



# Minnesota Seal Coat Handbook 2006

# **Revised 2006**



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equipment, design and construction for the field inspector. Divided into two main sections, this updated handbook provides direction for designers and field personnel.

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# MINNESOTA SEAL COAT HANDBOOK 2006

# **Final Report**

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# **June 2006**

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#### **FOREWORD**

This document is a revision of the Minnesota Seal Coat Handbook first published December 1998. Since its publication, this handbook has been extensively used in Minnesota and served as a model for other states and jurisdictions around the country.

Since 1998, there have been several advances in the seal coating process, including improved emulsions, updated Mn/DOT specifications, and improved techniques – this new information is reflected in the revised Handbook. In addition, new chapters have been added to the Handbook dealing with fog sealing, chip sealing for recreational trails, and frequently asked questions.

This revised Seal Coat Handbook is intended to be a practical tool for the designer and the technician. This revision was sponsored by the Minnesota Local Road Research Board's Research implementation Committee and was assembled with input from a Technical Advisory Panel made up of Mn/DOT, city and county engineers. Special thanks needs to be given to Thomas Wood, Mn/DOT, without whose knowledge, enthusiasm and generosity, this Handbook would not exist in its present form.

### CHAPTER 1. SEAL COAT INTRODUCTION

Seal coating is a common preventive maintenance activity in Minnesota performed by most cities, counties and rural Mn/DOT districts (1). It involves spraying asphalt cement on the surface of an existing pavement followed by the application of a cover aggregate. The asphalt cement is usually emulsified (suspended in water) to allow for it to be applied without the addition of extreme heat. The cover aggregate is normally either naturally occurring gravel or crushed aggregate such as granite, quartzite or trap rock (basalt).

#### **BENEFITS OF SEAL COATING**

The primary reason to seal coat an asphalt pavement is to protect the pavement from the deteriorating effects of sun and water. When an asphalt pavement is exposed to sun, wind and water, the asphalt hardens, or oxidizes. This causes the pavement to become more brittle. As a result, the pavement will crack because it is unable to bend and flex when exposed to traffic and temperature changes. A seal coat combats this situation by providing a waterproof membrane which not only slows down the oxidation process but also helps the pavement to shed water, preventing it from entering the base material.

A secondary benefit of seal coating is an increase in the surface friction it provides. This is accomplished by the additional texture the cover aggregate adds to the pavement. With time, traffic begins to wear the fine material from an asphalt pavement surface. This results in a condition referred to as raveling. When enough of the fine material is worn off the pavement surface, traffic is driving mostly on the course aggregate. As these aggregate particles begin to become smooth and polished, the roadway may become slippery, making it difficult to stop quickly. A seal coat increases the pavement texture and increases the surface friction properties.

#### CONDITIONS CONDUCIVE TO LONG LASTING SEAL COATS

In most cases, seal coating is done on roadways with low to moderate traffic volumes (up to several thousand vehicles per day). This is due to the increased chance of windshield damage to vehicles during and immediately after construction as traffic volume and speed limits increase. While it is possible to successfully seal coat high speed, high traffic roads such as interstate highways, special precautions must be taken when seal coats are placed on these types of roadways to minimize the chance of problems occurring. Refer to Chapter 9 of this handbook for more details.

Seal coats are affected greatly by weather conditions, especially during construction. The ideal conditions are a warm, sunny day with low humidity. Humidity and cool weather will delay the curing 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 cause major problems when seal coating. If the asphalt binder has not cured, it can become diluted and rise above the top of the cover aggregate. After the water evaporates, asphalt may cover the entire surface causing tires to pick up aggregate or track the binder across the surface. Seal coating should **never** be done when showers are threatening. For information on what to do if it begins to rain during construction, refer to Chapter 7 of this handbook.

Roadways to be seal coated should also be in relatively good condition. This means that there should be little, if any, load related distress such as alligator cracking, rutting and potholes. If these conditions exist, the road should not be sealed unless it is repaired first.

In summary, seal coating is a good maintenance technique for pavements with the following:

- Low to moderate block cracking.
- Low to moderate raveling.
- · Low to moderate transverse and longitudinal cracking.
- A smooth surface with low friction numbers.

#### MATERIALS USED IN SEAL COAT CONSTRUCTION

The two main materials used in seal coat construction are the asphalt binder and the cover aggregate. The asphalt binder is normally an asphalt emulsion. The cover aggregate can be either natural or crushed.

#### **Asphalt Binder**

The most commonly used type of asphalt binder for seal coats in Minnesota is an asphalt emulsion. The other type of binder used for seal coating is cutback asphalt. However, their use has declined rapidly due to the costly and harmful solvents used.

#### Cutback Asphalt

A cutback asphalt consists of asphalt cement dissolved in a solvent, typically kerosene or naptha (gasoline). The solvent softens the asphalt cement and allows it to be pumped and sprayed at fairly low temperatures. As the solvent evaporates into the atmosphere, only the asphalt cement remains. Once the solvent has evaporated, the cutback has fully cured.

#### Asphalt Emulsion

An asphalt emulsion consists of the following three components:

- Asphalt Cement;
- Water;
- Emulsifying Agent (surfactant).

The asphalt cement makes up about two thirds of the volume of the emulsion. The base asphalt used to make the emulsion typically has similar characteristics to the asphalt cement used in hot mix production. This is the same range that most asphalt cements used in hot mix production are in. In some cases, latex or polymer modified asphalt is used to make emulsion. These modified emulsions are used to improve early chip retention and seal coat durability.

Water is the second largest ingredient in the emulsion. It provides a medium for the suspension and transfer of the asphalt particles. When the asphalt and water separate from each other, the color of the emulsion will change from brown to black. When this process has occurred, the emulsion is said to have broken. The aggregate chips must be applied and rolled before this occurs, normally only a few minutes after the emulsion is applied.

The emulsifying agent, or surfactant, has two primary roles. First, it causes the asphalt particles to form tiny droplets which are able to be suspended in water. This is accomplished by the surfactant's ability to lower the surface tension between the asphalt and water. Having the asphalt particles suspended in the water allows the asphalt to be applied at much lower temperatures than it otherwise could be. Secondly, the emulsifying agent determines the electrical charge of the emulsion (cationic (+), anionic (-) or nonionic). It is important to choose an emulsion with an electrical charge that is opposite that of the aggregate. Since like charges repel, the emulsion will not bind well to aggregates with the same charge. Since most aggregates have a negative charge (2), Cationic (+) emulsions, such as CRS-2P, are used almost exclusively in Minnesota.

When an emulsion breaks, the asphalt particles separate from the water. Since the asphalt is heavier than the water, the water will rise to the top and eventually evaporate, leaving only the asphalt cement on the roadway.

#### **Cover Aggregate**

The cover aggregate should be *clean and dust free*, uniform in size and hard so that it provides a tight, durable surface able to withstand the abuse of snow plows and vehicles. In Minnesota, the gradation of seal coat aggregate is referred to as either FA-1, 2 1/2 or 3 (3). The larger the number, the larger the aggregate. The FA stands for Fine Aggregate. By far, the most commonly used sizes are FA-2 and FA-3. An FA-2 (Figure 1.1) consists mainly of particles smaller than 1/4 inch. An FA-3 (Figure 1.2) consists mainly of the chips smaller than 3/8 inch.



Figure 1.1. Example of an FA-2 Pea Rock (buckshot)



Figure 1.2. Example of an FA-3 Granite

A more detailed discussion of both the asphalt binders and cover aggregate can be found in Chapters 2 and 3 of this handbook.

#### EQUIPMENT USED IN SEAL COAT CONSTRUCTION

There are several different types of equipment normally used to construct a seal coat. The exact type and size may vary depending on the situation and roadway width. The list of equipment is as follows:

- Power Brooms;
- Asphalt Distributor;
- Chip Spreader;
- Pneumatic Tired Rollers;
- Haul Trucks:
- Front End Loader;
- Asphalt Tanker;
- Miscellaneous Hand Tools.

#### **Power Brooms**

There are two different types of power brooms used in seal coating. Seal coats constructed in rural settings typically use front mounted rotary sweepers (Figure 1.3) whereas those constructed in urban settings use pick-up sweepers (Figure 1.4). The brooms are used before the seal coat to clean any dirt or debris from the existing pavement surface. This provides a clean surface for the asphalt binder to adhere to. Once the seal coat has been constructed, the brooms are used to remove any excess aggregate not embedded into the binder.



Figure 1.3. Rotary sweeper typically used in rural areas



Figure 1.4. Pick-up sweeper typically used in urban areas

#### **Asphalt Distributor**

One of the key pieces of equipment on a seal coat project is the asphalt distributor. It must be able to apply a uniform layer of asphalt binder at the correct depth and width. If the binder is applied too heavily, flushing of the asphalt in the wheelpaths will result. If applied to thin, excessive chip loss will result. Most distributors used today have computerized controls which can regulate the pressure of the material to compensate for the speed of the vehicle. This results in a constant application rate, regardless of travel speed. Two distributors are normally used on a seal coat project. This allows one to continue to work while the other is being refilled by the tanker.



Figure 1.5. Computer controlled asphalt distributor



Figure 1.6. Computer control console of an asphalt distributor

#### **Chip Spreader**

Another important piece of equipment is the aggregate chip spreader. It must apply a uniform, even layer of aggregate across the entire width being sealed. As such, it must be calibrated properly and in good working order. A self-propelled chip spreader is desirable. This type of spreader pulls the aggregate trucks as it travels down the road. When the truck is empty, it is released by the spreader and another backs into place. If done correctly, almost no work stoppage occurs while refilling the spreader.

The newer chip spreaders are now equipped with computerized controls that allow the gates to open and close hydraulically, to compensate for the speed of the spreader. This ensures a constant application rate, regardless of travel speed.



Figure 1.7. Self-propelled chip spreader

#### **Pneumatic Rollers**

Perhaps the most overlooked pieces of equipment are the pneumatic tired rollers. Their primary function is to embed the aggregate into the asphalt binder and orient the chips on their flat side. It is important to have enough rollers to complete the rolling quickly. The chips need to be embedded into the binder before it breaks. Normally, a minimum of three rollers will be required. The first two, drive side-by-side rolling the outer edges. The third roller then follows closely behind, rolling the center of the lane. It is very important for the rollers to travel slowly, no more than 5 mph (8 km/hr), so the chips are correctly embedded into the binder.



Figure 1.8. Pneumatic tired rollers

#### **Haul Trucks & Front End Loaders**

A standard front end loader is required to load the aggregate from the stockpile into the delivery trucks. The one exception to this would be if the aggregate is being obtained directly from an aggregate supplier. In that case, the trucks would be loaded at the pit or quarry.

#### **Asphalt Tanker**

Another piece of equipment used on seal coat projects is an asphalt tanker. While this is not normally supplied by the agency or the contractor, the foreman/supervisor needs to be aware of how many will be needed, where they should be located, and when to schedule them to arrive. Proper placement and delivery of asphalt binder is essential for good production. Without it, workers will be continually waiting for material to be delivered.

#### **Miscellaneous Hand Tools**

Hand tools are often used to touch up areas where the seal coat does not fully cover the pavement surface, such as cul-de-sacs and corners of parking areas, particularly where curb and gutter is present. Tools such as push brooms, shovels and squeegees are normally used. It is very common to find these tools on the rollers since the roller operators will typically be the ones who do the touch up work.

#### **SUMMARY**

In summary, seal coating is a common, cost effective, preventive maintenance activity involving a number of different types of equipment, each playing a unique role in the process. Attention must be paid to the type and quality of materials as well as the condition and operation of the equipment. The experience of the equipment operator is of utmost importance. Even new, well-calibrated equipment, using the finest materials, will not produce a quality seal coat project without experienced and qualified operators.

#### **CHAPTER 2. SEAL COAT AGGREGATE**

Due to its geological history, Minnesota has an abundant supply of good quality aggregate. Consequently, there are many choices available when considering which aggregate to use for a seal coat project.

#### AGGREGATE TYPES

The Mn/DOT specification 3127, "Fine Aggregate for Bituminous Seal Coat" (4) identifies the following four classes of aggregate:

**Class A** aggregate consists of crushed quarry or mine trap (basalt, diabase, gabbro or other related igneous rock types), quartzite or granite. These are primary granites from the St. Cloud and Ortonville areas, quartzite form the New Ulm area and trap rock (basalt) from Dresser, Wisconsin.

**Class B** aggregate consists of all other crushed quarry or mine rock such as limestone, dolomite, rhyolite and schist. Primary, limestones available near the Rochester area have been used.

**Class C** aggregate consists of natural or partly crushed gravels obtained from a natural gravel deposit.

As with most any type of construction material, seal coat aggregates are chosen based on several factors such as availability, cost, the type of road being sealed and traffic volume and movement.

Some guidelines include:

**Resistance to Traffic Wear and Snow Plow Damage:** Class A aggregates are the hardest and can withstand the pounding by traffic better than either Class B or Class C aggregates. In addition, crused aggregate, such as Class A and B, lock together better than Class C aggregates due to their shape. This will generally result in better protection against snow plow blades.

**Effect on Asphalt Binder Quality:** Class B and C aggregates will generally require more asphalt binder because they are much more absorptive than Class A aggregates.

**Cost:** Class C aggregates are less expensive than Class A or B aggregates due to the lack of crushing.

**Resistance to Turning & Scuffing:** Because of crushing, Class A and B aggregates are much more angular than Class C aggregates and thus better able to withstand vehicle stopping and turning actions.

#### AGGREGATE APPLICATION RATE

When constructing a seal coat, the cover aggregate should be applied so it is only one-layer thick, unless a double or choke seal is being constructed (see Chapter 11). Applying too much aggregate not only increases the chance of windshield damage to passing vehicles but can also dislodge properly embedded stones. The exception to this is in areas where extensive stopping and turning movements take place, such as intersections and turn lanes. Using a light excess of aggregate, about 5 or 10 percent, can help reduce the scuffing caused by vehicle tires turning on the fresh, uncured, seal coat.

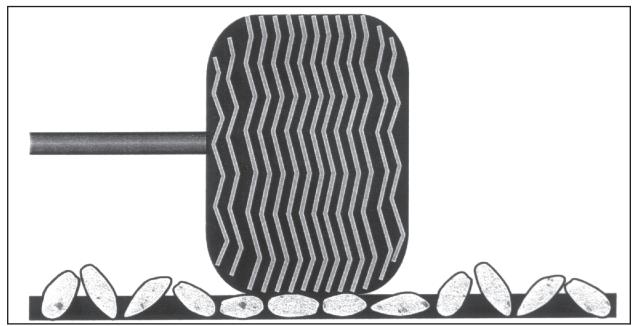
#### AGGREGATE SHAPE

The shape of an aggregate is characterized by the following:

- Flat or cubical; and
- Round or angular.

#### **Impact of Aggregate Flatness**

Traffic plays an important role in determining the chip orientation of seal coats constructed with flat and elongated aggregate. The flatter the aggregate, the more susceptible the seal coat will be to either bleeding in the wheelpaths or excessive chip loss in the non-wheelpath area. This is because traffic causes any flat chips in the wheelpath to lie on their flattest side. This results in a thinner seal coat in the wheelpath than in the non-traffic areas as shown in Figure 2.1. If the binder is applied too thick in the wheelpaths, bleeding will result when the chips lie on their flat side. If the binder is applied to thin, the chips in the non-traffic areas will be dislodged by traffic and snow plow blades.



**Figure 2.1.** Traffic causes flat chips in the wheelpath to lay down on their flattest side On low volume roadways and parking lots, this difference in seal coat thickness may not become a problem because it requires repeated applications of traffic to re-orient the chips on their

flattest side. If the traffic volume is low enough, or not confined to a specific area, such as a wheelpath, there may not be a large enough difference in chip height to cause a problem.

With cubical aggregate, traffic will not have a pronounced effect on chip orientation. No matter how the chips are oriented, the seal coat height will be essentially the same and chip embedment will be uniform.

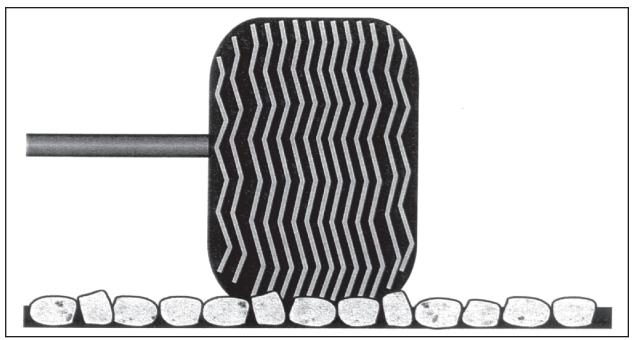


Figure 2.2. Traffic has little effect on cubical aggregate

The way to measure the flatness of an aggregate is the Flakiness Index (see Chapter 4). This index is the percentage, by weight, of the aggregate that consists of flat and elongated pieces. Most Class A and B aggregate in Minnesota have a Flakiness Index between 18 and 30 percent. Class C aggregates have lower Flakiness Indices, typically between 9 and 20 percent. Aggregate with Flakiness Indices over 25 percent should not be used for seal coating.

Tips for using flat aggregate:

- In the binder design process, calculate the amount of binder required for both the wheelpath and non-wheelpath areas. This will give you a feel for the difference in the seal coat thickness between these two areas.
- Flat aggregate should not be used on high volume roadways, period. There will either
  be too much binder in the wheelpaths or not enough between them. For high volume
  roadways, a cubical aggregate with a Flakiness Index of 20 percent or less should be
  used.
- Use a little extra aggregate (5-10%) in the wheelpaths to prevent the flat chips from sticking to the tires of the chip spreader and dump trucks while the binder is curing. This can be done by increasing the opening of the chip spreader gates in these areas.
   Remember, if enough binder is applied to hold onto the tall chips in the non-traffic

areas, the flat chips in the wheelpath will likely be covered with the binder. The excess aggregate will help to prevent them from sticking to vehicles.

#### **Impact of Aggregate Roundness**

The roundness of the aggregate will determine how resistant the seal coat will be to turning and stopping movements. A round aggregate is defined as an aggregate that is not crushed, with a crushed aggregate having at least one fractured face as defined by ASTMD 5821 (Mn/DOT 1214). Round aggregates are much more susceptible to rolling and displacement by traffic than angular aggregates, which tend to lock together better. Because of their shape, it is very difficult to achieve the same result with round aggregate unless the aggregate is extremely graded. The graded aggregate will allow the smaller stones to fill in the areas between the larger ones. However, as explained later in this handbook, graded aggregate has many problems of its own.

Tips for using round aggregate:

- When using a round aggregate, use a one-size gradation. Since round aggregates
  are more easily dislodged by snow plows, due to their lack of locking together, using
  a one-size aggregate will help prevent the plow blade form shaving off the tall stones.
- Extra care must be taken when constructing seal coats with round aggregate to
  ensure the proper embedment will be achieved. Due to their shape, seal coats
  constructed with round aggregate tend to be more susceptible to snow plow
  damage unless chips are deeply embedded into the binder.
- A double chip seal is a good option when using round aggregate, particularly on high volume roads. This type of seal involves placing two separate seal coats, one on top of the other. The aggregate used for the top layer is roughly half the size of the aggregate on the bottom layer. When the second layer of binder is applied, the bottom stones are 100 percent embedded. The smaller stones in the top layer area are too small to cause windshield damage. In addition, the surface is generally smoother than a single seal, which minimizes snow plow damage.

#### AGGREGATE GRADATION

Aggregate gradation also plays an important role in seal coat design, construction and performance. Gradation refers to the distribution of the various sized stones that make-up the aggregate matrix. Aggregates used in seal coat construction are normally classified as either one-size or graded.

#### **One-Size Aggregate**

The best seal coat gradations are those that are essentially one-size. An aggregate is considered one-size if nearly all of the material is retained on two consecutive sieves. This results in most of the stone pieces being in a narrow range of sizes as shown in Figure 2.3.

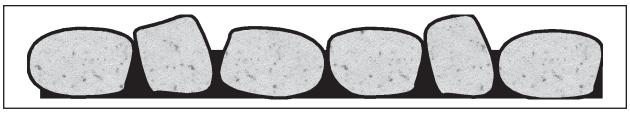


Figure 2.3. Cross section of a one-size seal coat aggregate

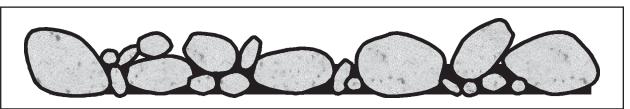
Notice that all of the chips are fairly close to the same size. Also, notice the large amount of space (voids) that exists between each stone. This is the space available for the asphalt binder to fill and a key component in determining the amount of binder required for good performance.

Some of the advantages of using a one-size aggregate are:

- Maximum friction is obtained between vehicle tires and the pavement surface because more chips are in contact with the tires.
- Checking for adequate binder can be determined quickly and accurately and there
  is less chance of bleeding because if one particle is embedded properly, nearly all
  of the others are also.
- Better drainage due to clear surface channels between the aggregate particles, which allows for rapid and positive removal of water.

#### **Graded Aggregate**

Graded aggregates cover a wide range of possibilities from dense graded to gap graded. The more graded an aggregate is, the less desirable it will be for seal coat construction. Because graded aggregates have lower air voids, there is less room to fit the binder in between chips. As a result, there is a fine line between applying too much binder (bleeding) and not enough (loss of aggregate). Failure to account for the aggregate's gradation will increase the chance of bleeding as the binder is squeezed out of the matrix by traffic.



**Figure 2.4.** Cross section of a graded seal coat aggregate *Some problems with using graded aggregate are:* 

- Some of the larger particles project so far above the average thickness of the seal coat they are torn out of the surface by vehicle tires and snow plow blades.
- Some of the smaller particles are so small they are completely submerged into the asphalt binder which causes bleeding.

- Because of the considerable range in particle sizes, vehicle tires make firm contact with fewer particles at a time resulting in less friction.
- It is difficult to determine the proper quantity of binder that will be both sufficient to hold onto larger particles and yet not submerge too many of the smaller particles.

The two most often used seal coat gradations in Minnesota are the Mn/DOT FA-2 and FA-3 gradations. Both are considered to be graded aggregates. However, within both of these gradation bands there is the possibility of a fairly one-size gradation as well as a very graded one.



**Figure 2.5.** Example of a one-size FA-4 seal coat aggregate



Figure 2.6. Example of a graded seal coat aggregate

#### **DUSTY AGGREGATE**

Aggregates containing dust should not be used for seal coating unless certain precautions are taken. To avoid dusty aggregate, the specified aggregate gradation should have 1 percent or less passing the #200 sieve (75µm). Dust will coat the outside of the aggregate particles and prevent them from bonding with the bituminous binder. Consequently, extensive chip loss will result.

If clean, dust-free aggregate is not available, one of the following **must** be done before the aggregate is used:

- Wash the aggregate to remove the dust. The washing process, which should be done with clean, potable water, involves screens which allow the unwanted fines to be removed. A conveyor is then used to stockpile the material where it is allowed to dry.
- Use a high-float emulsion, such as HFMS-2. This type of binder can be used with aggregates having as much as 5 percent passing the #200 sieve. The wetting agents used in this type of binder can cut through the dust coating and provide a good bond with the aggregate particles.



Figure 2.7. Evidence of a dusty aggregate

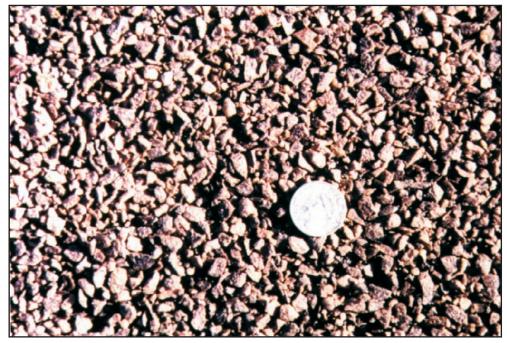


Figure 2.8. Dusty aggregate before sweeping



Figure 2.9. Dusty aggregate after sweeping (notice most of the large aggregate is missing)

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### **CHAPTER 3. ASPHALT BINDERS**

The main reason asphalt is used in road applications is because it is waterproof and adheres to stone. At room temperature, most asphalts are very stiff, too stiff to apply to a roadway. To get it into a form that can be applied requires the viscosity to be reduced. This can be done by:

- Heating;
- Making a cutback asphalt;
- Making an asphalt emulsion.

The two methods most often used for constructing seal coats are using cutback asphalts and asphalt emulsions.

#### **CUTBACK ASPHALTS**

Cutback asphalts (liquid asphalts) are asphalts that are dissolved in a petroleum (cutter). Typical solvents include naptha (gasoline) and kerosene. The type of solvent controls the curing time of the cutback and thus when it will obtain its ultimate strength. Rapid curing cutbacks use naptha (gasoline) while medium curing cutbacks use kerosene. The amount of cutter affects the viscosity of the cutback asphalt. The higher the cutter content, the lower the viscosity and the more fluid it will be. The use of cutbacks has declined rapidly over the years due to concerns over pollution and health risks as the solvents evaporate into the atmosphere. For example, for every 1,000 gallons of cutback asphalt applied, over 150 gallons of cutter (gasoline/kerosene) is released into the environment.

#### **Cutback Classification**

Cutbacks are divided into two classifications, Rapid-Curing (RC) and Medium-Curing (MC) depending on the solvent used. They are further defined by a number which indicates the minimum kinematic viscosity (fluidity) of the cutback. The lower the number, the more fluid the cutback is.

#### **ASPHALT EMULSIONS**

An emulsion is one phenomena that occurs when you mix two incompatible components together. Common examples of emulsions are milk, margarine, butter, beer and paint. Emulsions are made up of two components with one dispersed in the other. Maintaining the dispersion requires some way of overcoming the lack of compatibility. The methods that have been found to work over many years are high shear blending and chemical treatment. An asphalt emulsion consists of asphalt particles dispersed in water and chemically stabilized as shown in Figure 3.1

As molten asphalt is blended into fine droplets, the asphalt is brought into contact with a chemical solution (emulsifier) which provides the stabilization. After discharge, the emulsion consists of water with fine particles of asphalt dispersed in it. The only thing between the asphalt particles is water and the emulsifier. Since asphalt is not soluble in water, keeping it dispersed in fine particles is a significant feat.

#### **Emulsion Classification**

Emulsions are divided into three grades for classification: cationic, anionic and non-ionic. In practice, only the first two are used in roadway construction and maintenance. The cationic and anionic designation refers to the electrical charge of the emulsifier surrounding the asphalt particles. Cationic emulsions have a positive (+) electrical charge surrounding the asphalt particles while anionic emulsions have a negative (-) electrical charge.

Since opposite electrical charges attract, anionic emulsions should be used with aggregates having a positive (+) charge. Similarly, cationic emulsions should be used with aggregates having a negative (-) charge. Failure to use materials with opposite electrical charges may result in the materials repelling each other, causing failure.

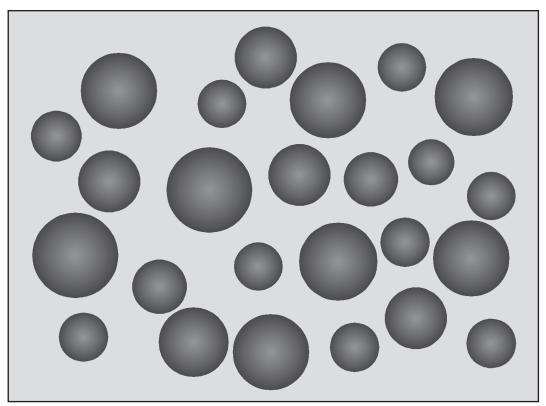


Figure 3.1. Asphalt emulsion

In addition to being classified by their electrical charge, emulsions are further classified according to how quickly they will revert back to asphalt cement. The terms RS, MS and SS have been adopted to simplify and standardize this classification. They are relative terms only and stand for Rapid-Setting, Medium-Setting and Slow-Setting. As the emulsifier is drawn toward aggregate surfaces with an opposite electrical charge, the asphalt particles begin to settle to the bottom of the emulsion. The speed at which this occurs is indicated by the RS, MS and SS designation.

Five grades of high-float emulsions are also available. High-float emulsions, so designated because they pass the Float Test (AASHTO T-50 or ASTM D-139), have a quality imparted by the addition of certain chemicals that permit a thicker asphalt film on the aggregate particles with a minimum probability of drainage. This property allows high-float emulsions to be used with somewhat dusty aggregate with good success.

Finally, emulsions are subdivided by a series of numbers that relate to the viscosity of the emulsion and the hardness of the base asphalt cement. The numbers "1" and "2" are used to designate the viscosity of the emulsion. The lower the number, the lower the viscosity and the more fluid the emulsion is. If the number is followed by the letter "h", the emulsion has a harder base asphalt. The grades in the following tables which are shaded are suitable for seal coat projects.

#### **Emulsifiers**

Emulsifiers are the chemical solutions that give the asphalt particles the ability to stay suspended in water. The two types of emulsifiers; cationic and anionic are both comprised of salts.

- a) Anionic Emulsifiers are comprised of acids reacted with a base such as caustic potash or caustic soda to form a salt. It is this salt that is the active emulsifier. The emulsifier attaches itself to the asphalt particles. The number and density of these emulsifier molecules determine how much negative (-) charge is on the surface of the asphalt particles. Figure 3.2 shows an anionic emulsified asphalt particle.
- **b) Cationic Emulsifiers** are also made of acid salts. Cationic emulsifiers give a positive (+) charge to the asphalt particles. The most often used emulsifiers in Minnesota, by a wide margin, are cationic. This is because most aggregates have a negative charge and thus attract cationic emulsifiers, causing a good bond. Figure 3.3 shows a cationic emulsified asphalt particle.

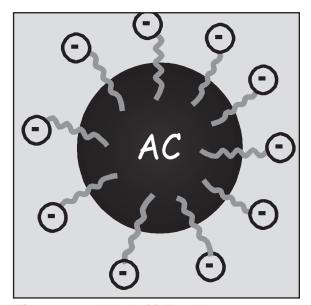


Figure 3.2. Anionic (-) Emulsion

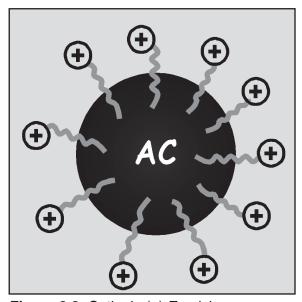


Figure 3.3. Cationic (+) Emulsion

#### Cationic Versus Anionic

Overall, cationic emulsions perform more reliably in the field and set up more quickly than anionic emulsions, provided the correct handling and application procedures are used.

#### In addition:

- Cationics are less sensitive to weather because they have a chemical break.
- Cationics can be stabilized without making break times longer.
- · Cationics are more critical in handling.
- Cationics need close attention to storage procedures.
- Cationics are more suitable for aggregates, silica aggregates included.
- No precoat is required for a cationic emulsion if aggregate is clean and dust-free.

#### **Properties of Emulsions**

All the properties of emulsions and their behavior under various conditions are directly related to the type and strength of emulsifier used.

**Breaking** refers to the event when the asphalt and water separate from each other. This occurs as the emulsifier leaves the surface of the asphalt particles due to it's attraction to the surface of the aggregate. Since asphalt is heavier than water, the asphalt particles will settle to the bottom of the solution.

Since *anionic emulsions* have a negative charge, as does almost every mineral, there will be no electrostatic attraction between the emulsion and the aggregate surface since like charges repel each other. For an anionic emulsion to break, the particles must get so close to each other that the repulsion forces are overcome by the attractive forces that exist between all things. This occurs by forcing the particles together in some way. During seal coating, this occurs as the water evaporates out of the emulsion. In Minnesota, the most commonly used anionic emulsion for seal coating is HFMS-2.

Cationic emulsions have a positive charge and since opposite charges attract, they are drawn toward most aggregate particles. Thus, a direct and very rapid reaction between the emulsion and an aggregate or pavement is possible as shown in Figures 3.4 and 3.5. The size of the charge, affects stability, i.e. the larger the charge, the more rapid the reaction. The other mechanism which affects curing is evaporation. After the chemical break is completed, the water must still be completely evaporated for the residual asphalt to achieve full strength. In Minnesota, the most commonly used cationic emulsion is CRS-2.

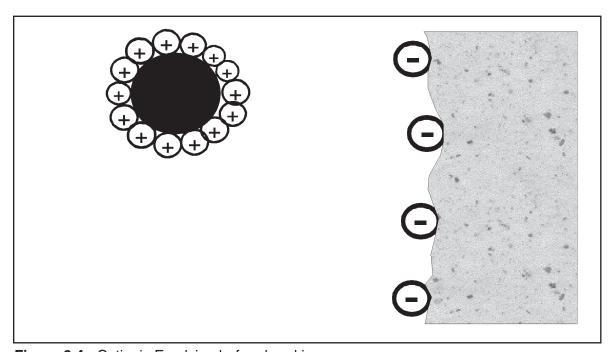


Figure 3.4. Cationic Emulsion before breaking

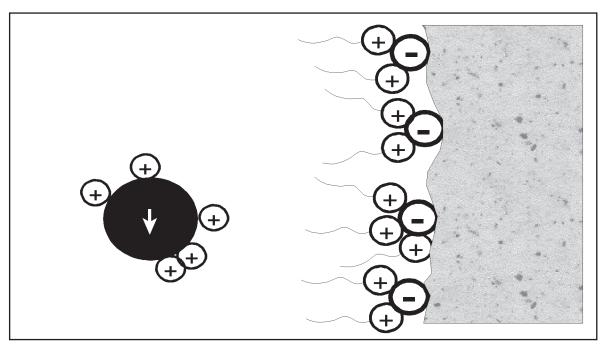


Figure 3.5. Cationic emulsion beginning to break

#### **Polymer Modified Emulsion**

Certain properties of asphalt emulsions can be enhanced by the addition of polymers. Common polymers used in emulsions are natural and synthetic latex, SBR and SBS polymers. Typically, about 2.5 to 3 percent polymer, by weight, is added to the emulsion.

Advantages of using polymers are:

- 1. **Early chip retention:** Using polymers allows same-day sweeping versus having to wait until the next morning.
- 2. Raises the softening point of base asphalt: The residual asphalt from a CRS-2 has an average softening point (temperature) of 108° F versus the residual asphalt from CRS-2p softening point of 128° F. This allows the user to be more aggressive with their application rate without the fear of bleeding. The more asphalt binder placed on the roadway the longer the chip seal will perform.
- 3. Greater protection of the chip seal: The elastomeric characteristics of the polymer-modified asphalt protect the chips from impact shock from turning traffic, stopping traffic, and snow removal equipment.
- 4. **Flexibility:** Polymer modified emulsions are available both in Cationic and Anionic (High Floats) emulsions.
- 5. Less waste of materials: With a polymer-modified emulsion, there is less chance of loose aggregate after final sweeping because of the ability of the asphalt to stretch and rebound the polymer-modified asphalt acts almost like a rubber band, springing back to its original position.

#### ADVANTAGES OF ASPHALT EMULSIONS

The main advantages of using emulsions rather than cutbacks can be summarized in terms of pollution control and safety.

#### **Pollution Control**

Kerosene and gas fumes are green house gases. In a cutback, they evaporate into the air and become pollutants. The cutbacks are designed this way. In an emulsion, there are no such pollutants.

#### Safety

Since emulsions are water based, they have no flash point and are not flammable or explosive. Drums of emulsion kept in the sun will not expand or burst. Being water based, emulsions do not pose any health risk to workers. Since they can be used at cooler temperatures (125 - 185° F., 52 - 85° C.), the likelihood of severe burns is also much less. The binder material should be accompanied by a Material Data Safety Sheet (MSDS).

#### STORAGE AND HANDLING OF ASPHALT EMULSIONS

As discussed earlier, there are advantages of using emulsions compared to hot asphalt cement and cutbacks. There are a few simple rules for successful use of asphalt emulsions. They are simple if one remembers how emulsions are made. **Oftentimes, suppliers are the best source of information on storage and handling of specific products.** Some general best practices are summarized here.

#### **Pumping**

Pumps compress or shear the material that they pump. This results in the emulsion being compressed. If this happens too severely or often the emulsion will become coarser and may go back to asphalt cement. Pumps should be selected carefully. Centrifugal pumps and some types of positive displacement pumps may be used.

#### **Temperature**

When materials get cold they shrink. In an emulsion, this means that the asphalt droplets get closer together. Thus, if the emulsion gets too cold, the asphalt particles can become too close together causing the emulsion to revert back to asphalt cement.

When materials get hot they expand. Thus for an emulsion, heating is a useful thing. However, when water gets hot its evaporation rate increases enormously. If the water leaves the emulsion, the asphalt droplets get closer together which can return the emulsion to asphalt cement. This can occur if any part of the emulsion gets hotter than 200° F (95° C).

This has a number of important results:

- When heating emulsion, do it gently and only to specification.
- Use agitation.
- Warm pumps before use.
- On bulk tanks in cold areas, electrical tracing is advisable.
- Do not apply direct heat to an emulsion with fire or a blow torch.

#### Cleaning

For emulsions, cleanliness is very important. A sloppy operation will produce problems. When an emulsion comes in contact with air it can begin to break. When a cationic emulsion comes into contact with metal it can also begin to break. Thus, if a pump is left without flushing it will clog. If lines are left part full of emulsion they will clog. The higher the performance of the emulsion the more critical cleaning is. Cleaning should be done before storage of equipment and it should be done thoroughly.

#### Cleaning Procedure:

- 1. Flush thoroughly with WATER.
- 2. Flush with kerosene, not diesel, distillate or other solvent. While these materials may cut asphalt cement, they are also incompatible with the emulsion and may break it rather than allow it to be flushed away.
- 3. Finish with a water flush. DO NOT FLUSH INTO THE EMULSION TANK.
- 4. If the pump or line is already clogged with asphalt cement, gentle heat may be applied at the blockage. Do not apply up the line as this will break the emulsion there.
- 5. Soak pumps with kerosene for an hour or more.
- 6. Reflush with water after blockage is removed.

# CHAPTER 4. SEAL COAT DESIGN

Seal coats should be designed to ensure that the proposed materials are of sufficient quality and have the desired properties required for a successful seal coat project. In addition, the design will determine the proper amount of cover aggregate and bituminous binder to apply. The design procedure recommended by the author is based on the one first presented in the late 1960's by Norman McLeod (5). This procedure was later adapted by the Asphalt Institute (6) and the Asphalt Emulsion Manufacturers Association (7). It was also the design procedure used by the Strategic Highway Research Program (SHRP) for designing the Special Pavement Study chip seal sections constructed across the United States (8).

## **ASPHALT BINDER CONSIDERATIONS**

In both cutback asphalts and asphalt emulsions, a portion of the binder is comprised of either cutter (cutbacks) or water (emulsions) which will evaporate as the binder cures. This will result in a collapse of the asphalt film; effectively reducing the height of the binder. In designing a seal coat is it important to know the *residual asphalt content* of the binder. The residual asphalt is the glue that remains on the roadway after the cutter or water has evaporated out of the binder.

As shown in Figure 4.1 cutback asphalts generally consist of about 85 percent asphalt cement and 15 percent cutter, by weight. Since the specific gravity of asphalt is very close to 1.0, this works out to about 85 percent asphalt cement and 15 percent cutter by volume. Asphalt emulsions generally consist of about two-thirds asphalt cement, with the remainder being water and emulsifier.

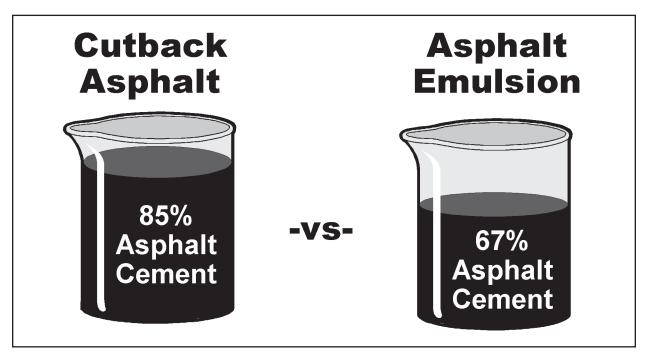


Figure 4.1. Comparison of the residual asphalt content of different binders

In Minnesota, many agencies reported problems when first switching from cutbacks to emulsions. Most of the problems occurred because they were applying the same amount of

emulsion as they had been with cutbacks. This results in approximately 20 percent less asphalt cement on the pavement *after* curing. This lack of binder led to excessive chip loss and lack of confidence in asphalt emulsions. This problem can be avoided if the concept of residual asphalts is understood.

In order for aggregate particles to remain on the roadway, they need to have approximately 70 percent of their height embedded into the *residual asphalt*. For this to occur with an asphalt emulsion, the binder must rise near the top of the aggregate particles. This is demonstrated in the Figure 4.2. If the emulsion rises just below the top of the aggregate (voids ~ 100 percent filled), the voids will be roughly two-thirds filled after curing since about one-third of the binder will evaporate. Failure to allow emulsions to rise this high will result in insufficient embedment and loss of the cover aggregate as soon as the seal coat is exposed to snow plows and traffic.

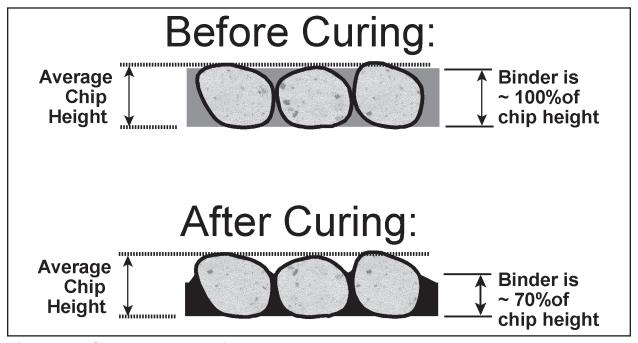


Figure 4.2. Change in volume after emulsion has cured

Refer to Chapter 3 of this handbook for more details an asphalt binders used in seal coat construction.

### **COVER AGGREGATE CONSIDERATIONS**

When designing a seal coat, there are several factors concerning the aggregate that must be considered. They all play a role in determining how much aggregate and binder should be applied to the roadway.

#### Gradation

The gradation of the cover aggregate is important not only for determining the aggregate application rate but also the binder application rate. The more graded the aggregate is, the closer the particles will be to each other on the roadway. This leaves very little room for the asphalt binder, which can cause bleeding. The best gradation for a seal coat aggregate is one-

size. This means that most every chip is the same size. A one-size aggregate has lots of room between the particles for filling with the binder. In addition, inspection is much easier because each chip is embedded approximately the same amount.

## **Particle Shape**

The shape of the aggregate particles can be round or angular, flat or cubical. Their shape will determine how they lock together on the roadway. The more they lock together, the better the seal coat is able to withstand turning and stopping of vehicles as well as damage from snow plows.

# **Bulk Specific Gravity**

The specific gravity, or unit weight, of the aggregate also plays a role in determining how much aggregate to apply to the roadway. Specific gravities of seal coat aggregate in Minnesota can differ by as much as 20 percent. The lower the specific gravity, the lighter the aggregate. It will take more pounds of a heavy aggregate, such as trap rock, to cover a square yard or meter of pavement than it will of a light aggregate, such as limestone.

# **Aggregate Absorption**

The amount of binder applied to the roadway not only needs to compensate for absorption into the existing pavement but also into the cover aggregate itself. Sedimentary aggregates such as limestone can have ten times the absorption of igneous aggregate such as granite or trap rock. Failure to recognize this fact and correct for it can lead to excessive chips loss due to lack of embedment.

### THE McLEOD DESIGN PROCEDURE

In the McLeod procedure, the aggregate application rate depends on the aggregate gradation, shape, and specific gravity. The binder application rate depends on the aggregate gradation, absorption and shape, traffic volume, existing pavement condition and the residual asphalt content of the binder

In Minnesota, the McLeod design procedure has been modified to apply slightly more binder in order to minimize snow plow damage in the non-wheelpath areas. This will be discussed later in this chapter.

The McLeod procedure is based on two basic principles:

- 1. The application rate of a given cover aggregate should be determined so that the resulting seal coat will only be **one-stone thick**. This amount of aggregate will remain constant, regardless of the binder type or pavement condition.
- 2. The voids in this aggregate layer need be **70 percent filled with asphalt cement** for good performance on pavements with moderate levels of traffic.

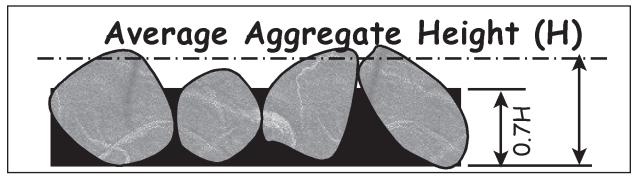


Figure 4.3. McLeod design: One-stone thick & proper embedment

Figure 4.4 shows an inspector checking for proper chip embedment. Notice that the chip is embedded about 70 percent into the residual asphalt. This will help to ensure good chip retention.



Figure 4.4. Proper embedment (~70%) into the residual asphalt

The key components of the McLeod design procedure are as follows:

### Median Particle Size

The Median Particle Size (M) is determined from the gradation chart. It is the theoretical sieve size through which 50 percent of the material passes (50 percent passing size). The gradation is determined using the following sieves:

**Table 4.1.** Sieve nest for seal coat gradations

Sieve Name	Opening U.S. Customary Units	Opening S.I. Metric Units
1 inch	1.000 in.	25.0 mm
3/4 inch	0.750 in.	19.0 mm
1/2 inch	0.500 in.	12.5 mm
3/8 inch	0.375 in.	9.5 mm
1/4 inch	0.250 in.	6.3 mm
No. 4	0.187 in.	4.75 mm
No. 8	0.0937 in.	2.36 mm
No. 16	0.0469 in.	1.18 mm
No. 50	0.0117 in.	300 μm
No. 200	0.0029 in.	75 µm



Figure 4.5. Seal Coat Sieve Nest

Flakiness Index (FI) is a measure of the percent, by weight, of flat particles. It is determined by testing a small sample of the aggregate particles for their ability to fit through a slotted plate (Figure 4.6).

There are five slots in the plate for five different size fractions of the aggregate. If the chips can fit through the slotted plate they are considered to be flat. If not, they are considered to be cubical. The lower the Flakiness Index, the more cubical the material is. The test is run according to Central Federal Lands Highway Division (CFLHD) DFT-508 (9).

The five slots in the plates are for the following:

- Slot 1: Material passing the 1 in. sieve (25 mm) but retained on the 3/4 in. sieve (19 mm).
- Slot 2: Material passing the 3/4 in. sieve (19 mm) but retained on the 1/2 in. sieve (12.5 mm).
- Slot 3: Material passing the 1/2 in. sieve (12.5 mm) but retained on the 3/8 in. sieve (9.5 mm).
- Slot 4: Material passing the 3/8 in. sieve (9.5 mm) but retained on the 1/4 in. sieve (6.3 mm).
- Slot 5: Material passing the 1/4 in. sieve (6.3 mm) but retained on the No.4 sieve (4.75 mm).

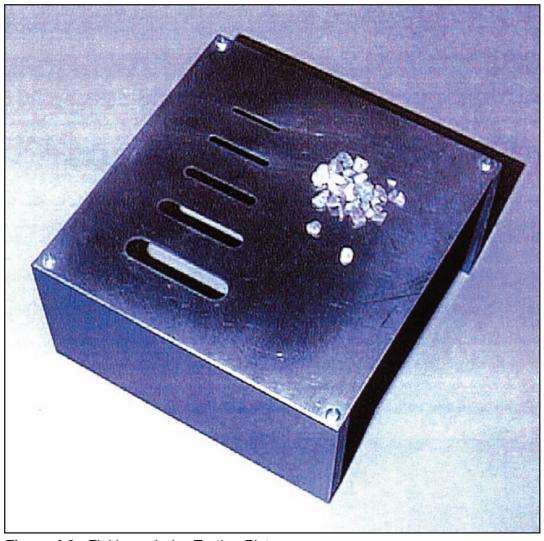


Figure 4.6. Flakiness Index Testing Plate

For most seal coat aggregate in Minnesota only the smallest three slots are used. This is because most seal coat projects do not use 1, 3/4 or 1/2 inch (25, 19 or 12.5 mm) stone. The weight of material passing all the slots is then divided by the total weight of the sample to give the percent flat particles, by weight, or Flakiness Index.

# **Average Least Dimension**

The Average Least Dimension, or ALD (H), is determined from the Median Particle Size (M) and the Flakiness Index (FI). It is a reduction of the Median Particle Size after accounting for flat particles. It represents the expected seal coat thickness in the wheelpaths where traffic forces the flat chips to lie on their flattest side.

The Average Least Dimension is calculated as follows:

$$H = \frac{M}{1.139285 + (0.011506) (FI)} \tag{1}$$

Where:

H = Average Least Dimension, inches or mm

M = Median Particle Size, inches or mm

FI = Flakiness Index, in percent

## **Loose Unit Weight of the Cover Aggregate**

The loose unit weight (W) is determined according to ASTM C 29 and is needed to calculate the voids in the aggregate in a loose condition. The loose unit weight is used to calculate the air voids expected between the chips after initial rolling takes. It depends on the gradation, shape, and specific gravity of the aggregate. Well-graded aggregate and aggregate with a high dust content will have the highest loose unit weight because the particles pack together tightly leaving little room for air. This air space between the aggregate particles is the only space available to place the binder.

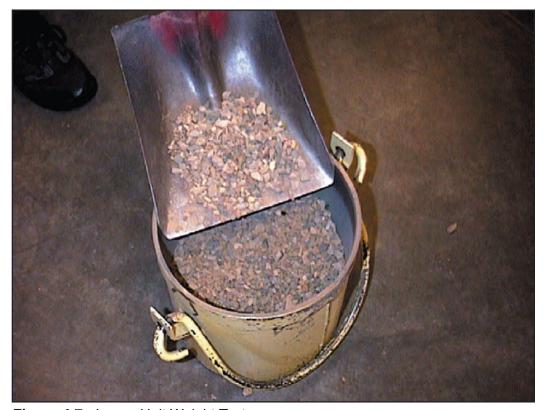


Figure 4.7. Loose Unit Weight Test

# **Voids in the Loose Aggregate**

The voids in the loose aggregate (V) approximate the voids present when the chips are dropped from the spreader onto the pavement. Generally, this value will be near 50 percent for one-size aggregate, less for graded aggregate. After initial rolling, the voids are assumed to be reduced to 30 percent and will reach a low of about 20 percent after sufficient traffic has oriented the stones on their flattest side. However, if there is very little traffic, the voids will remain 30 percent and the seal coat will require more binder to ensure good chip retention. One of the following equations is used to calculate the voids in the loose aggregate:

### U.S. Customary Units:

$$V = 1 - \frac{W}{62.4G}$$
 (2)

Where:

V = Voids in the Loose Aggregate, in percent expressed as a decimal

W = Loose Unit Weight of the Cover Aggregate, ASTM Method C 29, lbs/ft<sup>3</sup>

G = Bulk Specific Gravity of the Aggregate

### S.I. Metric Units:

$$V = 1 - \frac{W}{1000G}$$
 (3)

Where:

V = Voids in the Loose Aggregate, in percent expressed as a decimal

W = Loose Unit Weight of the Cover Aggregate, ASTM Method C 29, kg/m<sup>3</sup>

G = Bulk Specific Gravity of the Aggregate

## **Bulk Specific Gravity**

Different aggregates have different specific gravities or unit weights. This value must be taken into account in the design procedure because it will take more pounds of a heavy aggregate to cover a square yard of pavement than it will for a light aggregate. Table 4.2 can be used as a guideline for determining the specific gravity of typical seal coat aggregates in Minnesota.

Table 4.2. Typical Bulk Specific Gravity of Common Seal Coat Aggregates in Minnesota

Aggregate type			Class A		Clas	s B	Class C
		Granite	Quartzite	Trap Rock	Limestone	Red Rock	Pea Rock
Bulk	Min.	2.60	2.59	2.95	2.40	2.50	2.55
Specific	Max.	2.75	2.63	2.98	2.67	2.52	2.66
Gravity	Avg.	2.68	2.62	2.97	2.61	2.51	2.62

# **Aggregate Absorption**

Most aggregates absorb some of the binder applied to the roadway. The design procedure must be able to correct for this condition to ensure enough binder will remain on the pavement surface. Table 4.3 can be used as a guideline. A good rule of thumb is that Class A aggregates generally

do not require a correction for absorption, whereas Class B and C aggregates generally do. McLeod suggests an absorption correction factor, A, of 0.02 gal/yd² (0.09 L/m²) if the aggregate absorption is around 1 percent. The author recommends using this correction if the absorption is 1.5 percent or higher.

Table 4.3. Typical Absorption of Common Seal Coat Aggregates in Minnesota

A			Class A		Clas	s B	Class C
Aggregate t	ype	Granite	Quartzite	Trap Rock	Limestone	Red Rock	Pea Rock
Percent	Min.	0.40	0.61	0.31	1.75	no data	1.14
Absorption	Max.	0.92	0.72	0.59	5.44	no data	2.32
	Avg.	0.59	0.67	0.43	2.80	-	1.69

### **Traffic Volume**

The traffic volume on the pavement surface, in terms of the number of vehicles per day, plays a role in determining the amount of asphalt binder needed to sufficiently embed the chips. Generally speaking, the higher the traffic volume, the lower the binder application rate. At first glance this may not seem correct. However, remember that traffic forces the chips to lay on their flattest side. Consequently, the greater the traffic volume the greater the chance the chips will be laying on their flat side. If a roadway had no traffic, the chips would be laying in the same orientation as when they were first rolled during construction. As a result, they would stand taller and need more asphalt binder to achieve the desired 70 percent embedment. With enough traffic, the chips will be laying as flat as possible causing the seal coat to be as thin as possible. If this is not taken into account, the wheelpaths will likely bleed. The McLeod design procedure uses Table 4.4 to estimate the required embedment, based on the number of vehicles per day on the roadway.

Table 4.4. Traffic Correction Factor, T

<b>Traffic Factor</b> The percentage, expressed as a decimal, of the ultimate 20 percent void space in the cover aggregate to be filled with asphalt				
	Traffic - Vehicles per day			
under 100	100 to 500	500 to 1000	1000 to 2000	Over 2000
0.85	0.75	0.70	0.65	0.60

**Note:** The factors above do not make allowance for absorption by the road surface or by absorptive cover aggregate.

## **Traffic Whip-Off**

The McLeod procedure also recognizes that some of the cover aggregate will get thrown to the side of the roadway by passing vehicles as the fresh seal coat is curing. The amount that will do this is related to the speed and number of vehicles on the new seal coat. To account for this, a traffic whip-off factor (E) is included in the aggregate design equation. A reasonable value

to assume is 5 percent for low volume, residential type traffic and 10 percent for higher speed roadways such as county roads. The traffic whip-off factor is shown in Table 4.5

**Table 4.5.** Aggregate Wastage Factor, E (Source: Asphalt Institute MS-19, March 1979)

Percentage Waste* Allowed For	Wastage Factor, E
1	1.01
2	1.02
3	1.03
4	1.04
5	1.05
6	1.06
7	1.07
8	1.08
9	1.09
10	1.10
11	1.11
12	1.12
13	1.13
14	1.14
15	1.15

<sup>\*</sup>Due to traffic whip-off and handling

# **Existing Pavement Condition**

The condition of the existing pavement plays a major role in the amount of binder required to obtain proper embedment. A new smooth pavement with low air voids will not absorb much of the binder applied to it. Conversely, a dry, porous and pocked pavement surface can absorb a tremendous amount of the binder. Failure to recognize when to increase or decrease the binder application rate to account for the pavement condition can lead to excessive chip loss or bleeding. The McLeod procedure uses the descriptions and factors in Table 4.6 to add or reduce the amount of binder to apply in the field.

**Table 4.6.** Surface Correction Factor, S

	Correction	n, S
Existing Pavement Texture	S.I. Metric (L/m²)	U. S. Customary (gal/yd²)
Black, flushed asphalt	-0.04 to -0.27	-0.01 to -0.06
Smooth, non-porous	0.00	0.00
Slightly porous & oxidized	+0.14	+0.03
Slightly pocked, porous & oxidized	+0.27	+0.06
Badly pocked, porous & oxidized	+0.40	+0.09

The inspector needs to be aware of these condition should they change at some point throughout the project.

Most agencies seal roadways built during different years by different contractors with different materials as part of a single contract. Included may be new pavements, old pavements, porous pavements, flushed pavements, etc. For this reason, *it is not practical to assume that all roadways to be sealed in a given project will need the same amount of asphalt binder.* 

Examples of some of these pavement conditions are shown in Figures 4.8 to 4.11.

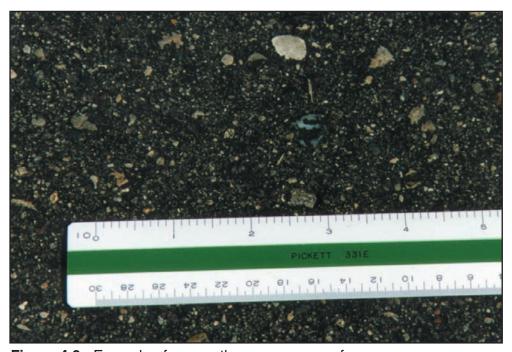


Figure 4.8. Example of a smooth, non-porous surface



Figure 4.9. Example of a slightly porous and oxidized surface



Figure 4.10. Example of a slightly pocked, porous and oxidized surface



Figure 4.11. Example of a badly pocked, porous and oxidized surface

### McLEOD SEAL COAT DESIGN EQUATIONS

Once all the lab testing as completed, the following equations are then used to determine the aggregate and binder application rates. While the results may need to be adjusted in the field, especially the binder application rate, they have shown to provide a close approximation of the correct quantity of materials.

## **Aggregate Design Equation**

The aggregate application rate is determined from the following equations:

# U.S. Customary Units:

$$C = 46.8(1-0.4V)HGE$$
 (4)

## Where:

C = Cover Aggregate Application Rate, lbs/yd²

V = Voids in the Loose Aggregate, in percent expressed as a decimal (Equation 2)

H = Average Least Dimension, inches

G = Bulk Specific Gravity of the Aggregate

E = Wastage Factor for Traffic Whip-Off (Table 4.5)

$$C = (1-0.4V)HGE \tag{5}$$

Where:

C = Cover Aggregate Application Rate, kg/m<sup>2</sup>

V = Voids in the Loose Aggregate, in percent expressed as a decimal (Equation 3)

H = Average Least Dimension, mm

G = Bulk Specific Gravity of the Aggregate

E = Wastage Factor for Traffic Whip-Off (Table 4.5)

# **Binder Design Equation**

# U.S. Customary Units:

$$B = \frac{(2.244)(H)(T)(V) + S + A}{B}$$
 (6)

Where:

B = Binder Application Rate, gallons/yd<sup>2</sup>

H = Average Least Dimension, inches

T = Traffic Factor (based on expected vehicles per day, Table 4.4)

V = Voids in Loose Aggregate, in decimal percent (Equation 2)

S = Surface Condition Factor, gal/yd² (based on existing surface, Table 4.6)

A = Aggregate Absorption Factor, gallons/yd<sup>2</sup>

R = Residual Asphalt Content of Binder, in percent expressed as a decimal

## S.I. Metric Units:

$$B = \frac{(0.40)(H)(T)(V) + S + A}{R}$$
 (7)

Where:

B = Binder Application Rate, liters/m<sup>2</sup>

H = Average Least Dimension, mm

T = Traffic Factor (based on expected vehicles per day, Table 4.4)

V = Voids in Loose Aggregate, in decimal percent (Equation 3)

S = Surface Condition Factor, liters/m<sup>2</sup> (based on existing surface, Table 4.6)

A = Aggregate Absorption Factor, liters/m<sup>2</sup>

R = Residual Asphalt Content of Binder, in percent expressed as a decimal

One additional calculation has been made to the McLeod design to account for snow plow damage. After the binder design equation is done using the ALD, it is recalculated using the Median Particle Size in place of the ALD. This will give the binder required if none of the chips lay flat. The average of these two values is then used as the starting point for the field test sections discussed in Chapter 7 of this manual. It had been found that if this is not done, insufficient binder will exist in the non-traffic areas and snow plows will shave off the stones in these areas.

The following example is given to demonstrate how to use the design equations to determine binder and cover aggregate application rates.

### **SEAL COAT DESIGN EXAMPLE**

A 150 pound (68kg) sample if an FA-3 granite seal coat aggregate has been submitted for design. The traffic on the road to be sealed is 850 vehicles per day. The pavement surface is slightly pocked, porous and oxidized. The binder will be a CRS-2 emulsion with 67% residual asphalt.

Step 1: Determine the aggregate gradation, bulk specific gravity and percent absorption

#### Gradation results:

Sieve	Sieve	Opening	Percent
Name	U.S. Customary	S.I. Metric	Passing
1/2 inch	0.50 in.	12.5 mm	100
3/8 inch	0.375 in.	9.5 mm	92
1/4 inch	0.25 in.	6.3 mm	85
No. 4	0.187 in.	4.75 mm	18
No. 8	0.0937 in.	2.36 mm	6
No. 16	0.0469 in.	1.18 mm	3
No. 50	0.0117 in.	300 μm	1
No. 200	0.0029 in.	75 µm	0.4

- Based on AASHTO T 84-94 the bulk specific gravity of was determined to be 2.71.
- Based on AASHTO T 84-94 the aggregate absorption was determined to be 0.3 percent.

# Step 2. Determine the Median Particle Size

The gradation results in the table above are then plotted on a gradation chart. The Median Particle Size is determined by extending a horizontal line at 50 percent passing mark until it intersects the gradation curve. A vertical line is then projected downward which gives the Median Particle Size. This is the theoretical size where half of the stones are larger and half smaller. It is considered to be theoretical because there may not actually be any stones that size.

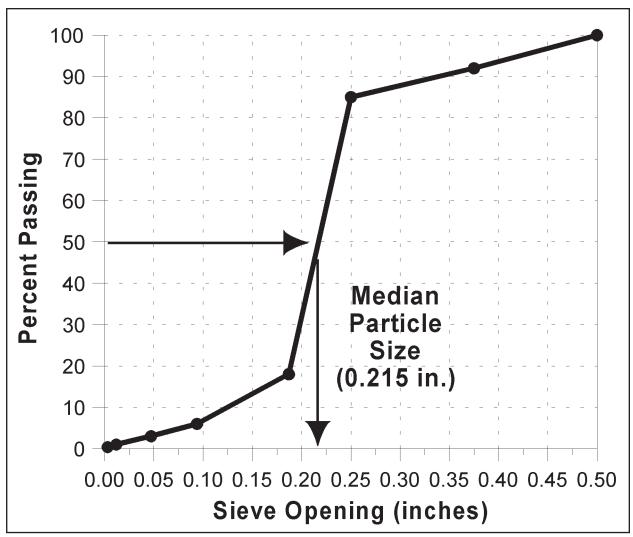


Figure 4.12 Gradation Chart for the Design Example showing the Median Particle Size

# Step 3. Determine the Flakiness Index (FI)

The aggregate used to determine the gradation is then broken down into the following fractions:

- (1) Passing the 1 in. sieve but retained on the 3/4 in. sieve;
- (2) Passing the 3/4 in. sieve but retained on the 1/2 in. sieve;
- (3) Passing the 1/2 in. sieve but retained on the 3/8 in. sieve;
- (4) Passing the 3/8 in. sieve but retained on the 1/4 in. sieve; and
- (5) Passing the 1/4 in. sieve but retained on the No. 4. sieve.

Since all of the material passed the 1/2 in. sieve, only the last three fractions are used. The aggregate particles in each fraction are tested to see if they fit through the slotted plate (Figure 4.6). The results are shown on the next table.

### Flakiness Index Test Results

Size Fraction	Weight Retained on Slot (grams)	Weight Passing Slot (grams)
1/2 to 3/8 in.	54.2	12.3
3/8 to 1/4 in.	123.3	43.5
1/4 in. to No.4	184.4	89.5
Totals	361.90	145.3

The Flakiness Index is calculated as follows:

$$FI = \frac{\text{(Weight of Flat Chips)}}{\text{(Weight of Sample)}} = \frac{\text{(145.3)}}{\text{(361.90 + 145.3)}} = \frac{\text{(145.3)}}{\text{(507.2)}} = 28.6 \text{ percent}$$
 (8)

# Step 4. Determine the Average Least Dimension (H)

The Average Least Dimension, or ALD, is the expected thickness of the seal coat in the wheelpaths after any flat chips have been oriented on their flattest side by traffic. It is calculated from the Median Particle Size (M) and the Flakiness Index (FI) as follows:

## U.S. Customary Units:

$$H = \frac{M}{1.139285 + (0.011506) (FI)} = \frac{0.215 \text{ in.}}{1.139285 + (0.011506)(28.6)} = 0.146 \text{ inches}$$
(9)

### S.I. Metric Units:

$$H = \frac{M}{1.139285 + (0.011506) (FI)} = \frac{5.50 \text{ mm}}{1.139285 + (0.011506)(28.6)} = 3.75 \text{ mm}$$
(10)

## Step 5. Determine the Loose Weight of the Aggregate (W)

A metal cylinder with the volume of 0.50 ft³ (0.014m³) was loosely filled with aggregate (as shown in Figure 4.7) until full. The weight of the aggregate was then determined. This was repeated three time with results in the following table. The average of the three is then used to determine the Loose Unit Weight of the aggregate.

# Loose Weight Test Results

Test Number	Weight of the Aggregate in the Cylinder (lbs)	Weight of the Aggregate in the Cylinder (kg)
1	45.25	20.57
2	45.32	20.60
3	45.29	20.59
Average	45.29	20.59

The Loose Unit Weight (W) is calculated as follows:

## U.S. Customary Units:

$$W = \frac{\text{Weight of aggregate}}{\text{Volume of cylinder}} = \frac{45.29 \text{ lbs}}{0.50 \text{ ft}^3} = 90.58 \text{ lbs/ft}^3$$
(11)

## S.I. Metric Units:

$$W = \frac{\text{Weight of aggregate}}{\text{Volume of cylinder}} = \frac{20.59 \text{ kg}}{0.014 \text{ m}^3} = 1,471 \text{ kg/m}^3$$
 (12)

# Step 6. Determine the Voids in the Loose Aggregate (V)

Using Equations 13 and 14, the voids in the loose aggregate are calculated. The higher the voids, the more room for the asphalt binder and the more one-size the aggregate is.

## U.S. Customary Units:

$$V = 1 - \frac{W}{62.4G} = 1 - \frac{90.58 \text{ lbs/ft}^3}{(62.4)(2.71)} = 0.46$$
 (13)

## S.I. Metric Units:

$$V = 1 - \frac{W}{1000G} = 1 - \frac{1,471 \text{ kg/m}^3}{(1000)(2.71)} = 0.46$$
 (14)

Since 0.46 is fairly close to 0.50, this is a fairly one-size aggregate.

# Summarizing the above information:

Test	U.S. Customary Units	S.I. Metric Units
Median Particle Size	0.215 inches	5.50 mm
Flakiness Index	28.6 percent	28.6 percent
Average Least Dimension	0.146 inches	3.75 mm
Loose Unit Weight	90.58 lbs/ft³	1,470 kg/m³
Voids in the Loose	0.46	0.46
Aggregate		
Traffic Volume	500 - 1000 vehicles/day	500 - 1000 vehicles/day
	Uses 5% whip-off	Uses 5% whip-off
Surface Condition	Slightly pocked, porous and	Slightly pocked, porous and
	oxidized	oxidized
Bulk Specific Gravity	2.71	2.71
Aggregate Absorption	0.31 percent	0.31 percent
	No adjustment needed	No adjustment needed
Residual Asphalt Content of the Binder	0.67	0.67

## **Cover Aggregate Application Rate**

# U.S. Customary Units:

$$C = 46.8 (1-(0.4)(V))(H)(G)(E) = 46.8(1-(0.4)(0.46))(0.146 \text{ in.})(2.71)(1.05) = 15.8 \text{ lbs/yd}^2$$
 (15)

# Where:

C = Cover Aggregate Application Rate, lbs/yd²

V = Voids in the Loose Aggregate, in percent expressed as a decimal

H = Average Least Dimension, inches

G = Bulk Specific Gravity of the Aggregate

E = Wastage Factor for Traffic Whip-Off (Table 4.5)

## S.I. Metric Units:

$$C = (1-(0.4)(V))(H)(G)(E) = (1-(0.4)(0.46))(3.75 \text{ mm})(2.71)(1.05) = 8.7 \text{ kg/m}^2$$
 (16)

# Where:

C = Cover Aggregate Application Rate, kg/m<sup>2</sup>

V = Voids in the Loose Aggregate, in percent expressed as a decimal

H = Average Least Dimension, mm

G = Bulk Specific Gravity of the Aggregate

E = Wastage Factor for Traffic Whip-Off (Table 4.5)

The recommended results should be rounded up to the nearest pound or kilogram. Once the aggregate application rate has been determined it is a good idea to test it. This is done by spreading the recommended amount of aggregate in a one square yard (or one square meter) plywood box. The aggregate should provide a one-stone thick layer. This will provide a good representation of how the seal coat should look in the field. In the field, the aggregate application rate does not need to be adjusted to account for traffic or surface condition as does the binder.

## **Binder Design Equation**

The binder application rate is determined from the following equations:

# U.S. Customary Units:

$$B = \frac{(2.244)(H)(T)(V) + S + A}{R}$$
(17)

Where:

B = Binder Application Rate, gallons/yd²

H = Average Least Dimension, inches

T = Traffic Factor (based on expected vehicles per day, Table 4.4)

V = Voids in Loose Aggregate, in decimal percent (Equation 2)

S = Surface Condition Factor, gallons/yd² (based on existing surface, Table 4.6)

A = Aggregate Absorption Factor, gallons/yd<sup>2</sup>

R = Residual Asphalt Content of Binder, in decimal percent

Binder Application Rate for Wheelpaths:

$$B = \frac{(2.244)(0.146 \text{ in.})(0.70)(0.46) + 0.06 + 0.00}{0.67} = 0.25 \text{ gal/yd}^2$$
(18)

This application rate should provide proper embedment of the chips once they have laid on their flattest side. In Minnesota, it is recommended that the binder application rate for non-traffic areas also be calculated and the average of the two be used as the starting point in the field. This is done by substituting the Median Particle Size for the Average Least Dimension.

Binder Application Rate for non-wheelpaths areas:

$$B = \frac{(2.244)(0.215 \text{ in.})(0.70)(0.46) + 0.06 + 0.00}{0.67} = 0.32 \text{ gal/yd}^2$$
(19)

Take the average of the two as the starting point in the field:

Starting Application Rate in the Field = 
$$\frac{0.25 + 0.32}{2} = 0.29 \text{ gal/yd}^2$$
 (20)

$$B = \frac{(0.40)(H)(T)(V) + S + A}{R}$$
 (21)

Where:

B = Binder Application Rate, liters/m<sup>2</sup>

H = Average Least Dimension, mm

T = Traffic Factor (based on expected vehicles per day, Table 4.4)

V = Voids in Loose Aggregate, in decimal percent (Equation 3)

S = Surface Condition Factor, liters/m² (based on existing surface, Table 4.6)

A = Aggregate Absorption Factor, liters/m<sup>2</sup>

R = Residual Asphalt Content of Binder, in decimal percent

Application rate for wheelpaths:

$$B = \frac{(0.40)(3.75 \text{ mm})(0.70)(0.46) + 0.27 \text{ L/m}^2 + 0.00}{0.67} = 1.12 \text{ L/m}^2$$
 (22)

The binder application rate in the non-traffic areas is:

$$B = \frac{(0.40)(5.50 \text{ mm})(0.70)(0.46) + 0.27 \text{ L/m}^2 + 0.00}{0.67} = 1.46 \text{ L/m}^2$$
(23)

Once again, take the average as a starting point in the field:

Starting Application Rate in the Field = 
$$\frac{1.12 + 1.46}{2}$$
 = 1.29 L/m<sup>2</sup> (24)

## **SUMMARY**

In summary, a good seal coat design incorporates many factors of the binder and aggregate. The results should yield a good starting point for field test sections. Experience has shown that the aggregate application rate determined from the equations is almost always the correct rate to apply in the field. However, since the binder application rate makes assumptions concerning the amount of texture and porosity of the existing pavement, the binder application rate will almost always need to be adjusted. Most of the time it will need to be adjusted upward (apply more binder).

A good tool to use in the field is a binder adjustment chart. This type of chart calculates the design application rate for all combinations of traffic (Table 4.4) and surface condition (Table 4.6). It can be used by the inspector to make adjustments in the field. Figure 4.13 shows the binder adjustment chart for the above example.

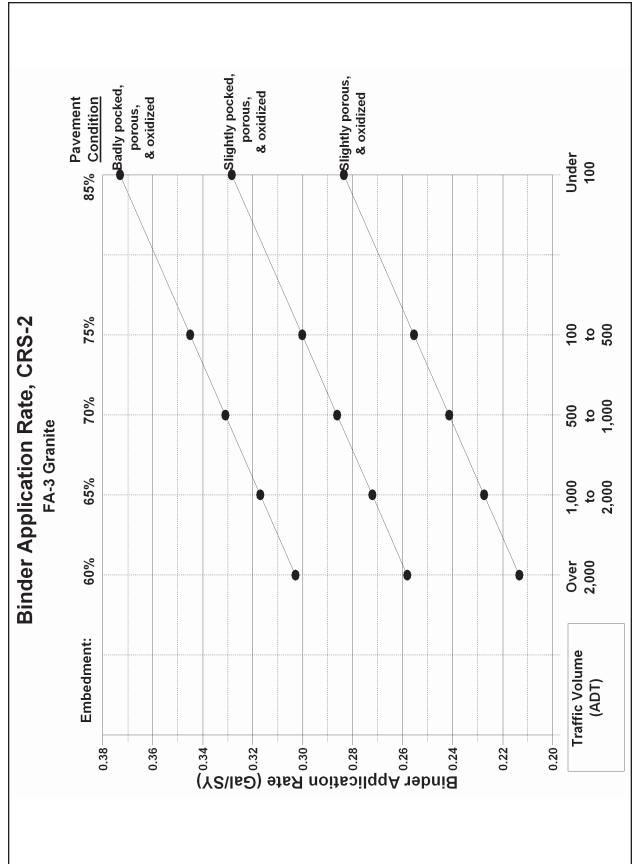


Figure 4.13. Example of a Binder Adjustment Chart

# CHAPTER 5. FOG SEALING

Fog sealing is a method that is used to lock in chips by placing a light application of a diluted asphalt emulsion over a chip seal. It is commonly done to ensure reduction of stone loss and to add life to the pavement by increasing a pavement's impermeability to water and air.

Fog seals may be applied to an existing pavement as a means of rejuvenation or to a new chip seal application to reduce stone loss and increase pavement life. In any application, the fog seal material (emulsion) must be of sufficiently low viscosity to penetrate the voids.

### SURFACE PREPARATION AND SITE CONDITIONS

Fog sealing can only be done on a clean, dry pavement surface. As part of a new chip seal application, it should be done immediately after sweeping. To be effective, fog seals need to break quickly (revert to solid asphalt) and cure completely (lose water to form a cohesive film). Asphalt films do not form well at low temperatures. Therefore, warm conditions with little to no chance of rain are necessary to ensure successful applications. Fog seals should not to be applied when the air temperature is below 60°F. If unexpected rain occurs, prior to the emulsion breaking, the emulsion may wash out of the pores of the pavement and break on the surface of the pavement creating a slippery surface.

### FOG SEAL APPLICATION

When applying a fog seal, properly calibrated distribution trucks are critical. Spray nozzles should be adjusted based on the manufacturer's recommendation to ensure proper application.

Mn/DOT specifications call for fog sealing all chip seal applications as a matter of course, with the exception of residential streets. The standard application method is to lap the centerline in both directions. For example, if the travel lanes are 12-feet wide, then the fog seal should be applied to a 13-foot swath of roadway in both directions, lapping over the centerline. What this accomplishes is the maximum placement of embedment on the area of the roadway receiving the least amount of traffic. In Minnesota, this is especially critical as it ensures protection of the chip seal during the winter months from the impact of snow removal equipment. In one test of fog sealing applied under these specifications, it was found that the fog-sealed roadway suffered no snowplow damage while the non-fog-sealed segment suffered close to a 15-percent loss of chips along the centerline.

#### APPLICATION RATE

The normal application rate is from 0.06 to 0.12 gallon per square yard of diluted CSS-1h emulsion (depending on the size of chip used). A higher rate of application is used for coarser chips with the rate lowering as the chips become more fine. Minnesota requires a dilution rate of one part emulsion done at the place of the emulsion manufacture.

## THE BENEFITS OF FOG SEALING

There are numerous benefits resulting from a fog seal application.

- 1. The traveling public thinks it is driving on a new HMA surface rather than a chip seal.
- 2. The emulsion is diluted, which yields a very low viscosity that allows most, if not all, of the additional asphalt binder to fill the chip voids increasing embedment by up to 15-percent with no bleeding.
- 3. The fog seal re-seals any chips that may have partially broken loose during sweeping operations.
- 4. Darkening the pavement surface with a light application of asphalt emulsion allows the pavement surface temperature to rise. The subsequent softening of the binder allows the chips to orient to their least dimension more quickly. This factor is very important in Minnesota where late season chip seal projects are more susceptible to failure due to colder weather conditions.
- 5. Fog sealing can provide a designer with a chance for a "re-do" of a chip seal application. If, after traffic has driven on the surface, it appears that embedment is low, an engineer can add additional binder to the chip seal by increasing the fog seal amount. In some cases, the amount of fog seal emulsion applied increased to over 0.20 gallon per square yard.
- 6. When a fog seal is applied, a reduced amount of paint is necessary to make pavement markings visible on the surface.

# CHAPTER 6. CHIP SEALING FOR RECREATIONAL TRAILS

Because of the unique ways in which recreational trails are used and maintained, designing and applying a chip seal under these circumstances requires a slight modification of practices then when sealing a road or street. Ensuring a smooth-surfaced and even pavement surface is critical on a recreational trail. For this reason, use of an FA-1 aggregate gradation is recommended. Using a fine-graded aggregate will allow the material to distribute more evenly throughout the binder, resulting in a longer-lasting and smoother wearcourse.

### CHIP SEAL APPLICATION FOR RECREATIONAL TRAILS

Historically, the procedure for chip sealing recreational trails has been to lay down 2/10 of a gallon of asphalt binder followed by an application of 18-20 pounds of FA-1 graded aggregate per square yard. By laying down more binder than is typical when designing for a road or city street, additional aggregate will be needed for the chip seal. The combination of a thicker asphalt binder and a heavier application of fine-graded aggregate will result in a chip seal in which the aggregate is more evenly distributed throughout the binder material. What this means is that, as the chip seal wears down over time, the surface will remain relatively smooth with an even distribution of aggregate throughout.



Figure 6.1.

### SURFACE TREATMENT

The best possible scenario when smoothing out a freshly-applied chip seal on a recreational trail is to use a rubber-tired roller in addition to a double-drum steel roller. The steel roller will ensure that the aggregate is well-compacted and firmly set in the asphalt binder. By following this with a rubber-tired roller, a smoother surface will be ensured.

#### BEST PRACTICES FOR RECREATIONAL CHIP SEALING

Chip seals on recreational trails should only be applied during that time of the year when the trail is most structurally sound. In Minnesota, this would be during the high summer months of July and August. Since this time period also corresponds to the times when the trail will be most heavily-used, good advance warning of the application is critical. This would include signage along the trail alerting riders to dates and times of application as well as other means of notification, such as information distributed through the agency that manages the trail.

Similar to chip seals applied on roads and streets, sweeping on recreational trails should occur as soon as possible but no more than 24 hours after application. A kicker broom can be used, sweeping excess aggregate to the side of the trail, but only in relatively rural areas where this would be an acceptable practice. In other instances, a pick-up broom would have to be used to pick up the surplus rock.

If a fine-graded, FA-1 aggregate has been used, a fog seal application should not be necessary on recreational trails. The use of the heavier binder and fine-graded aggregate will accomplish what a fog seal is intended to do; namely, to ensure good aggregate embedment and a smooth surface wearcourse.

# BENEFITS OF RECREATIONAL CHIP SEALING

By managing recreational trails with a regular program of chip seal applications, the life of the trail will be extended while providing for a better recreational experience for trail users. Just as roads and streets need to receive regular maintenance to extend their pavement life, so do recreational trails. Unfortunately, some trails have degraded to the extent that they are no longer good candidates for a chip seal application. If a trail is severely block cracked and/or suffers from severe pavement deformation, then it is not a good candidate for a chip seal and will likely need to be reconstructed. However, if an asphalt-paved recreational trail has a reasonably smooth and uniform surface but is in need of some surface rehabilitation, then a chip seal can help to extend its life at a very reasonable cost. Recreational trails can be re-sealed every six to seven years, similar to best practices for road and street sealing. By thinking proactively about maintaining recreational trails, road designers and engineers can more effectively manage the trail infrastructure in their community. Chip seal applications are a relatively low-cost and cost-effective method for recreational trail pavement preservation.

# CHAPTER 7. FIELD INSPECTOR RESPONSIBILITIES

Inspecting seal coat projects is an area unfamiliar to many individuals. As with any other type of construction, the inspector must be familiar with the process and know what to look for to achieve quality results. They key to a successful seal coat project is to have a knowledgeable field inspector who can calibrate the equipment, determine if enough material is being applied to the roadway and recognize and correct any problems that arise. In addition, the field inspector sets the quality standards for the project.

#### PRECONSTRUCTION MEETING

Once the project has been bid and awarded or the public works department has completed required field preparations, a preconstruction meeting is scheduled, normally, a week prior to construction. The purpose of the meeting is to review the project parameters, timeline, and establish quality expectations. Attendees should include:

- Engineer/Public Works Director representing the owner.
- Field inspector, representing the owner.
- The designated person representing the contractor.
- Field supervisor (who should not double as a member of the crew doing the work and have authority to make field decisions).
- A recording secretary to take minutes of the meeting.

## What occurs ar the preconstruction meeting:

The Owner's Engineer/Public Works Director

- Verifies the contract documents are in order and approval to proceed is given.
- Discusses the method of payment, contract approval process, and a general overview of the project.
- Reviews/approves subcontractor(s) if any, and materials to be used on the project.
- Determine responsibility for public notification of chip sealing activities.

# The Field Inspector

- Distributes maps of the area(s) to be seal coated.
- Points out roads not to be seal coated as a part of the project (county roads, state roads, new city roads, roads under construction, etc.).
- Describes the work and reviews the contractor's responsibilities.
- Discusses bituminous material and application rates (ranges).
- Discusses aggregate materials and application rates (ranges).

- Approves equipment scheduled for the project and indicates areas where overnight parking is allowed.
- Discusses pre-sweeping and pick-up sweeping requirements, including a schedule.
- Reviews protection of existing structures and preferred method to cover manholes, gate valves, etc.
- Discusses daily commencement of work parameters.

The field inspector also inspects and approves the material to be used, determines sites to stockpile the aggregate, and location(s) for the binder transports to park during the operation prior to commencement of the project.

# Operation Field Supervisor

- Reviews anticipated starting date and normal hours.
- Discusses completion date seal coat portion and pick-up sweeping process.
- Reviews material delivery schedules.

### A TYPICAL SEAL COAT PROJECT

While not every seal coat project is the same, there are many things that will be repeated from project to project. The field inspector must be familiar with these items and pay close attention to them in order for the project to proceed smoothly. The following section will give the field inspector a good overview of what typically occurs during a seal coat project and the role they play.

## **Day One Activities**

## Review the Project

Prior to beginning the work, the inspector should drive the first few roads to be seal coated to ensure they are clean, dry, and free of obstructions, verify that appropriate traffic control is in place and that structures in the road are properly covered or protected. The inspector should also inspect and calibrate all equipment for proper operation, check for leaks, proper tire pressure on rollers, binder temperature in distributors, and ensure that all needed equipment is on the site.

Once this has been done, the equipment has been calibrated and the binder application rate adjusted for the actual field conditions, the project can proceed full speed ahead. The first day of the operation requires the field inspector's full attention and time to set the expected quality standards with the field supervisor.

Calibrating the distributor(s) and the chip spreader and notifying the field supervisor of adjustments of application rates are done frequently throughout the first day of operation.

The field inspector checks yields on binder and aggregate and discusses procedures with the field supervisor to establish the desired quality standards. The first day will set the expectations of both the filed inspector and field supervisor for the balance of the project.

# Calibrate the Chip Spreader

When the seal coat crew is assembled, the first task performed by the inspector is to calibrate the chip spreader. Calibrating the spreader will ensure that all of the gates across the front of the spreader are applying the same amount of the aggregate, ensuring uniform coverage. Also, the calibration procedure will determine the number of pounds required to apply a single layer (one stone thick) of aggregate. Refer to Chapter 8 of this handbook for more details on calibration.

Another important reason to calibrate the spreader is to ensure the amount of aggregate being placed remains within specified payment and design standards.

Lastly, the spreader needs to be calibrated before the binder application rate can be evaluated. If the cover aggregate is applied heavily (i.e. more than one layer), it will be difficult to determine if the correct amount of binder is being applied. The inspector must sweep off all the excess aggregate before he/she can determine how much embedment is being achieved.



**Figure 7.1.** Too much aggregate (no binder is visible)

## Determine the Proper Binder Application Rate

Because certain assumptions are made in the seal coat design process, the actual binder application rate must be verified in the field. Once the chip spreader is calibrated so that it is applying a single uniform layer of aggregate, the binder application rate is determined. If the

existing pavement surface is oxidized, porous and/or has lots of texture due to raveling or popouts it will require more asphalt binder. This is because some of the binder will be absorbed into the pavement and not be available for bonding to the cover aggregate. In some cases, this can be quite extreme. Increases in the binder application rate due to the existing surface conditions can add as much as 60 percent. Failure to recognize this fact can lead to the loss of aggregate in as little as one year. In order for the seal coat to be successful, the inspector must be able to determine if the proper embedment is being obtained.

## This is done by the following:

- Spray approximately 50 feet (15 meters) of one lane of pavement at the design application rate.
- Apply a single layer of cover aggregate from the calibrated chip spreader.
- Inspect the height of the binder in relation to the height of the chips in the wheelpaths of the chip spreader. The binder should rise almost to the top of the chips to ensure proper embedment after the binder cures.
- Adjust the binder application rate as necessary, generally in 0.02 gal/yd² (0.09 L/m²) increments up or down.
- Repeat until the application rate being applied is yielding the proper embedment. See Figure 5.3.
- Record the setting on the distributor's computer for comparison with the actual application rate later that day.



Figure 7.2. Not enough binder (binder is too low)



Figure 7.3. Correct amount of binder (binder has risen to top of chips)



Figure 7.4. Darker wheelpaths indicate binder has risen near the top of the aggregate

## **Day Two through Completion**

The days following should allow the inspector to monitor, inspect, and observe the operation with minimal procedural adjustments needed. The field inspector spends the majority of his/her time walking behind and ahead of the operation checking for the following:

- Making decisions on application rate adjustments.
- Ensuring full width application of seal coat.
- Requiring touch up of uncovered binder before rolling.
- Ensuring structures in the road are being protected and promptly cleaned after final rolling.
- Making sure the distributor is not applying binder too far ahead of the chip spreader (if binder starts to turn black, before the chips are applied, the distributor is too far ahead).
- Ensuring the roller operation occurs immediately behind the chip spreader.
- Making sure the traffic control devices are keeping up with the project.

Generally, the inspector will be observing and inspecting the operation from the binder application to the final rolling to ensure the product meets the desired results. At the end of each day the inspector tours the areas sealed and looks for bleeding problems, excess aggregate or

float, and how well the curing process is working. Any concerns or problems noticed should be brought to the attention of the field supervisor and corrections made as needed.

The field inspector should keep a daily dairy of the project's progress, quantities of aggregate and binder placed, weather conditions, any problems that occurred, and the performance of the equipment and operators. The inspector and field supervisor should agree on pay item quantities and calculate yields on a daily basis to minimize overruns and avoid disagreements at closing of the project.

# The Last Day

On the last day of the seal coat project, the owner's field inspector and the field supervisor should do the following:

- Agree on total pay quantities for the project in writing.
- Remove excess binder or aggregate for the site or agree on the schedule to do so.
- Review the daily diary of the project and discuss methods or ways to improve the operation for future projects.
- Clean up the sites used to store the equipment or stockpile materials.

## **Helpful Guidelines for the Field Inspector**

Appearance Checks by Field Inspector

- To determine if your application rates are appropriate to the road surface condition, try a wave test.
  - 1. Allow sealed area to cure for at least an hour or until aggregate is totally dry and dusty.
  - 2. Place your hand on the road with fingers spread and in a rapid waving motion lightly brush any loose chips until you see the remaining aggregate that stuck into the binder.
  - 3. Visibly check to see if the aggregate is uniformly covering the binder, compacted into the binder consistently, and there is adequate aggregate coverage.
  - 4. You will be able to judge if you need to adjust application rates up or down using this procedure.
- Excessive aggregate or float after an hour of curing takes place indicates the application rates should be reduced to the point where you are getting single layer coverage and minimal excess float remaining.
- Binder bleeding out the aggregate consistently after rolling indicates you should reduce the application rate of binder rather than increase the application rate of the aggregate.

- If after doing a wave test, you see that rock chips are not staying in place, you should increase the binder application rate.
- Bluish colored smoke from the binder as it is applied means binder is too hot check temperature gauge on distributor and allow to cool to specified temperature before proceeding.
- Streaking or binder lines appearing prior to initial rolling of the aggregate means that the height of the distributor bar is too high or too low and operator should adjust accordingly. See Chapter 8 for details.
- The binder will be brown in color at application and will turn black as it breaks or cures.
- The rock chips must be applied prior to the binder breaking to ensure the bond between the aggregate, the binder and the road occurs.
- On a hot, low-humidity day the binder will break in 3 to 5 minutes. The chips should be rolled before this happens.
- The field inspector will get a strong indication of the success of the seal coat by touring the areas the next spring after winter of plowing and freeze-thaw cycles.

#### **Weather Problems**

The field inspector and the supervisor should agree daily if weather conditions are conductive for seal coating. Threatening weather conditions often result in a wait and see posture. If rainfall occurs, no seal coating should take place until the roads are totally dry and clean (re-sweeping with a pick-up sweeper may be required prior to resuming project).

- If an unexpected rainfall occurs, discontinue seal coating immediately inspect areas sealed that have not yet cured for puddles of brownish colored water bleeding out of chips. Blotting with 1/8 inch minus (3.2 mm -) rock of the same type as the seal coat usually will save the seal coat and heal it satisfactorily. Other material to use for blotting includes clean washed sand or natural pit run gravel but they leave a contrasting color on the aggregate and do not have as pleasing an appearance.
- If the rain is severe enough that blotting does not heal it, you may have to re-seal over the top of the failed areas with a small aggregate (1/8 inch minus, 3.2 mm -) aggregate of the same type as the seal coat once it is totally dry. Binder application rates vary from 0.10 0.20 gallons per yard, depending of severity.

### Miscellaneous

- Placing traffic cones over lawn sprinkler heads helps prevent roads from getting wet if sprinklers cannot be turned off.
- Attention to dirt and debris on the road is required throughout the project. It is not uncommon to re-sweep ahead of the operation on a daily basis. A clean and dry road is critical to the success of the seal coat.

• Maintaining close proximity of the asphalt distributor, the chip spreader and the rollers are vital to the lasting adherence of the seal coat to the road surface.

# Sweeping

Pick-up sweeping should occur as soon as possible after application of the seal coat and no later than the next morning. The field inspector should inspect the equipment for leaks. Fuel or hydraulic leaks will destroy the bond between the seal coat and the pavement surface. Leaky sweepers or trucks should not be allowed on the project until they are repaired or replaced.

The sweeping operation includes the following:

- A location to stockpile sweepings.
- Full width sweeping attaining at least 85% pick-up of loose chips.
- Minimizing turning movements of sweepers and trucks at low speeds to avoid damage to seal coat.

The field inspector should do a windshield inspection behind the sweeping operation to ensure the following:

- That all roads sealed are swept.
- To note defects in seal coat requiring attention by contractor.
- To check to see that all structures are uncovered.
- To monitor the progress and quality of the sweeping operation.

### SUMMARY

The field inspector is key to the success of a seal coat project. The inspector's role as an overseer ensures specifications are being adhered to and quality standards are met. The inspector's work aids the contractor or public workforce in the production and coordination of the project to produce an acceptable final product as economically as possible while minimizing inconvenience to the public. Seal coat field inspection requires full-time attention and hands-on involvement to accomplish the desired quality of the end product and continued reliable service of the road system.

# FIELD INSPECTOR'S CHECKLIST

1. Prec	onstruction Mee	eting
	Date	Location
	Contractor/Public	Workforce
	Project Superviso	or
	Phone	
	Subcontractors/	Material Supplies
	Aggregate	
	Binder	
	Subcontractors	
	Project Schedul	e
	Material Delivery	
	Starting Date	
	Estimated Compl	etion Date
	Review provision	s of contract specifications such as:
	□ Distribute maps	s of roads to be sealed.
	☐ Indicate location	ns to stockpile aggregate, park equipment and locate delivery transports
	□ Discuss traffic	control requirements.
	□ Review preferre	ed method of covering structures in the roadway.
	□ Discuss specifi	c procedures for sealing radii, cul-de-sacs, sweeping operations, etc.

1. DAY C	ONE ACTIVITIES	
٠	Check Road conditions	No
	Comment:	
٥	Traffic control in place:	No
٠	Structures protected:	No
٥	Appropriate equipment/operators on site: Yes	
٥	Calibrate distributor:	
٠		No
٥	Record settings of distributor and spreader after calibration:  Spreader  Distributor	

Monitor and check yields of aggregate and binder throughout the day and adjust rates accordingly.

# 3. PROJECT DIARY

□ Weather conditions: TemperatureHumidity		
□ Update map showing roads that have been seal coated.		
□ Binder quantity placed	gallons.	
□ Note binder left in distributors (if any) for next day's operation	on.	
□ Estimated aggregate placed	tons.	
Note performance of equipment, operators, and overall quality of the operation.		
□ Note application rates and any adjustments made.  Binder		
Rock		
<ul> <li>Pick-up sweeping should occur 24 to 72 hours after application</li> <li>Verify schedule and inspect operation as it proceeds in addition</li> </ul>		

Field Inspector should record the following information on a daily basis:

# 4. THE LAST DAY OF THE PROJECT

- □ Verify that all roads scheduled to be sealed have been and that the pick-up sweeping operation is completed prior to contractor or workforce leaving the project area.
- ☐ Field inspector and field supervisor agree on total pay quantities for the project in writing.
- ☐ Remove excess binder and/or aggregate from the site or agree on a schedule to do so.
- Clean up sites used to store equipment or stockpile materials.

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# 8. EQUIPMENT CALIBRATION

Calibrating and maintaining the equipment used in seal coating is an important step in achieving good results. Poorly calibrated or mis-calibrated equipment can negate what would otherwise be a quality seal coat project. Calibrating the chip spreader and asphalt distributor ensures that:

- All of the chip spreader gates are applying the same amount of aggregate across its entire width.
- The chip spreader is applying the desired amount of aggregate per unit area.
- The distributor spray bar nozzles are all adjusted to the same angle, resulting in uniform coverage of the binder across the entire lane.
- None of the spray bar nozzles are plugged with debris.
- The spray bar height is correct. If it is too high, the fans will overlap too much. If it is too low there will be areas with insufficient binder. Both conditions will cause streaking.

The following pages describe the calibration procedures and adjustments that routinely must be made to both the aggregate chip spreader and asphalt distributor before the project starts.

#### **CHIP SPREADER CALIBRATION**

The recommended procedure for calibrating an aggregate chip spreader is ASTM D5624-95.

Calibrating a chip spreader requires the following:

- A twelve to sixteen foot length of a grooved rubber mat (depending on the width of the spreader), typically used as stair runners. They can be purchased from building supply stores and come in either 27 or 36 inch widths. The mat is then cut into 1 foot wide strips. The result will be mats that are either one-fourth or one-third of a square yard, depending on how wide they are (27 or 36 inches). The grooves run across the short dimension of the mats.
- A scale of some type to weigh the chips. A spring loaded dairy scale has been used successfully.
- Twelve to sixteen one-gallon size plastic food bags to be used for holding the contents of each rubber mat during weighing.
- Wide masking or duct tape to prevent the rubber mats from slipping on the pavement surface.
- A notepad and pen or pencil for recording the results.
- A 5-gallon bucket for storing and carrying all of the above.

# **Chip Spreader Calibration Steps:**

# Step 1

The rubber mats are laid side by side on the roadway until they extend the entire width of the chip spreader. To prevent the mats from slipping, wide masking tape can be used on the upstream end of the mats as shown in Figure 8.1.

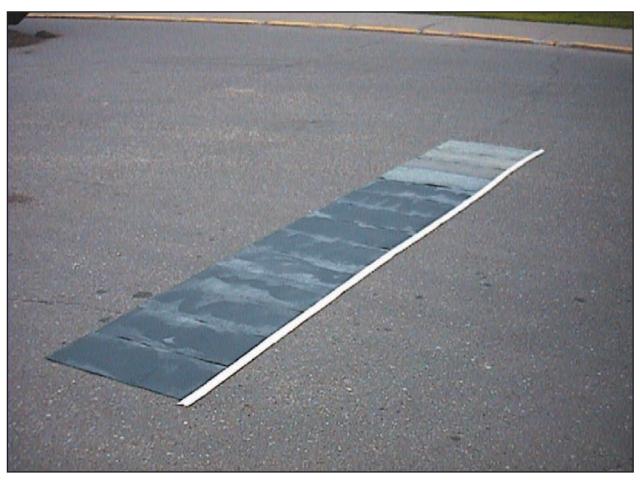


Figure 8.1. One-foot wide rubber mats are placed into position

The chip spreader is driven over the mats. The spreader should begin dropping chips about 6-8 feet before the mats to ensure the gates are open and functioning properly. It is critical that the spreader travel speed and tachometer be monitored to ensure they are the same as those used during construction. The inspector should record these values to make sure this is done. If the spreader is traveling too fast or slow during calibration, it will not provide correct information as to the actual yield obtained during production.



Figure 8.2. The rubber mats are covered with aggregate from the chip spreader

The aggregate dropped on each mat is then carefully emptied into the one-gallon plastic bags. The order of the bags must be kept straight so the gate openings can be matched to the proper mat.

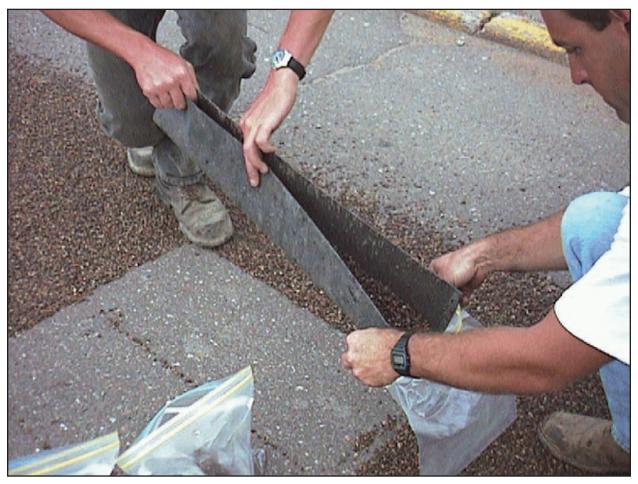


Figure 8.3. The aggregate on each mat emptied into plastic bags

The content of each bag is weighed and converted to pounds per square yard or kilograms per square meter. This amount is recorded on the notepad along with the position of the gate relative to the outer edge.



Figure 8.4. The contents of each bag are weighed and recorded

The first adjustment made is to get all of the gates to drop the same amount of aggregate, even if it is not the desired amount. This will involve adjusting individual gate openings on the front of the spreader.



Figure 8.5. A spreader gate is adjusted

The test is repeated until all of the gates are placing the same amount of aggregate, plus or minus one pound per square yard. Once all of the gates are dropping the same amount of aggregate, the main feed is adjusted until the correct amount of aggregate is being placed. Normally the spreader must be adjusted two or three times before all the gates are dropping the same amount and the amount they are dropping is the target amount.

The calibration can be done the day before construction to reduce any delays. If possible do the calibration off-site so that all of the equipment and personnel are not waiting on the roadway while the calibration is done. This procedure will normally take between 30 and 60 minutes to complete. One way to speed up the calibration procedure is to adjust as much as possible before loading the hopper with aggregate. With the hopper empty and all the gates opened, the distance between the roller and the bottom edge of each gate should be the same.

#### ASPHALT DISTRIBUTOR CALIBRATION

Several calibration procedures or adjustments should be done to the asphalt distributor before it is used. While these adjustments are very simple and quick, failure to perform them can lead to a non-uniform application of binder that not only affects the appearance of the seal coat but also its performance.

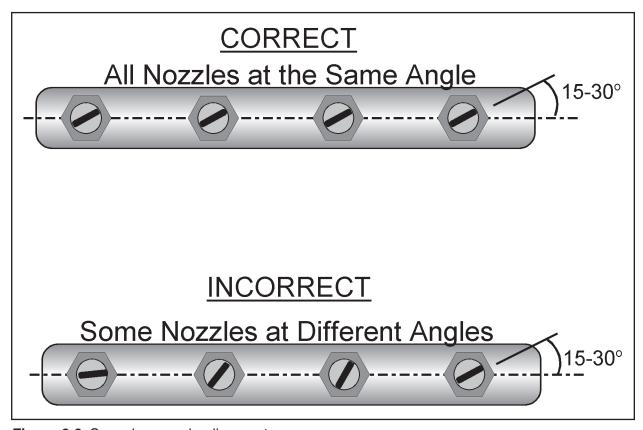


Figure 8.6. Spray bar nozzle alignment

## SPRAY BAR NOZZLE ALIGNMENT

The first thing that should be done to the distributor is to check the spray nozzles. In order for the distributor to spray a uniform layer of binder, the angle of each nozzle must be the same. The exceptions to this are the two nozzles on the very end of the spray bar. These nozzles are typically angled almost perpendicular to the spray bar to create a straight, uniform edge. Before beginning a seal coat project, the angle of each nozzle should be checked and adjusted as needed. Adjustment is very easy to do, typically only involving the slight turn of a wrench or other tool provided by the distributor manufacturer. In addition, each nozzle opening should be checked for grass or other debris that may be obstructing the opening.



Figure 8.7. Spray bar nozzle showing poor alignment



Figure 8.8. Spray bar nozzle showing proper alignment

# **SPRAY BAR HEIGHT ADJUSTMENT**

The next step in adjusting the distributor is to determine if the spray bar is at the correct height. This is done by shutting off certain nozzles and examining the point at which the fans hit the pavement surface. For a triple lap application, two nozzles should be shut off for every one that is open. For a double lap application every other nozzle should be shut off. The distributor operator then sprays for a very quick moment. If the fans do not hit the pavement surface at the same point, the spray bar is either too high or too low and should be adjusted accordingly. As the distributor becomes less full, the spray bar will rise slightly due to the decreased weight on the vehicle. However, this is normally a minimal height and can be ignored.

If the spray bar is not adjusted to the proper height above the pavement, one of two situations will result. Either the spray bar will be too high, in which case the fans will overlap too much in certain areas resulting in ridges or it will be too low, in which case there will be gaps between the fans. In either case, streaking will be the result and is not desired.

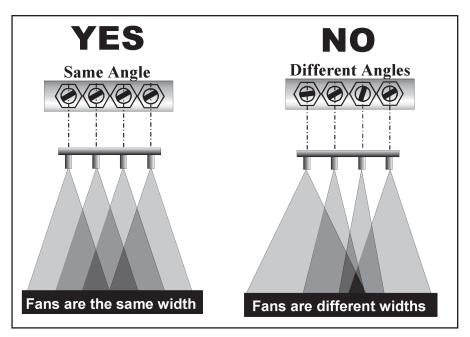


Figure 8.9. Spray bar nozzle alignment

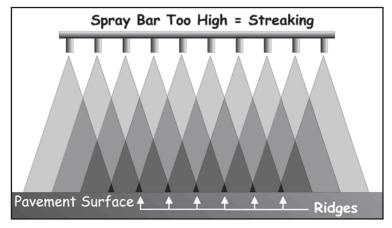


Figure 8.10. Spray bar is too high (ridges)

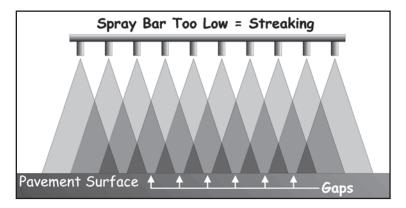


Figure 8.11. Spray bar is too low (gaps)

To determine if the spray bar is at the correct height, the following test should be done before any work begins.

# For a Triple Lap Application:

To determine if the spray bar height is correct for a triple lap application, conduct the following test:

- 1) Make sure all of the nozzles are aligned to the same angle.
- 2) Shut off two consecutive nozzles for each that is left open (Figure 8.12).
- 3) Spray binder for a brief moment and examine the point where the fans hit the pavement surface. If they do not meet at the same point, the spray bar is not at the correct height.
- 4) If the fans overlap, the spray bar is too high. If they are too far apart, the spray bar is too low. Adjust the bar as needed and repeat until the fans meet the pavement at the same point.

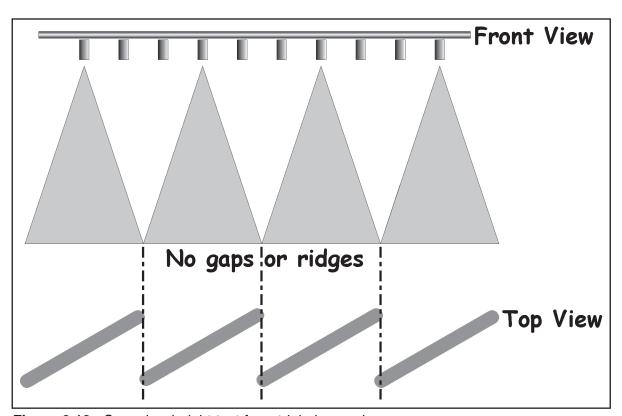


Figure 8.12. Spray bar height test for a triple lap seal

# For a Double Lap Application:

To determine if the spray bar height is correct for a double lap application, conduct the following test:

- 1) Make sure all of the nozzles are aligned to the same angle.
- 2) Shut off every other nozzle (Figure 8.13).
- 3) Spray binder for a brief moment and examine the point where the fans hit the pavement surface. If they do not meet at the same point, the spray bar is not at the correct height.
- 4) If the fans overlap, the spray bar is too high. If they are too far apart, the spray bar is too low. Adjust the bar as needed and repeat until the fans meet the pavement at the same point.

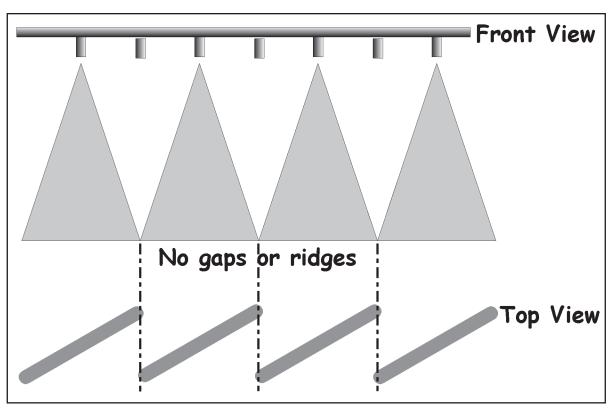


Figure 8.13. Spray bar height test for a double lap seal

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# 9. COMMON PROBLEMS and SOLUTIONS

Construction of a good seal coat depends on a number of factors, including the following:

- Aggregate gradation, hardness, size and shape.
- Asphalt binder grade, viscosity and electrical charge.
- Existing pavement condition.
- Construction methods.
- Equipment used and skill of operator.
- · Traffic volume and movement.

Insufficient detail to any of these factors can result in defects in the sealed surface. The degree of the defect can range from a minor cosmetic one to complete failure and loss of the seal coat aggregate. The three most common problems that occur in the construction of a seal coat are:

- Loss of Cover Aggregate.
- Bleeding or Flushing.
- Streaked Appearance.

#### PROBLEM: LOSS OF COVER AGGREGATE

Perhaps the most common problem, and the least desirable, is the loss of some or all of the cover aggregate. Possible causes are:

- Insufficient asphalt binder.
- Poor rolling of longitudinal seam at the centerline.
- Allowing the binder to break before chips are placed and rolled.
- Dusty aggregate.
- Poor gradation.
- Excessive snow plow down pressure.

#### Solution #1: Apply more asphalt binder

Without a doubt, the most common reason for loss of seal coat aggregate, especially in large amounts, is the lack of asphalt binder. Because most asphalt emulsions have only 65 to 70 percent residual asphalt, it is necessary to apply binder so that it will rise almost to the very top of the aggregate layer. This is because of the extensive loss in volume that occurs as the water and emulsifier evaporate during curing (Figure 9.1).

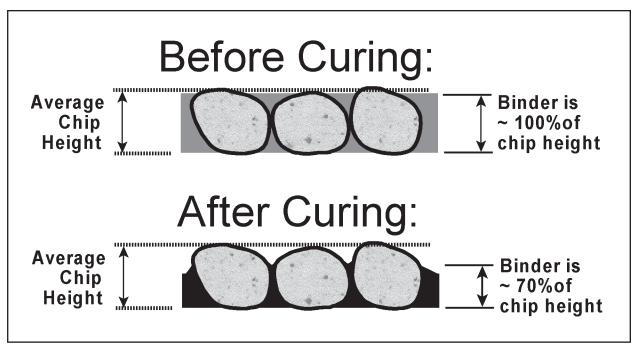


Figure 9.1. Change in volume after emulsion has cured

In addition, old and/or porous pavements, as well as the cover aggregate itself, can absorb some of the binder intended for holding onto chips. If extra binder is not applied to account for this, chip loss will result. Remember, the goal is to have as many stones as possible be about 70 percent embedded into the residual asphalt. The residual asphalt is the asphalt cement remaining on the pavement after water and emulsifier have evaporated.

Performing a seal coat design and constructing field test strips will determine the correct binder application rate. In some cases, the field application rate had to be increased be as much as 50 percent to account for absorption onto existing pavement surface and cover aggregate.

#### Solution #2: Use a clean, dust-free aggregate

Aggregates containing dust should not be used for seal coating unless precautions are taken. To avoid dusty aggregate, the specified aggregate gradation should have 1 percent or less passing the #200 sieve (75µm).

Dust coats the outside of the aggregate particles and prevents them from bonding with the bituminous binder. Consequently, extensive chip loss will result.

If clean dust-free aggregate is not available, one of the following **must** be done before the aggregate is used:

- Wash the aggregate to remove dust.
- Use a high-float emulsion, such as HFMS-2.
- Pre-coat the chips with asphalt cement.

More detail on seal coat aggregates can be found in Chapter 2 of this handbook.

#### PROBLEM: BLEEDING OR FLUSHING

Bleeding, also referred to as flushing, is defined as "excess asphalt in the wheelpath, or traffic areas." It is caused by too much asphalt binder. If the binder is applied too thick, it may rise above the top of the aggregate and stick to the construction equipment. More often, the binder is just below the surface of the pavement after curing and is sucked to the top by traffic, particularly on hot days.

#### Solution #1: Use a cubicle aggregate

Using flat aggregate can greatly increase the rick of bleeding. This is because traffic forces flat chips in the wheelpath to lay down on their flattest side. If there are enough flat chips, they will be driven down below the surface of the binder in the traffic areas.

# Solution #2: Reduce the asphalt binder application rate

Bleeding can also occur when using cubical aggregate if too much binder is applied to the pavement. All of the above point out the need for performing a seal coat design and constructing test sections prior to construction.

For more details on seal coat design, refer to Chapter 4 of this handbook.

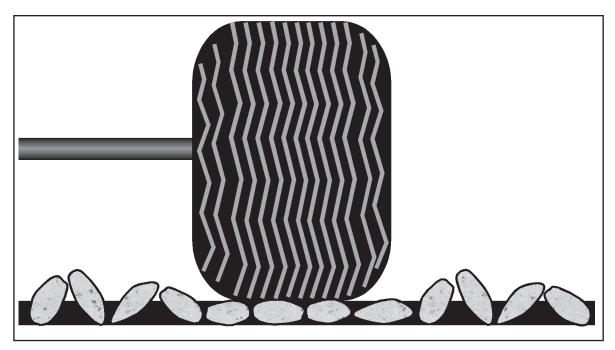


Figure 9.2. Traffic cause flat chips in the wheelpath to lay down on their flattest side

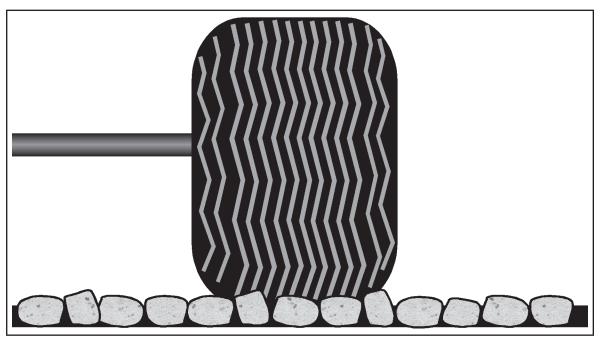


Figure 9.3. Traffic has little effect on cubical aggregate

## PROBLEM: STREAKED APPEARANCE

Streaking is identified by longitudinal grooves or ridges in the seal coat surface. Though streaking is primarily a cosmetic problem it is an undesirable one none the less. If the distributor is calibrated properly, streaking can virtually be eliminated. Figure 9.4 shows an example of streaking.



Figure 9.4. Example of streaking caused by incorrect spray bar height (notice streaks)

The three most common causes of streaking, in order of occurrence, are:

- Incorrect Spray Bar Height.
- Misalignment of the Nozzles.
- Clogged Nozzles.

#### Solution #1: Check the spray bar height

If the distributor's spray bar is the wrong height, the fans of asphalt from the nozzles will not meet the pavement surface at the same point. As a result, there will be gaps, if the bar is too low and ridges if the bar is too high. Both result in a non-uniform layer of asphalt binder.

When using small aggregate, such as FA-2, the problem is much more noticeable because the chips can become securely embedded in the ares where ridges of binder exist. In Figure 9.5, notice that for a triple lap application, every fourth nozzle should hit the pavement at the same point. For double lap application, every other nozzle should meet the pavement at the same point.

Refer to the calibration section of this handbook for more details.

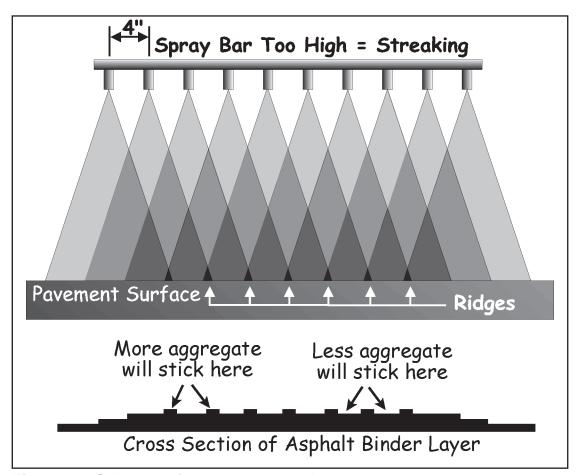


Figure 9.5. Schematic of incorrect spray bar height

# Solution #2: Align the nozzles properly

In order for the asphalt binder to be a uniform thickness across the pavement surface, the spray bar nozzles must all be set at the same angle. If the nozzles are at different angles, the width of the fans will also be different. This results in a non-uniform application. Normally, the angle of the nozzles can be adjusted with a simple turn of a wrench.

## Solution #3: Make sure the nozzles are not clogged

Because asphalt is sticky, and its viscosity increases when it cools, the nozzles of the spray bar are susceptible to clogging from stiff asphalt as well as grass and weeds which may be picked up during construction. Prior to beginning a seal coat project, the nozzles of the spray bar should be inspected and cleared of any debris. The emulsion must be heated to approximately 150° F (66°C) so that viscosity of the old binder in the nozzles can be reduced enough to prevent clogging. During construction, the spray pattern should be checked often and any noticeable blockage should be cleared immediately.



Figure 9.6. Evidence of a dusty aggregate

#### PROBLEM: BAD CENTERLINE JOINT

If the existing roadway has a deteriorated centerline joint it should be repaired prior to seal coating. A poorly compacted paving seam will absorb much more of the binder than the surrounding pavement. The result is insufficient binder in this area and loss of cover aggregate. Since snow plows tend to ride on this high spot of the pavement, having a good longitudinal seam is important to the longevity of the seal coat project.

# Solution: Apply a fog seal

Placing a fog seal in this area will help to prevent too much of the binder from being absorbed into the pavement. A two to three foot wide application of CRS-2 emulsion applied about 0.01 - 0.2 gallons/sq. yd. has worked well as shown in Figure 9.7. The emulsion should be allowed to cure prior to placing the seal coat.



Figure 9.7. Fog seal on centerline prior to seal coat to prevent excess absorption

#### PROBLEM: LOSS OF AGGREGATE AND/OR BLEEDING IN CUL-DE-SACS

One of the most common problems encountered when seal coating in urban areas is the loss of cover aggregate, and subsequent bleeding in cul-de-sacs.



**Figure 9.8.** Wrong way to sealcoat a cul-de-sac (emulsion will break before chips are placed and rolled)

# Solution: Use proper technique materials

The main cause of aggregate loss in cul-de-sacs is poor construction technique. In most cases, the binder is not placed properly. As a result, it breaks before the chips are applied and/or rolled. This is because of the increased viscosity of the binder. Once the binder breaks, it is nearly impossible to properly embed and coat the aggregate particles.

Another common error when seal coating cul-de-sacs is too much overlap of adjacent passes of the distributor. If the distributor operator is not careful, two or even three times the desired thickness of binder can be applied in certain areas. This will result in bleeding and cause the seal coat to be very tender which will cause scuffing as vehicles stop and turn.

Refer to Chapter 11 for the recommended way to seal coat a cul-de-sac.

#### PROBLEM: UTILITIES IN THE PAVEMENT

When seal coating in urban areas where manholes and gate valves in the street are common, the asphalt binder will stick to these structures unless precautions are taken.

# Solution: Cover the utilities

To prevent the binder from adhering to the utilities, they are normally covered. Appropriate covers range from roofing paper, kraft paper or sand. Some agencies use the same type of aggregate for covering utilities as they do for the seal coat, only much smaller. Since the material must be disposed of properly, using sand is the preferred method. The manholes and gate valves are normally covered just prior to the seal coat being placed.



Figure 9.9. Sand cover on manholes

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# CHAPTER 10. FREQUENTLY ASKED QUESTIONS ABOUT CHIP SEALING

- 1. Q) I have a locally produced chip that does not meet any of Mn/DOT's gradation specification for the different sizes (FA-2, FA-2 1/2, or FA-3). Can I still successfully use these chips?
  - A) Yes, as long as there is less than 1 percent passing the # 200 sieve, you should be able to successfully use the chips. If you have more than 1 percent passing, check with your binder supplier to see what it recommends. The Mn/DOT chip seal design program will give you application rates for the chip and asphalt binder (see Mn/DOT website).
- **2. Q)** Is there a good way to determine if I have placed enough asphalt binder on my chip seal project?
  - A) Determining if you have the proper embedment is a little bit like playing poker; if you look closely, there are always signs for you to follow. One sign in chip sealing is to look closely at crack seals that exist in your pavement. These areas have almost no absorption when compared to a normal HMA surface. If you do not see signs of the crack seal shadowing through the chip seal, then you are probably low on embedment.
- **3. Q)** A surprise rain shower caught us when we were laying down our chip seal. What can we do to limit the amount of damage done by the rain?
  - A) Getting caught in a surprise shower is one of the joys of chip sealing in the Midwest. One of the first things to do is increase the aggregate cover rate by 100 percent as you finish covering the asphalt binder. If you have a truck with a sander on the job to repair damaged areas, have it sand the fresh chip seal. Any extra covering you can place on the chip seal helps to protect if from the rain. If you are lucky and have aggregate lime available, use it to blot the chip seal. This will cause the Cationic emulsion to break faster. Of course, the best case scenario is for you to watch the weather closely and suspend operations if you believe there is a chance of rain.
- **4. Q)** My starts and stops to change trucks on the chip spreader result in spots that are rough and very dark. What can I do to improve them?
  - A) One successful method of dealing with starts and stops is to use roofing felt as a launching pad. Place one or two pieces of felt across the lane. The distubutor can start spraying on the felt and then the felt can be removed after the application is complete, leaving a clean and straight edge.
- 5. Q) Does fog sealing on a chip seal reduce the friction number to an un-safe level?
  - A) The answer is "no", assuming you've properly designed your fog seal. The macro texture available on chip seals yields such high friction numbers (> 50) that a slight reduction from a newly placed fog seal still results in the friction numbers that achieve a safe level (<30).
- **6. Q)** What is a good way to adjust chip and emulsion in the field for changing conditions (ie: more porous pavement conditions), after calibrating the equipment and setting the rates?
  - A) See response to question # 2 above.
- 7. Q) How do pavement and air temperatures affect seal coat operations?
  - A) If the air and pavement temperature are low during construction, the chip seal will take much longer to develop enough strength to withstand traffic. One other point to consider

is the time of day. For example, it may be forecast to be 60°F at 6:00 AM on July 1 which is a very different indication than if you had a 60°F at 4:00 PM. Now if it is 60°F at 4:00 PM, applying a chip seal is not recommended because the temperature will fall after sunset.

- **8. Q)** How does ADT affect seal coat design and is there a maximum ADT on a roadway to be considered for seal coating?
  - A) ADT affects chip seal design in the following way: as the ADT goes up, the chip seal needs less asphalt binder. The reason for this is that increased traffic causes a higher percentage of the chips to be orientated on their least-dimension side. The inverse is that as ADT decreases, the asphalt binder must be increased. This is because there is less chance for the chips to be orientated on their least-dimension side with lower traffic volumes.

Roadways with ADT of 20,000 have been successfully chip sealed in Minnesota; however, most agencies use 10,000 ADT as their cut-off point when considering a chip seal application.

- **9. Q)** Will ADT or anticipated truck traffic volumes affect the type of oil or aggregate used in a seal coat?
  - A) The answer is "yes." Increased ADT or truck traffic requires using a stronger binder. Mn/DOT recommends using CRS-2p (Cationic Rapid Set polymer modified) because it builds strength in a matter of hours while it can take weeks for non-modified asphalt to develop strength. The aggregate will also be affected on a high-volume or high truck traffic roadway, with a more durable aggregate required.
- **10. Q)** How many times can you chip seal the same pavement?
  - **A)** You can chip seal a structurally sound pavement an unlimited number of times if you want. There are some counties that have placed as many as four chip seals on a roadway and they are planning on continuing to chip seal the roadway every seven to ten years as long as the roadway is structurally sound.
- **11. Q)** What is the maximum rut depth a seal coat can fix?
  - **A)** If the average rutting is over 1/4-inch, the roadway is marginally sound as a candidate to receive a chip seal.
- **12. Q)** What do I need to know about protecting pavement markings during operations and/or re-applying markings after operations?
  - A) If you have pavement markings that need to be saved, there is cover-up tape available that can be placed over the marking to preserve it during the chip seal application. As for re-applying pavement markings, if you are using latex paint, you can apply as soon as the sweeping is completed. Epoxy paint requires a minimum of 14-days of curing before it can be used.
- **13. Q)** Can I successfully re-use the sweepings from a seal coat application on another seal coat?
  - A) Yes, sweepings can be re-used. It is recommended that, at a minimum the chips be re-screened. If possible, re-washing the chips would be the best-case scenario. If you are using sweepings that have not been washed, use a high-float emulsion such as HFMS-2. If you are re-using sweepings, you should test them and design accordingly, making sure you select the appropriate binder.

# **CHAPTER 11. SPECIAL SITUATIONS**

There are certain situations that can occur that will present special challenges on seal coat projects. Among these are:

- Cul-de-sacs.
- Intersections & Turn Lanes.
- Parking Lots.
- High Volume Roadways.

Each of these will be discussed below.

#### **SEALING CUL-DE-SACS**

Chip sealing cul-de-sacs presents unique challenges for the seal coat crew. The most common problems associated with sealing cul-de sacs is excessive loss of the cover aggregate. Primarily this is caused from either insufficient aggregate embedment (i.e. not enough binder) or placing the aggregate after the asphalt binder has already broken resulting in a poor bond between the binder and the aggregate. The following items contribute to the difficulty sealing a cul-de-sac.

- 1) Its large area and round shape requires extra care by the distributor operator in order to prevent overlaping of successive passes which can lead to bleeding.
- 2) Since the traffic flow is not as channelized as other roadways, the chips never end up on their flattest side. As discussed previously in this manual, this will require more binder to achieve proper embedment.
- 3) If the application of the binder is not planned carefully, the binder will break before the chips are placed and rolled. Once the binder breaks, it will be nearly impossible to achieve a good bond between the binder and the aggregate.
- 4) The turning movements in the cul-de-sac cause the chips to want to roll over. Using an aggregate with a poor gradation or shape can lead to problems with exposed binder as the particles roll over.

The following figures show the proper way to seal a cul-de-sac to ensure that the chips are placed and rolled before the binder breaks. This process has been observed in the field and has proven to result in good embedment.

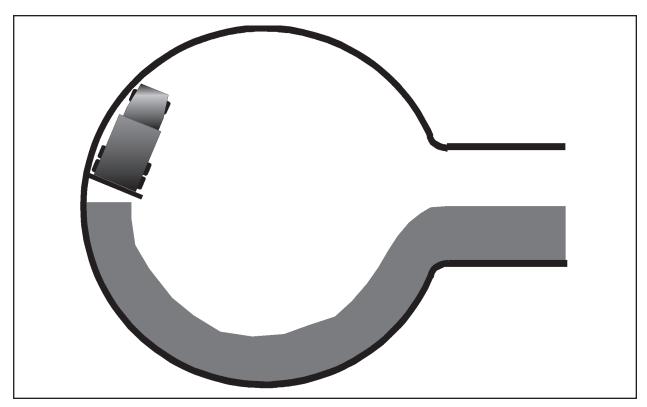


Figure 11.1. Distributor sprays halfway around the perimeter of the cul-de-sac.

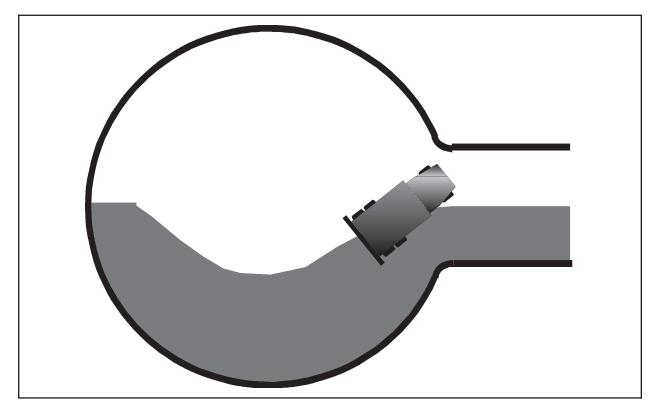
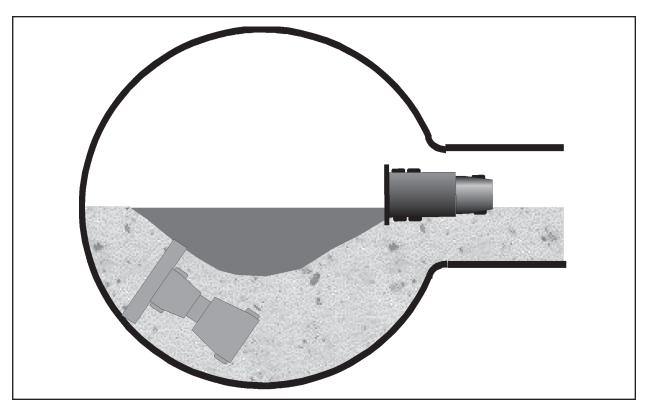
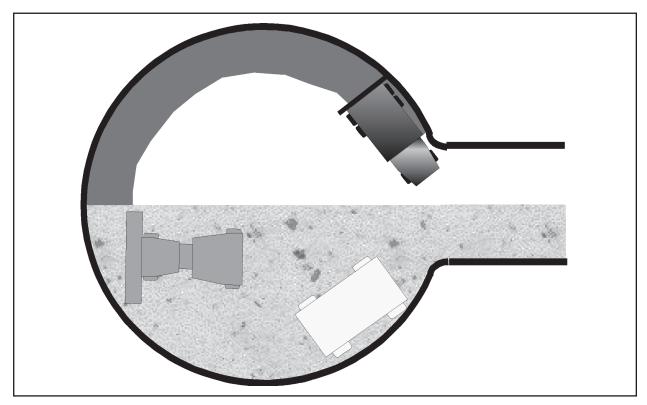


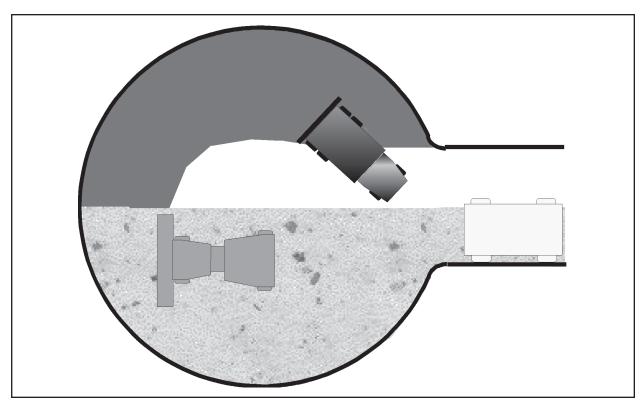
Figure 11.2. After backing into position, the distributor sprays adjacent to the previous pass.



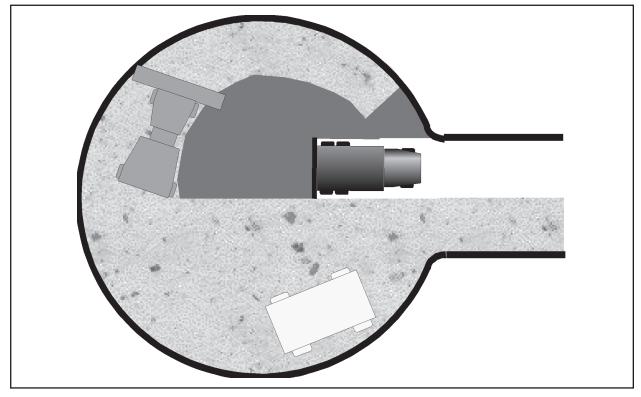
**Figure 11.3.** After backing into place, the distributor completes half of the cul-de-sac. The chip spreader and rollers begin working.



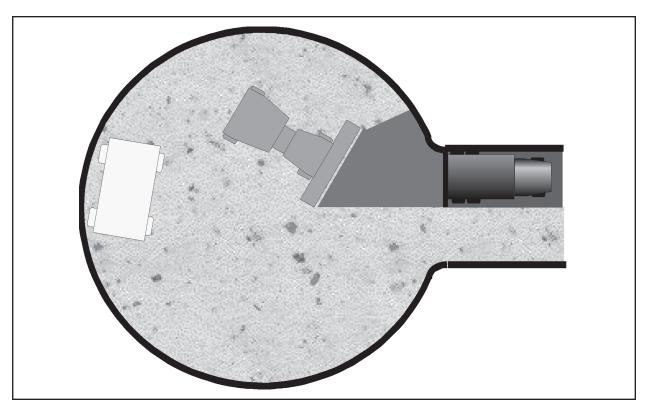
**Figure 11.4.** Distributor backs up to previous perimeter pass and completes spraying around the outside of the cul-de-sac. The spreader and rollers continue to work.



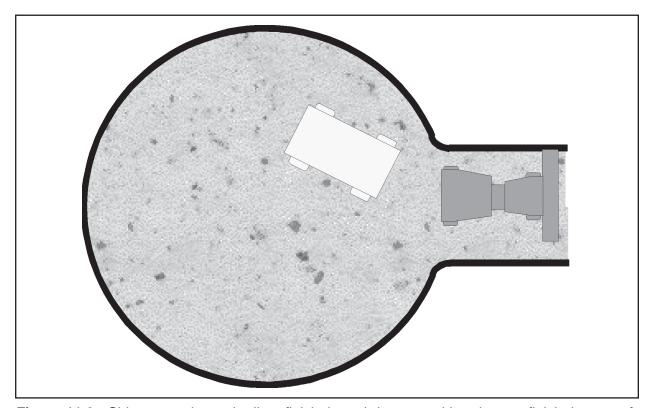
**Figure 11.5.** Distributor continues matching up with previous pass around the perimeter. Spreader and rollers finish the first half of the cul-de-sac.



**Figure 11.6.** Distributor is ready to make its final pass out of the cul-de-sac. The spreader begins covering the other half of the cul-de-sac while the roller continues to work.



**Figure 11.7.** Distributor makes its final pass out of the cul-de-sac and completes the other entrance lane into the cul-de-sac. The spreader and rollers are nearly finished.



**Figure 11.8.** Chips spreader and rollers finish the cul-de-sac and head out to finish the rest of the street.

#### INTERSECTIONS AND TURN LANES

Intersections and turn lanes also can present special challenges. Among the reasons are increased turning, which can cause scuffing, chip rollover and channelized traffic which causes the chips to lay very flat and can lead to bleeding if not accounted for. In addition, stopping action at intersections can suck the binder to the surface of the pavement, especially on hot summer days.

#### **PARKING LOTS**

Parking lots, like cul-de-sacs, involve large expanses of pavement which must be sealed in many passes of the distributor and chip spreader. Careful planning and proper operation of the distributor and spreader will help to ensure good results. The goal is to achieve proper embedment and roll the chips before the binder breaks.

#### **HIGH VOLUME ROADWAYS**

One of the main reasons seal coating is primarily used on low to moderate trafficked pavements is the fear of cracked or broken windshields caused by flying, loose aggregate during and shortly after construction. Long term, there is also the potential for bleeding problems if flat aggregate is used. Because traffic will cause aggregate to lay on its flattest side, high traffic roadways will have a more chips laying on their flat side than low volume roadways due to the increase in the number of vehicles. If the aggregate used has a high Flakiness Index, the difference in height between the traffic and non-traffic areas will be very pronounced. The result will either be bleeding in the wheelpaths or loss of aggregate between them, both of which are undesirable. Some of the precautions that can be taken to minimize the potential for problems on higher volume roadways are:

Use a Choke Seal. This involves applying second layer of aggregate on top of a conventional seal coat. The aggregate in this top layer is much smaller than the aggregate in the bottom layer. When they are rolled, they will be become lodged into the voids in the bottom layer which locks the bottom aggregate together. With this type of surface the chance of any of the bottom stones becoming dislodged is greatly reduced.



**Figure 11.9.** Schematic of a Choke Seal (One layer of binder two layers of aggregate)

2) Use a Double Seal. This involves applying a second layer of binder and aggregate. The second layer of binder will totally encase the bottom layer in asphalt. The aggregate in the top layer is normally half the size of the aggregate beneath it. As a result, the surface locks together, similar to a choke seal, greatly reducing the possibility of loose rocks. If there are any loose rocks, they will be the small ones in the top layer which will also greatly reduce any chance of damage to vehicles.

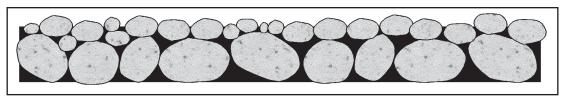
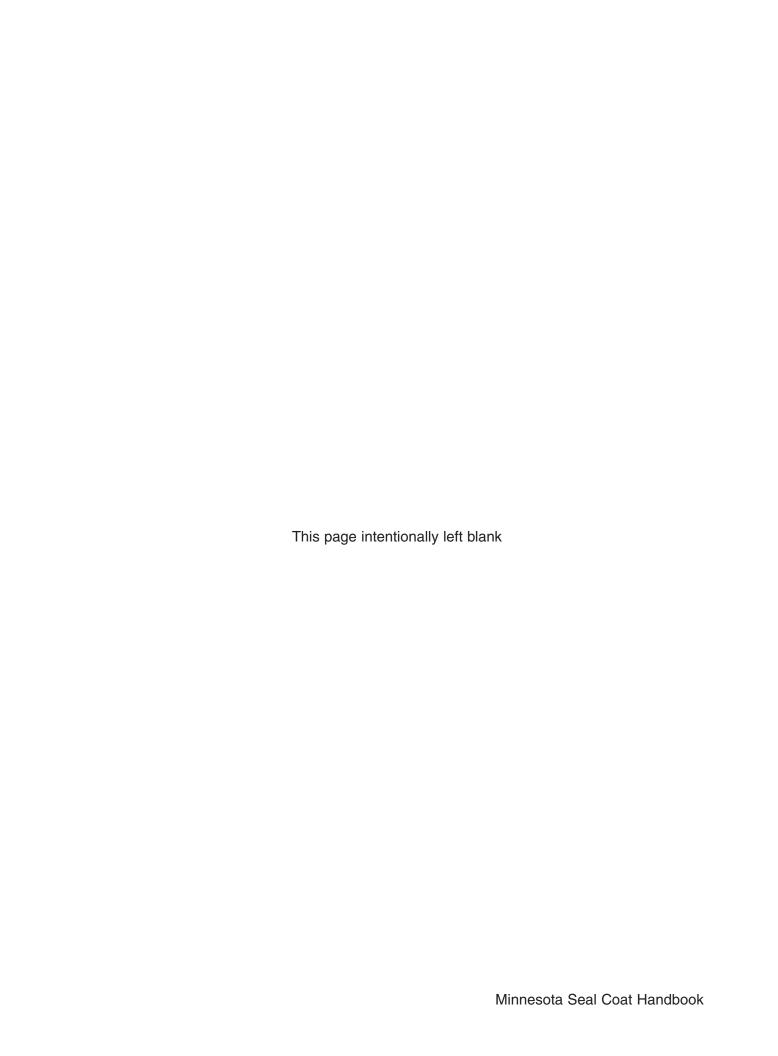


Figure 11.10. Schematic of a Double Seal (two layers of binder and aggregate)

3) Use a smaller aggregate such as Mn/DOT FA-2. One sure way to avoid cracking windshields is to use aggregate small enough that this won't happen. The downside to this is the protective layer of asphalt cannot be very thick when using small aggregate.

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# **APPENDIX**



# Appendix A. Current Seal Coat Special Provisions

(2356) SEAL COAT REVISED 09/22/2005 SP2000-128.1

### **DESCRIPTION**

Construct a seal coat on a prepared surface. A seal coat is the application of bituminous material, followed immediately by an application of a single layer of aggregates. Fog seal the completed seal coat.

# **MATERIALS**

#### A. Bituminous Material

- 1. Provide CRS-2P, bituminous material for seal coat, as specified in Mn/DOT 3151.E.
- 2. Provide a CSS-1h, bituminous material for fog seal, as specified in Mn/DOT 3151.E.

### B. Seal Coat

Provide a Class A, B, or C aggregate, as specified in Mn/DOT 3137.2B. Use aggregates, uniform in quality and free from wood, bark, roots and other deleterious materials. All Class C aggregates shall be 80% crushed one face (mechanical or natural), of the plus 4.75 mm [#4] fraction (use Mn/DOT Laboratory Manual Method 1214). Gradation and quality requirements are specified in Table 1. All percentages are by weight. The aggregate size to be used will be shown in the Plans.

**Table 1** (Values are the percent passing the sieve).

Sieve Size	FA-1	FA-2	FA- 2 1/2	FA-3	FA-4	QC range
12.5 mm [ <b>1/2 inch</b> ]	100	100	100	100	100	
9.5 mm [ <b>3/8 inch</b> ]	100	100	100	90-100	0-60	±5%
6.3 mm [ <b>1/4 inch</b> ]	100	100	0-80	0-70	0-15	±7%
4.75 mm <b>[# 4</b> ]	0-100	0-100	0-50	0-25	0-5	±7%
2.36 mm [# <b>8</b> ]		0-40	0-12	0-5	<del></del>	±4%
1.18 mm [ <b># 16</b> ]	0-30	0-10	0-5	<del></del>		±4%
300 μm [ <b># 50</b> ]	0-15	0-5		<del></del>	<del></del>	±4%
150 μm [ <b># 100</b> ]	0-5	<del></del>		<del></del>		±4%
75 μm [ <b># 200</b> ]	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	0.0-1.0	
Material Tests						
% Shale, max. Mn/DOT 1209	5	5	5	3	2	
Flakiness Index, max. %, FHL T 508 <sup>1</sup>	N/A	25	25	25	25	
Los Angeles Rattler, max. % loss, AASHTO T 96 (Mn/DOT modified			37	37		

<sup>&</sup>lt;sup>1</sup> Aggregate retained on each sieve, which comprises at least 4 percent of the total sample shall be tested.

# C. Water

Use potable water, compatible with the seal coat

#### **SEAL COAT DESIGN**

The quantity on the Plans for bituminous material for seal coat is for estimating and bidding purposes only.

The contractor will design the seal coat using Mn/DOT's seal coat design method, available through the Mn/DOT web site. Base the design on the traffic volume(s) and pavement condition(s). Determine the starting application rate for the bituminous material and seal coat aggregate. Provide the following design information to the Project Engineer, two weeks before construction is to begin:

- (1) Test results required in Table 1.
- (2) Seal coat aggregate design application rate.
- (3) Bituminous material design application rate.
- (4) Loose unit mass [weight] of the aggregate.
- (5) Bulk specific gravity of the aggregate.
- (6) 150 lb sample of each proposed aggregate source.

All Mn/DOT projects will have the design reviewed by Mn/DOT District Materials Office personnel. Failure of the Contractor to submit 150 lbs of material for each source to Mn/DOT for design review at least 14 days before start of construction may result in postponement of the start of the project until a design has been completed as determined by the Engineer. The Contractor will be charged one working day for each weekday that the Project is delayed.

After the seal coat design has been established, the aggregate supplied to the project shall conform to the QC tolerances in Table 1. The tolerance range does not extend the specification limits set in Table 1.

Note: The seal coat aggregate design rate is the minimum amount of material based on the design program. If additional material is needed, this material is incidental to the square meter [square yard] bid price.

#### Schedule of Price Reduction for Seal Coat Construction.

Failing gradations will result in a price reduction. The Contract bid price for seal coat will be reduced 1 percent, for each 1 percent passing outside of the requirements for any sieve, except the 75  $\mu$ m [# 200] sieve. The 75  $\mu$ m [# 200] sieve will have 1 percent price reduction for each 0.1 percent outside of the specification. All failing results will be added together. These deductions apply to the specification range, in Table 1. If any gradations fall outside of the quality control range but within specifications, stop construction and a new design will be required.

Failing flakiness tests will result in a \$1,000 reduction for each failing test.

#### **EQUIPMENT**

#### A. Distributor

Use a distributor as specified in Mn/DOT 2321.3C1.

# B. Aggregate Spreader

Use a self-propelled mechanical type aggregate spreader capable of distributing the aggregate uniformly to the required width and at the designed rate. Use a self-propelled type mounted on pneumatic-tired wheels.

#### C. Pneumatic-Tired Rollers

Provide a minimum of three (3) self- propelled pneumatic-tired rollers as specified in Mn/DOT 2321.3C2.

## D. Brooms

Provide motorized brooms with a positive means of controlling vertical pressure and capable of cleaning the road surface prior to spraying bituminous material and removing loose aggregate after seal coating.

### **CONSTRUCTION REQUIREMENTS**

#### A. Weather Limitations

Construct seal coat operations (including traffic restrictions on the freshly constructed seal coat) and fog sealing according to the following:

- (1) Not before May 15 or after August 10, for the part of Minnesota located in the North and North-Central Road Spring Restriction Zone. Not before May 15 or after August 31, for the part of Minnesota located south of the North and North-Central Spring Road Restriction Zone.
- (2) Work only during daylight hours.
- (3) Start when the pavement and air temperature are 15.5 °C [60 ∞F] and rising.
- (4) The road surface may be damp. There shall be no standing water.
- (5) No construction is allowed in foggy weather.

## B. Road Surface Preparation

Clean all pavements to be seal coated. Sweep the pavement with a motorized broom to remove loose material. Clean depressions not reached by the power broom, using hand brooming.

Cover iron (manholes, gate valve covers, catch basins, sensors, etc.) to prevent adherence of the bituminous material. Suitable covering includes plywood disks, sand, Kraft paper, roofing felt or other approved methods. Remove the protective coverings before opening the road to traffic.

Apply a tack coat, if required, to the prepared road surface in accordance with Mn/DOT 2357. Payment for tack will be made under Item 2357.502 (Bituminous Material for Tack Coat).

### C. Application of Bituminous Material

Begin the rate of application for the bituminous material as determined by the seal coat design. Construct a test strip 30 meters [100 feet] long to ensure the bituminous material application rate is adequate. After applying the bituminous material to this test strip, place the seal coat aggregate at the design application rate. Inspect the aggregate in the wheel paths for proper embedment. Make adjustments to the rate of application, if necessary. Construct one full lane width at a time. Make additional adjustments to the rate of application during the Project, if needed.

Apply the bituminous material above the minimum limits specified below:

Bituminous Material	Minimum Temperature	Ideal Temperature
CRS-2P	60° C [ <b>140</b> ° <b>F</b> ]*	76.6-82.2º C [ <b>170-180º F</b> ]
CSS-1h	37.7° C [ <b>100° F</b> ]	

<sup>\*</sup> Intended for uniform lay down of emulsion.

## D. Application of Seal Coat

Prior to construction, calibrate the aggregate spreader in accordance with ASTM D5624, in the presence of the Engineer. The allowable deviation in the amount of aggregate spread on each of the rubber mats shall not exceed  $\pm 0.5 \text{ kg/m}^2$  [ $\pm$  1 pound per square yard] in the transverse direction, or  $\pm$  0.5 kg/m<sup>2</sup> [ $\pm$  1 pound per square yard] in the longitudinal direction, from the design application rate.

Provide uniformly moistened aggregates, which are damp at the time of placement. Immediately (within one minute) after the bituminous material has been sprayed, apply the aggregates. The speed of the spreader shall be such that the aggregates are not rolling over, and starting and stopping of the spreader is minimized. The edges of the aggregate applications shall be sharply defined. Previously used (sweeping) aggregates will not be allowed.

# E. Rolling Operations

Complete the initial rolling within 2 minutes after applying the aggregate. Proceed at a recommended speed less than or equal to 8 km per hour [5 miles per hour], to prevent turning over aggregate. Make a minimum of three complete passes over the aggregate. Roll the aggregate so the entire width of the treatment area is covered in one pass of all the rollers. The total compacting width of each pneumatic-tired roller shall exceed 1.5 m [5 ft].

# F. Sweeping

Sweep off the surplus aggregate on the same day of the seal coat construction. Sweep with care to not dislodge aggregate that is setting. Re-sweep areas the day after the initial sweeping. The Contractor will dispose of the surplus seal coat aggregate in a manner satisfactory to the Engineer.

### G. Protection of the Surface

No traffic is permitted on the seal coated road surface until after the specified rolling has been completed and the bituminous material has set and will not pick up on vehicle tires.

### H. Protection of Motor Vehicles

The Contractor is responsible for claims of damage to vehicles until the roadways and shoulders have been swept free of lose aggregate and permanent pavement markings have been applied. If permanent pavement markings are to be applied by State forces, the Contractor's responsibility end's after completion of the fog seal and placement of temporary pavement markings.

## I. Application of Bituminous Material for Fog Sealing

Fog seal completed seal coated areas, after sweeping and before placement of permanent pavement markings. Construct the fog seal as specified in Mn/DOT 2355, as modified as follows: Construct a 30 meter [100 foot] test strip. Review the application of diluted (1:1) bituminous material and adjust the application rate as needed. Apply between 0.3 to 0.8 liters per square meter diluted [0.07 to 0.18 gallons per square yard, diluted]. Apply the fog seal to minimize the amount of overspray. Do not allow traffic on the fog seal until it has cured.

### J. Progress of Work

The seal coat will usually cure within 24 hours under dry conditions and temperatures above 15.5 °C [60 °F]. Allow the seal coat to cure a minimum of one day before fogging. The fog seal can be applied after the seal coat is cured. The fog seal will usually cure within 2 hours under dry conditions and temperatures above 15.5 °C [60 °F]. Interim pavement markings can be placed after the fog seal cures. The permanent pavement markings shall not be placed for three days after placing the fog seal.

# **METHOD OF MEASUREMENT**

### A. Bituminous Material

- 1. Measure the bituminous material for fog seal by volume, at 15 °C [60 °F], undiluted. This material must be diluted (1:1) before application.
- 2. Measure the bituminous material for seal coat by volume, at 15  $^{\circ}$ C [60  $^{\circ}$ F].

## B. Seal Coat

Measure the seal coat by area of pavement surfaced.

### **BASIS OF PAYMENT**

- (A) Payment for bituminous material for fog seal: as specified in Mn/DOT 2355.5.
- (B) Payment for the accepted quantity of bituminous material for seal coat (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.
- (C) Payment for the accepted quantity of seal coat 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, purchasing of aggregate, delivery of aggregate, all labor, equipment, and materials necessary for the placement of the seal coat for full lane coverage, sweeping of any loose aggregate after construction and other requirements as specified.
- (D) Payment will be made in accordance with the schedule set forth below at the Contract bid price for the specified unit of measure. Such payment, in each instance, is compensation in full for all costs incidental thereto.

	<u>ltem</u>	Item No.
Liter [Gallon]	Bituminous Material for Fog seal	2355.502
Liter [Gallon]	Bituminous Material for Seal coat	2356.505
Square meter [Square yard]	Seal Coat FA- (add size)	2356.604

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# Appendix B. REFERENCES

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- 3. Standard Specifications for Construction. Minnesota Department of Transportation, St. Paul, MN, 1995, pp 697-700.
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- 7. A Recommended Guideline for Single and Multiple Chip Seals Using Asphalt Emulsion. Asphalt Emulsion Manufacturers Association. Annapolis, MD, 1985.
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