2022)

Existing Surface Condition	Correction Factor, gal/yd² (L/m²)
Flushed-bleeding	–0.06 (0.19)
Smooth, non-porous	–0.03 (0.09)
Slightly porous, slightly oxidized	0.00
Slightly pocked, porous, oxidized	+0.03 (0.09)
Badly pocked, porous, oxidized	+0.06 (0.19)

Commentary

Proper application rates for emulsified asphalt and aggregate applications are crucial to ensure the longevity and durability of sand seals. Rates must fall within specified ranges to prevent issues such as bleeding or raveling of aggregates. Rates can be verified using the methods mentioned in 4XX.5.5.1 and 4XX.5.5.2.

4XX.5.6.2 *Verify equipment and workmanship*

Contractor shall provide documentation that equipment has been calibrated in the current construction season. All equipment shall be checked during the test strip construction. Adequate workmanship shall be provided by the construction crew for the sand seal construction, which includes adequate and proper surface preparation, sand seal application, rolling, and sweeping.

4XX.5.7 *Traffic Control*— Traffic may be allowed onto the fresh sand seal after rolling is completed and before sweeping. A pilot car shall be used on two-lane roadways during construction. Barricades, signage, and traffic control shall follow the current Manual on Uniform Traffic Control Devices (MUTCD) standards.

4XX.5.8 *Application of emulsified asphalt*

Apply the emulsified asphalt at the rate determined by the test strip within ±5 percent. The temperature of the emulsified asphalt at the time of application shall be above 120°F (48.9°C).

Commentary

If the temperature of the emulsified asphalt is lower than 120°F (48.9°C), there is risk of less material being applied than desired due to high viscosity.

4XX.5.8.1 *Guide on field adjustment of emulsified asphalt*

Although the emulsified asphalt application rate is determined by the tests strip, roads can change over the length of a job. Therefore, there may be a need to slightly increase the application rate when traveling along older, more aged pavement than the test strip, or decrease the amount of emulsified asphalt when traveling along bleeding surfaces as shown in Table 2. This emphasizes the need for examining any unique project conditions during the preconstruction meeting, to be aware of these sections before the start of work.

4XX.5.9 *Application of Cover Aggregate*—Provide uniformly moistened aggregates, which are damp at the time of placement. Damp aggregates shall be saturated but surface dry with approximate moisturecontent between 1 and 3 percent depending on the aggregate absorption capacity. The aggregate spreader shall follow closely behind the emulsion distributor.

Commentary

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

4XX.5.9.1 *Guide on field adjustment of covering aggregates*

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 aggregates, but not so much that aggregates adhere to the pneumatic rollers. Not having enough cover sand will cause pickup on rubber tires.

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.

4XX.5.10 *Workmanship*

When placing a sand seal, the longitudinal and transverse joints shall be uniform, neat in appearance, and shall not contain material build-up or uncovered areas. Longitudinal joints shall be placed on lane lines, edge lines, or shoulder lines and shall have a maximum overlap of 2 in. (75

mm). Joints are acceptable if there is no more than 0.25 in (6.5 mm). Longitudinal joints shall be straight in appearance along the centerline, lane lines, shoulder lines, and edge lines. All transverse joints shall be clean and straight. At the start of each day(s) of production and at approaches, place a 5 ft. (1.5 m) minimum width of paper/plastic on the existing pavement. Cover all bridge ends with paper/plastic to ensure no sand seal is placed on the bridge. Remove the paper/plastic once the sand seal has cured and properly dispose of the excess material from the project site. Place and spread all courses as continuously as possible, keeping the number of construction transverse joints to a minimum. Once the end of the mat and a straight line is created, the distributor truck or aggregate spreader truck shall be lifted, and the remaining material shall be removed and properly disposed of from the project site.

Longitudinal lines at shoulders shall be straight to provide a good appearance. Longitudinal edge lines shall not vary by more than ±2 in. (50.8 mm) in 100 linear ft (30.5 m). If the contractor is unable to meet this requirement, they shall be required to establish a pilot line.

The finished surface shall have a uniform texture free from excessive surface defects, for example, 0.25 in. (6.35 mm) gap for longitudinal joints, and no more than 0.25 in. (6.35 mm) gap for a transverse joint between the pavement surface when placing a 10-ft (3.05 m) straightedge perpendicular to the joint. If these criteria are exceeded, the contractor shall stop work and correct them.

4XX.5.11 *Longitudinal joints* – Create the longitudinal joint in the sand seal along the centerline of two-lane highways or at the lane lines of roadways with more than two lanes.

Longitudinal joints shall be straight on tangent sections and uniformly follow the traffic lane on curve sections. Longitudinal joints shall be smooth, particularly on roadways with high-speed traffic.

4XX.5.12 *Transverse construction joints* – When beginning a new application of the sand seal transversely abutting the previously placed sand seal a transverse paper joint shall be used so excess emulsified asphalt is not placed at the joint. The transverse paper joint shall be formed by placing 36-in. (91.4 cm) wide Kraft paper on top of the previously applied sand seal so the edge of the paper aligns with the joint that will be formed when the previously placed sand seal meets the newly applied sand 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 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.

4XX.5.13 *Sweeping*

Excess aggregate shall be swept off the new surface if specified. 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.

Commentary

Do not sweep embedded aggregate until at least 85 percent of the total moisture present in the sand seal has evaporated or aggregates may become dislodged. Moisture present consists of

moisture in the aggregates and moisture present in the emulsified asphalt.

Sweeping may not be specified if a sand seal is applied on low speed and low volume road (less than 500 vehicles per day)

The aggregate sweeping rate can be determined by the amount of sand removed from the surface area during the sweeping process. For pickup sweeper or vacuum sweeper trucks, the amount of aggregates can be obtained through their hoppers. For rotary sweepers, the excess aggregates are swept to the roadside, which can be collected and weighted. To calculate this rate, one must consider the total amount of sand removed and divide it by the overall area that was swept. Additionally, to obtain the percentage of excess aggregates, the aggregate application rate should be divided by the aggregate sweeping rate.

4XX.5.14 *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 (4.8 km/h). Three complete roller passes of the aggregates 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

The rolling operation for sand seal is intended to fulfil two objectives. First, the aggregate should become embedded into the asphalt emulsion. Second, there should be enough excess aggregate to provide a traveling surface where the asphalt emulsion is not picked up onto tires and the sand provides friction. For the coarser aggregate gradations, sand seal rolling approaches more of a chip seal behavior, but embedment is not considered during rolling regardless of the aggregate gradation.

4XX.5.15 *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 sand seal and placement of temporary pavement markings.

4XX.5.16 *Sequence of work*

Construct the sand 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 sand 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 sand seal.

4XX.5.17 *Project documentation*

The contractor shall supply daily documentation to the Agency that includes the following:

- Aggregate used, tons (Mg) in dry condition
- Emulsified asphalt used, gallons (L)
- Surface area completed, square yards (square meter)
- Surface area application rates of emulsified asphalt, aggregates

4XX.5.18 *Quality assurance*

Referred to sand seal quality assurance guide developed during NCHRP 14-48.

4XX.6 MEASUREMENT

The Engineer will measure the acceptably completed sand seals as specified in the "AASHTO Guide Specifications for Highway Construction" (2020) or as specified in Sections 4XX.6.1, 4XX.6.2 and 4XX.6.3.

4XX.6.1 *Emulsified asphalt* —Measure the undiluted emulsified asphalt by volume, gal (L), at 60°F (15.6°C).

4XX.6.2 *Aggregate* — Aggregate will be measured based on the area of pavement surfaced, lb/yd^2 (kg/m^2).

4XX.6.3 *Area treated with sand seals* — Measure the total area treated with sand seal applications, yd^2(m^2).

4XX.7 Warranty

4XX.7.1 *Warranty*

When specified in the plans, or special provisions, warrant the sand seal product for the period specified such as one year or two years. The warrant process shall follow the Guide Specifications for Highway Construction, Appendix X1 – Generic Warranty. Perform any required remedial work to correct deficiencies identified in periodic evaluations and maintain the product during the warranty period. When specified, provide acceptable warranty bonds for the warranty period as specified in Subsection 1.2 of Appendix X1 (AASHTO, 2020).

Develop and obtain the Agency's approval of remedial action(s) for those parts of the warranted sand seal that do not meet specified standards of performance. Complete the approved remedial work, as specified in Subsection 1.3(D) of Appendix X1, at no additional cost to the Agency.

A Conflict Resolution Team will be formed to resolve any disagreements associated with the warranty work as specified in Subsection 1.6 of Appendix X1.

4XX.7.2 *Final Warranty Acceptance*

The Agency will evaluate the pavement performance within 30 days of the completion of the warranty term. Perform any required remedial work based on the results of the final survey in accordance with Subsection 1.3 (D) of the Appendix X1. The Agency will issue a final warranty acceptance letter or and equivalent certification and release final payment (retainage) upon verification that all required performance thresholds are met.

4XX.8 PAYMENT

Payment for sand seals will be made by either paying for the materials as unit costs, or for the completed sand seal by area of pavement sealed.

Commentary

The advantage of payment by the square yard for a completed sand seal is simplicity if the area is easily defined. The disadvantage is that an incentive is created to reduce material quantities. Reduced emulsified asphalt quantities can lead to aggregate loss. A good practice could be to pay the Contractor by the square yard for the aggregate to motivate them to use as frugal as possible and to pay emulsified asphalt by the gallon to encourage adequate emulsion application rates.

4XX.8.1 *Payment by unit price of materials*—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 sand seal 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 sand seal	gal (L)
State ##	Aggregate for sand seal	ton (Mg)

4XX.8.2 *Payment for completed sand seal*

Payment for the accepted quantity of the sand 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 materials, delivery of materials, all labor, equipment, and materials necessary for the placement of the sand seal for full pavement coverage, sweeping of any loose aggregate after construction and other requirements as specified. Either 4XX.8.2.1 or 4XX.8.2.2. can be selected to pay the Contractor.

4XX.8.2.1 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 ##	Sand seal	yd^2 (m^2)

4XX.8.2.2 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 ##	Sand	yd^2 (m^2)
State ##	Emulsified asphalt for sand seal	gal (L)

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