

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION CHIP SEAL COAT MANUAL



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JANUARY 2007

DISCLAIMER

Note: This manual provides a written account of how certain activities are performed and is designed to guide and assist staff in performing their functions. When appropriate, there may be deviations from these written procedures due to changes in personnel, policies, interpretation, law, experimentation with different systems, or simply evolution of the process itself. This manual may be changed at any time. Staff are encouraged to review this manual periodically and suggest changes in the manual to keep the manual current and to minimize differences between the manual and actual practices.

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CHIP SEAL COAT MANUAL

INTRODUCTION

This manual was developed to be used as an informational resource for constructing a quality seal coat project. If you are looking for individual project contract requirements please refer to the Plan Notes, Supplemental Specifications and Special Provisions.

A seal coat generally consists of a layer of asphalt binder that is covered by a single layer of embedded aggregate or “chips”. Seal coats are used as a preventative maintenance treatment to prolong the life of a pavement, correct surface raveling, prevent oxidation, provide skid resistance to worn pavements and seal the existing bituminous surface against the intrusion of air and water. The average life of a seal coat is about 7 years.

A seal coat adds little or no structural value to the existing pavement, but by preventing oxidation and the intrusion of water it enables the pavement to be preserved. Even though a seal coat adds little or no structural value it is not uncommon to apply a chip seal to a pavement that has structural distresses. A seal coat will often reduce the rate of deterioration until a future improvement is made.

MATERIALS

A. Asphalt

The type of asphalt to use for a seal coat is based upon the type of cover coat material available in the area, the amount of traffic on the highway to be sealed, and the condition of the existing pavement. NDDOT generally uses cutback asphalt or emulsified asphalt for a seal coat.

1. **Cutback Asphalts.** Cutback asphalts are manufactured by adding petroleum solvents to asphalt cements. The petroleum solvents are used to reduce the viscosity of the asphalt cement for lower application temperatures.

Application of the asphalt to the aggregate or pavement causes the solvent to escape by evaporation. The evaporation of the solvent causes the asphalt to "set".

Cutback asphalts do not obtain their ultimate adhesion properties until most of the solvent used to reduce the viscosity evaporates. During this curing period, the chips can be displaced under traffic. When using a cutback, traffic must be controlled and held to a reduced speed until most of the solvent is evaporated.

There are three types of cutback asphalts, rapid curing (RC), medium curing (MC), and slow curing (SC). When cutback asphalts are used, NDDOT will generally use an MC 3000 for sealing. Heating any asphalt cement can be hazardous. Heating cutback asphalt is more dangerous because cutbacks contain solvents that are used to reduce the viscosity. An RC uses naphtha (gasoline) as a solvent to reduce the viscosity and an MC uses kerosene as a solvent. Because of this, the RC's are no longer used by the Department because of safety concerns; they have low flash points and are extremely volatile. Extreme care must be taken when using cutback asphalt so a spark or flame does not come in contact with the cutback asphalt or even the gases from the cutback asphalt.

Cutback asphalts flow more readily than emulsified asphalts and are more likely to penetrate surface cracks. If the distributor does not apply the asphalt uniformly to the roadway surface, the cutback asphalt will flow together better than a high float emulsion will. This same property however will cause the oil to flow into the low areas of the pavement, like wheel ruts, leaving less oil on the high spots. This uneven distribution will result in poor chip embedment on the high spots, leading to chip loss, and bleeding through of the oil in the low spots.

When using cutback asphalt, dry or open pavement will absorb some of the asphalt intended for the seal coat. A higher application rate may be required on these pavements. When the existing pavement has areas that are rich in

asphalt the surplus asphalt in the existing mix may come up through and cause the new seal coat to be over asphalted. In this case a smaller application rate may be required.

It is also important to note that when using cutback asphalt the residual asphalt remaining after the asphalt has cured is much higher than when using an emulsion. Typically the residual asphalt in MC 3000 cutback asphalt is 80% whereas the residual asphalt in an emulsion is around 65%. Because of this a smaller application rate is required with cutback asphalt than would be with an emulsion.

MC 3000 cutback asphalt can be used with NDDOT's Class 42 or 43 aggregate (chips). The chips should be spread on the roadway immediately after shooting the asphalt. About 60-70% of the chip should be embedded in the asphalt. If the chips or roadway are wet the excessive moisture can hinder adhesion with cutback asphalt.

- 2. Emulsified asphalts.** Emulsified asphalts are manufactured by mixing asphalt cement, water, and an emulsifying agent. The asphalt cement is suspended in water by an electrical charge imparted by the emulsifying agent. There are two types of emulsified asphalts, anionic and cationic. If the emulsifying agent is anionic, the asphalt will have a negative charge. If the emulsifying agent is cationic, the asphalt will have a positive charge.

Aggregates have a positive, negative or mixed charge on the surface. The only way to know the charge of the aggregate you are using is to test it. Adhesion between the aggregate and the asphalt is best if using negatively charged asphalt with positively charged aggregate or vice versa.

There are a number of other factors that contribute to the adhesion of the asphalt to the aggregate. (1) Emulsions begin to break when the water is removed from the asphalt. The water can be removed by evaporation, pressure (rolling), or by absorption. In actual use, the breaking of the emulsion is usually a function of all three factors. As the water is removed

the asphalt begins to coalesce and form a continuous film of asphalt. The continuous film of asphalt is the residual asphalt that remains after the water is completely removed. The temperature of this residual asphalt is less than the maximum recommended spraying temperature of 160°F. Attempting to seat chips into cool asphalt can be accomplished, but it is not a best practice. **It is very important that the chips be spread on the emulsified asphalt and rolled prior to the asphalt breaking.** Waiting until the emulsion starts to break reduces the ability for the rollers to embed the aggregate into the asphalt and it increases the chance of chip loss when the roadway is opened to traffic, especially after snow plow operations begin. (2) Rolling the chips directly behind the spreader will facilitate chip embedment and help displace the water. (3) Another good practice when using an emulsion is to use damp (not wet) chips to reduce the absorption by the chips and give the asphalt more time to envelop the chips before the asphalt breaks. The adhesion of the asphalt to the chip depends on the water in the emulsion to allow the asphalt the time needed to envelop the chip. (4) Of equal concern is selecting the right emulsified asphalt based on the cleanliness and grading of the aggregate used.

Emulsified asphalts can be categorized into different classes based on electrical charge and curing time. Different types of emulsified asphalts used as seal oils are:

Anionic Rapid Set

Rapid Set(RS),

High Float Rapid Set(HFRS)

High Float Rapid Set Polymer Modified(HFRS-2P)

Anionic Medium Set

Medium Set(MS),

High Float Medium Set(HFMS)

High Float Medium Set Polymer Modified(HFMS-2P)

Cationic Rapid Set

Cationic Rapid Set(CRS),

Cationic Rapid Set Polymer Modified(CRS-2P)

Cationic Medium Set (CMS)

High Float Emulsions. One of the common emulsions used by the department for seal coats is the high float emulsion. The department started using high float medium set emulsions (HFMS-2) for seal coats years ago. At that time, the specification for the HFMS-2 was very close to the AASHTO recommended specification. This specification was developed as mixing grade asphalt. Mixing grade or Medium setting asphalts do not break immediately upon contact with aggregate. The initial specification for the high float medium set asphalt allowed the use of a chip that has more dust (minus 200 material). This mixing grade emulsion was also more forgiving and allowed more time for the placement of the aggregate. This allowed the contractor to delay the application of the chips to prevent the asphalt from rolling out in front of the spreader and causing bumps. Increased traffic and the subsequent demand for an earlier restoration of roadway use required the department to modify this specification. The specification was modified to include a demulsibility test. The demulsibility test indicates a relative rate at which emulsified asphalt will break when coming in contact with aggregate. The inclusion of the demulsibility test into our specifications changed the HFMS-2 specification so it would react more aggressively with the aggregate and pavement and begin to break sooner. The change in the specification resulted in the emulsion beginning to break immediately upon application to a dry pavement. When the emulsion begins to break, the ability to envelop the chips begins to diminish. Prompt application and rolling of the chips to seat the aggregate has become very important.

It is important to note that the prompt application of chips to a high float is not without problems. High float asphalt is different from a conventional emulsion because of the high float characteristic. The high float emulsion acts more like a gel which can cause problems when chips are spread immediately after it is applied. If the spreader is moving too fast or if

it throws, rather than drops, the chips onto the freshly applied emulsion the emulsion will roll out in front of the spreader and cause bumps. Adjustments must be made by the spreader operator to alleviate this problem. The practice of applying the high float emulsion and waiting for it to break before applying the chips is not a good practice. This practice will increase your chances of having chip loss and broken windshields when snow plowing operations begin.

High Float emulsions contain wetting agents. These wetting agents will penetrate a dust coating on the chips and allow a medium set high float emulsion (HFMS-2) to be used with a Cl. 42 chip which has as much as 5% passing the 200 sieve. The high floats are also less susceptible to changes in temperature and give better asphalt retention under extreme temperatures.

They soften less in the summer and do not harden as much in the winter. When applied to the roadway, the high float emulsions are more resistant to flow than the cutback asphalts. This makes them less susceptible to bleeding and more conducive to uniform chip embedment. However, this resistance to flow can cause some problems, it can make the asphalt more prone to streaking if the viscosity is too high, the temperature too cold, or if the equipment is not functioning properly.

CRS Emulsions. The CRS emulsions are excellent emulsions to use for seal coats, but are not as forgiving as high float emulsions. They set very rapidly and must have the chips spread on the oil immediately after the oil is sprayed on the road. The rapid set does not allow adequate time for the emulsion to flow through a graded chip before it begins to set. The rapid set of the CRS emulsions also makes them less tolerant to poor construction practices. CRS emulsions should be used when the seal coat will be exposed to immediate heavy traffic such as on the Interstate, US highways or in urban areas. A CRS emulsion is an excellent choice for a seal coat in all areas where a clean chip is available. CRS emulsions should only be used with a chip with less than 1.5% passing the 200 sieve. Dust (minus 200 material) in the chips will accelerate the set of a CRS emulsion and will not allow time for the oil to form a good adhesion to the chip.

3. **Polymer Modified Asphalts.** Using polymers in seal oils provides increased adhesion to the existing surface, increases aggregate retention and flexibility, and allows the roadway to be opened to traffic earlier. Polymers also minimize bleeding and enhance the durability of the chip seal. They can improve a seal coat on any roadway and are highly recommended for seal coats in high traffic areas. Polymers should be limited in their use only by cost.

B. Aggregates

The DOT specifies different classes of aggregate (sand or chips) to use for seal coat projects. They are a Class 41, Class 42, Class 43 chip, and Class 45 sand. The District selects the aggregate based on the type of oil that is to be used.

The Department uses a graded chip for seal coats primarily because of availability. Ideally the chips should be cube-shaped. Flat or elongated particles tend to become aligned on their flat sides and can become completely covered with asphalt. Additional chips lay on top of the flat chips and are not embedded properly into the asphalt. To get proper chip retention the aggregate should be embedded into the oil so it is covered about 60-70%.

It is important to note that the aggregate should be applied at the correct rate. More aggregate is not better. Extra aggregate can dislodge any properly embedded aggregate during the rolling process and prevent the chips from seating properly into the asphalt. The improperly seated aggregate will most likely be dislodged when snow plow operations begin.

The Department specifies four different type of cover coat material. They are as follows:

1. **Class 41 Chips.** Class 41 chips are a graded chip and allow a maximum of 1.5% of the material to pass the 200 sieve. The CI 41 chip is a clean chip and must be used when specifying a CRS emulsion.

2. **Class 42 Chips.** Class 42 chips are a graded chip and allow up to 5% of the material to pass the 200 sieve. When using a CI 42 chip a high float medium set (HFMS) emulsion or an MC 3000 should be specified.
3. **Class 43 Chips.** Class 43 chips are a graded chip and allow up to 2% of the material to pass the 200 sieve. The CI 43 chip is recommended when using a high float rapid set (HFRS) emulsion.
4. **Class 45 Sand.** Class 45 sand is generally clean washed sand with up to 3% passing the 200 sieve. When using CI 45 sand a high float medium set (HFMS-2) emulsion is generally used.

DESIGN

Seal coat projects begin in the District. The District identifies seal coat projects and develops the plans for the project. The district selects the type of oil they elect to use, the type of cover coat material, and determines the estimated cost of the project.

The standard application rates used for a chip seal are as shown below. The actual application rates may vary depending on the size of the chip and condition of the existing pavement.

A. MC-3000

Aggregate Application Rate: 25.0 lb/yd²
 Asphalt Application Rate: 0.30 gal/yd² - 0.34 gal/yd²

B. HFMS & HFRS

Aggregate Application Rate: 25.0 lb/yd² - 28.0 lb/yd²
 Asphalt Application Rate: 0.32 gal/yd² - 0.43 gal/yd²

C. CRS

Aggregate Application Rate: 25.0 lb/yd² - 28.0 lb/yd²
 Asphalt Application Rate: 0.38 gal/yd² - 0.43 gal/yd²

The standard application rates used for a sand seal are as shown below. The actual application rates may vary depending on the condition of the existing pavement.

Sand Application Rate: 0.10 lb/yd² - 15.0 lb/yd²

Asphalt Application Rate: 0.15 gal/yd² - 0.20 gal/yd²

EQUIPMENT

The basic equipment for a chip seal should include:

- A. Asphalt Distributor.** An asphalt distributor should provide a uniform application of asphalt over the entire width being sprayed. Standard equipment on most distributors should be:
- valve system that governs the flow of material.
 - pump tachometer or pressure gauge that registers pump output.
 - bitumeter with an odometer that indicates the number of feet per minute and total distance traveled.
 - spray bar capable of vertical adjustment and adjustable length.
 - heating coils and burner.
 - thermometer well and accurate thermometer.
 - volume gauge or graduated measuring stick.
- B. Aggregate Spreader.** An aggregate spreader should be capable of depositing the designated amount of aggregate per area in a smooth, uniform layer. The control gates should be arranged so that they can be adjusted while the aggregate spreader is in motion.
- C. Rollers.** The rollers should be Self-Propelled Pneumatic Tired Rollers, equipped with at least seven wheels of equal size and 14 ply tires. The tires should be inflated uniformly so air pressure does not vary by more than 5 psi (34.5 kPa). The rear wheels should be staggered with the front wheels so the entire area is rolled in one pass.

- D. **Brooms.** Brooms should have a means of controlling the vertical pressure on the broom head to avoid dislodging embedded chips.
- E. **Supply Tanks.** Supply tanks should be capable of retaining the temperature of the asphalt within the temperature limits.
- F. **Aggregate Haul Trucks.** Trucks should be capable of a controlled discharge to avoid over loading the spreader box.

CONSTRUCTION REQUIREMENTS

A. Surface Preparation.

The surface should be swept clean of all loose material. Hardened patches of clay and mud may have to be removed by other means.

Prior to applying the seal coat, all holes, depressions, and other defective or distressed areas should be repaired. If possible, the repairs should be allowed to cure for 1 week for hot mix patches and 3 weeks for cold mix patches prior to the seal coat application.

Cold mix patches are often very porous and may require the application of a fog coat prior to sealing. If a fog coat is not applied, the patched area may absorb the seal oil and chip loss may occur.

B. Weather Conditions.

Weather conditions can affect a seal coat greatly during construction. High humidity and cool weather will delay the cure time and cause the seal coat to be tender for a longer period of time making it more susceptible to damage by traffic. Rain can also cause major problems when sealing. If the asphalt has not cured, rain can cause the asphalt to come to the surface. When the water evaporates, the top of the chips may be tacky and vehicle tires may cause the seal coat to ravel. The ideal conditions for sealing are hot dry sunny days when rain is not threatening.

C. Asphalt Application

The asphalt should be applied in a uniform layer so that the cover aggregate is embedded about 60 to 70 percent into the asphalt. Application rates should be determined by the Engineer based on the size of the chips furnished and the porosity of the surface being covered. Due to the pace at which a seal coat normally proceeds, it is essential that initial results be observed and adjustments to the application rates be made promptly.

D. Aggregate Retention.

The embedment of the aggregate into the asphalt should be checked the day following the placement of the seal coat. Remove several of the largest stones and determine if the 60 % to 70 % embedment has been obtained. If an inadequate application of asphalt was shot, a fog seal can be applied to get the proper embedment. A diluted CSS-1h or SS-1h (usually 50/50) can be applied at a rate of .1 to .2 gallons per square yard. The application rate will vary depending on the embedment of the chips. Cover aggregate is not required, but CI 45 sand can be used as a choke sand to help secure the chips.

E. Asphalt Application Rate.

The Engineer should compute the yield of each shot to determine the application rate. The asphalt application rate can be determined using the following procedure:

Asphalt used, 880 gallons at 150°F
Distance covered, 3000 feet
Width covered, 12 feet

Correct the volume of asphalt for the temperature of the asphalt being used as follows:

For asphalt having a specific gravity above 0.966,
 $K = 0.00035$ per degree.

For asphalt having a specific gravity between 0.850 and 0.966,
 $K = 0.00040$ per degree.

For emulsified asphalt,
 $K = 0.00025$ per degree.

Example for emulsified asphalt:

Correction factor = $1 - [K (\text{Temperature} - 60^\circ)]$ or,

Correction factor = $1 - [.00025 (150^\circ - 60^\circ)]$

Correction factor = 0.9775

$$880 \text{ gal @ } 150^{\circ}\text{F} \times 0.97750 = 860 \text{ gal @ } 60^{\circ}\text{F}$$

$$\frac{3000 \text{ ft} \times 12 \text{ ft}}{9 \text{ ft}^2/\text{yd}^2} = 4000 \text{ yd}^2$$

Determine the Rate of application as follows:

$$\frac{860 \text{ gal}}{4000 \text{ yd}^2} = 0.22 \text{ gal/yd}^2 \text{ @ } 60^{\circ}\text{F}$$

F. Asphalt Streaking.

A common problem when applying the asphalt is the non-uniform application of the asphalt on the road surface. This is commonly referred to as streaking and can happen in a longitudinal or transverse direction. Longitudinal streaking shows up as alternating lean and heavy narrow bands of asphalt running parallel to the centerline of the road. Transverse streaking runs across the road. Streaking not only leaves an unsightly appearance, it reduces the service life through poor chip embedment and subsequently a loss of chips.

- Transverse streaking is caused by spurts in the asphalt spray from the distributor spray bar. These spurts may be produced by pulsation of the asphalt pump due to worn or loose parts, improper pump speed, or poor governor control of the pump motor.
- Longitudinal streaking can be caused by a number of factors; two of the most common causes are the wrong angle setting of the orifices (snivies) and the spray bar height. Other items that cause streaking are; the wrong snivies being used for the application rate desired, the snivies are worn or plugged, the asphalt is too cold to pump, the viscosity of the asphalt is too high, the asphalt pump speed is set wrong, or the pump pressure is too low.

G. Spray Bar.

It is important to check the spray bar to make sure that all nozzles are aligned, uniformly sized, and cleaned to ensure a uniform application of asphalt. To maintain

the correct spray nozzle angle setting, the angle of the long slit in the nozzle openings must be adjusted so that the spray fans will not interfere with each other. The recommended angle, measured from the spray bar axis, is from 15 to 30 degrees as shown in Figure 1.

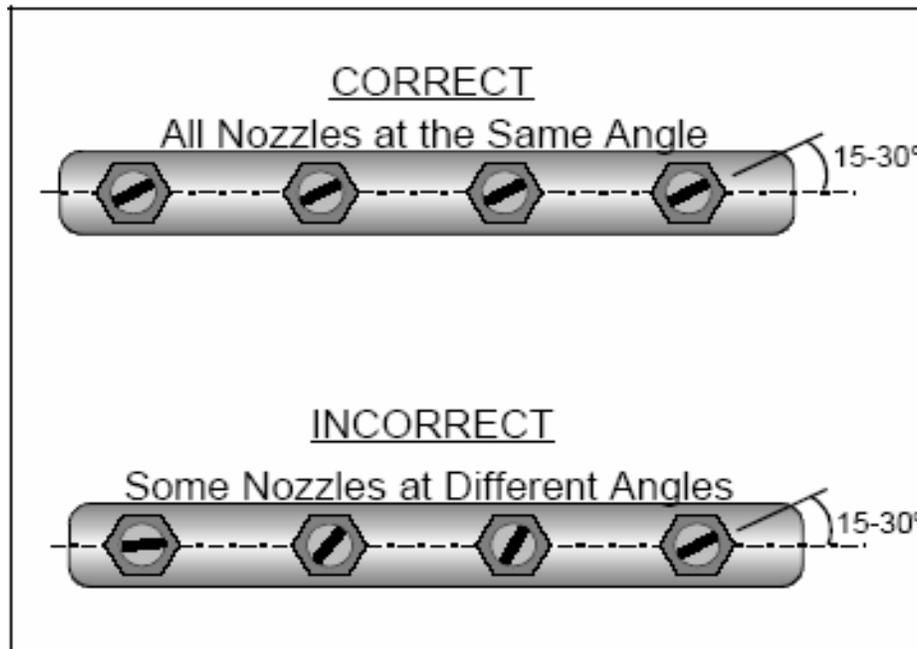


Figure 1

To ensure a uniform spread, the spray bar must be set and maintained at the proper height above the pavement surface. If it is set too high, wind distortion of the spray fans may occur. If the wind causes the oil to blow, a wind shield should be placed around the spray bar. Normally the contractor has the height of the spray bar adjusted properly. If it becomes necessary to adjust the height of the spray bar, determine the pump speed or pressure and heat the asphalt to the application temperature to make the adjustment. Plug alternate nozzles and operate the distributor with the spray bar at different heights until the test area is covered with a single film of asphalt. In this position, the spray fans will just touch at the roadway surface. Open all the nozzles to obtain a double lap of asphalt. Raising the spray bar an additional 50% will produce triple lap coverage. Good results should be achieved with triple coverage, but an exact double coverage can be used. Figure 2 illustrates the heights of the spray bar necessary to achieve the appropriate coverage.

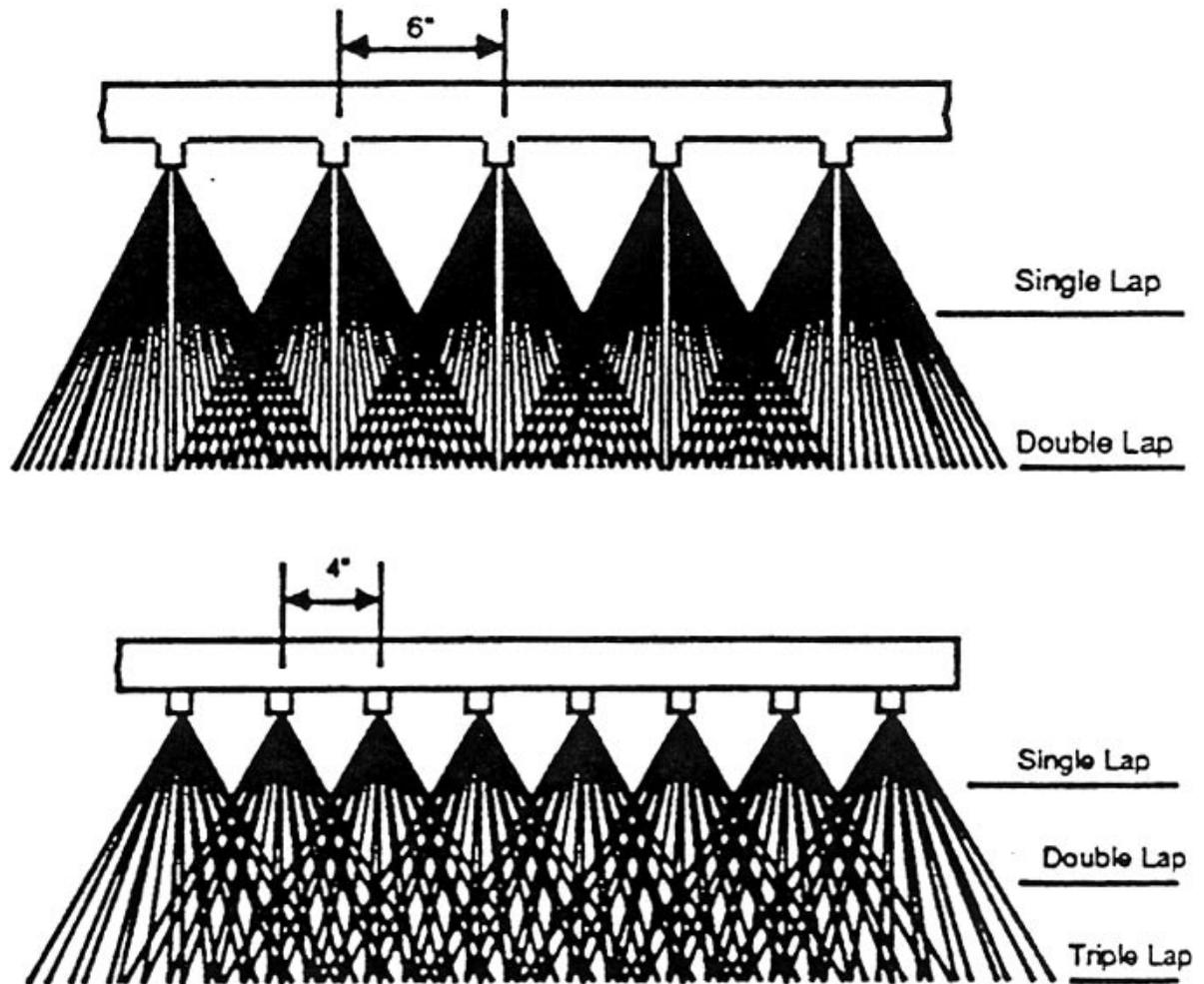


Figure 2

If you are not certain that the spray bar is providing a uniform coverage, it may be necessary to calibrate the distributor. The following method can be used to test the distributor nozzles for uniformity: 1.) Using disposable containers (such as concrete cylinder molds) attach a wire or heavy cord-like material to the sides so that they can be hung below each nozzle of the distributor. 2.) Turn on the distributor bar until the containers are approximately half to three-quarters full. 3.) Compare the containers to see if they all contain the same amount of asphalt. 4.) If the containers do not contain the same amount of asphalt, adjustments should be made to the distributor.

To ensure proper asphalt application the following items should also be addressed:

- The distributor should only be loaded and unloaded to the point where the height of spray bar remains relatively constant regardless of the load.
- The distributor should not be allowed to empty when applying the asphalt. Running the pumps empty will cause the asphalt to be applied unevenly.
- The application of asphalt should be stopped immediately whenever streaking occurs and the cause of streaking should be corrected before resuming work.
- The application of asphalt should be stopped immediately when any nozzles appear to be malfunctioning.

If you have made all of the corrective measures to the distributor and streaking is still occurring, try tipping the spray bar, the additional fanning of the spray may solve your problem.

H. Asphalt Application Temperatures.

The asphalt application temperature range will vary depending on the type of asphalt used. The following table is a guideline:

Type	°Fahrenheit	°Celcius
RC 70	105-175	40-79
RC 250	140-225	60-107
RC 800	175-225	79-107
RC 3000	215-290	102-143
MC 70	105-175	40-79
MC 250	140-225	60-107
MC 800	175-225	79-107
MC 3000	215-290	102-143
SC 70	105-175	40-79
SC 250	140-225	60-107
SC 800	175-225	79-107
SC 3000	215-290	102-143
RS-1	80-185	27-85
RS-2	125-185	52-85

HFRS-2	125-185	52-85
CRS-1	125-185	52-85
CRS-2	140-185	60-85
HFMS-1	80-185	27-85
HFMS-2	125-185	52-85

Asphalt should only be applied when sufficient cover aggregate is at the site to cover the area to be shot. Hand sprayers should be used to apply asphalt to small or inaccessible areas. Cover roadway appurtenances to protect them from asphalt over-spray.

I. Aggregate Application

As stated earlier, the aggregate should be applied in a uniform layer so that it is embedded about 60 to 70 percent into the asphalt. It is extremely important that enough aggregate is on hand to cover the entire area where asphalt was applied. Due to the pace at which a seal coat normally proceeds, it is essential that initial results be observed and adjustments be made promptly. The Engineer should compute the rate of application of the aggregate immediately after placement to determine the application rate. The aggregate application rate can be determined using the following procedure:

Tons of aggregate placed: 36 tons
 Distance covered: 3000 feet
 Width of lane: 12 feet

$$36 \text{ tons} \times 2000 \text{ lbs/ton} = 72,000 \text{ lbs of cover aggregate}$$

$$\frac{3000\text{ft} \times 12\text{ft}}{9\text{ft}^2/\text{yd}^2} = 4000 \text{ yd}^2$$

Rate of application:

$$\frac{72,000 \text{ lbs}}{4000 \text{ yd}^2} = 18.0 \text{ lbs/yd}^2$$

It is very important that the Aggregate Spreader be calibrated prior to beginning construction. Calibration of the spreader can be accomplished with several sheets of canvas cut to exactly to one square yard and a scale. Make several runs with the spreader at different gate settings and different speeds over the canvas sheets. Weigh the aggregate on each sheet to determine the appropriate gate setting and spreader speed.

Following are the application procedures with the different types of asphalts:

1. Cutback Asphalts.

When using cutback asphalts, it is preferred that the cover aggregate be dry when applied to the roadway. The aggregates may be flushed with water to control dusting, but they should be well drained when applied to the roadway.

The cover aggregate should be applied immediately following the asphalt application.

2. High Float Emulsified Asphalts.

When using high float emulsions, it is preferred that the cover aggregate be flushed, well drained and visibly damp when applied to the roadway. **The cover aggregate should be applied prior to emulsion breaking and as close to the distributor as possible.**

3. Cationic Emulsions.

When using cationic emulsions, the cover aggregate should be washed, well drained, and be visibly damp when applied to the roadway. **The cover aggregate should be applied within one minute following the asphalt application.** If an application of emulsified asphalt is not covered before it begins to "break", corrective action should be required.

The spreader speed should be watched so that it does not cause the aggregate to roll and bounce. This can cause the top side of the chips to become tacky. The tacky surface of the chips can cause the rollers and traffic to pick up or displace the chips. Blotter material should be spread immediately to stop any raveling that might occur.