

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, it is 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.

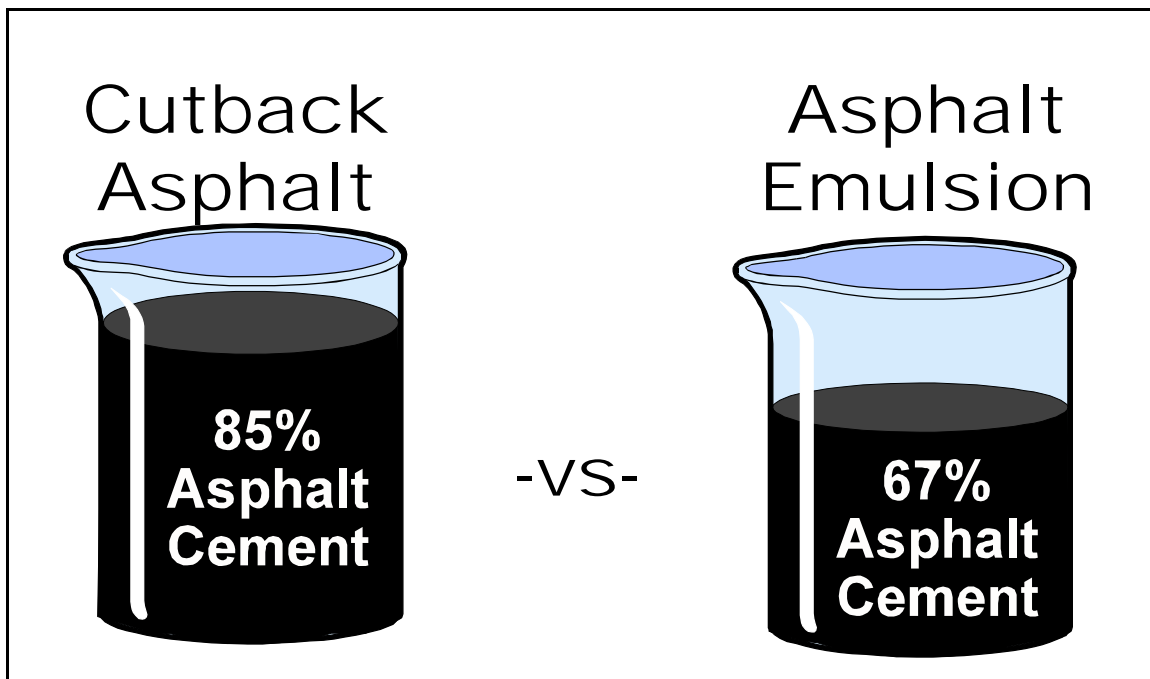


Figure 4.1. Comparison of the residual asphalt content of different binders.

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 asphalt 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.

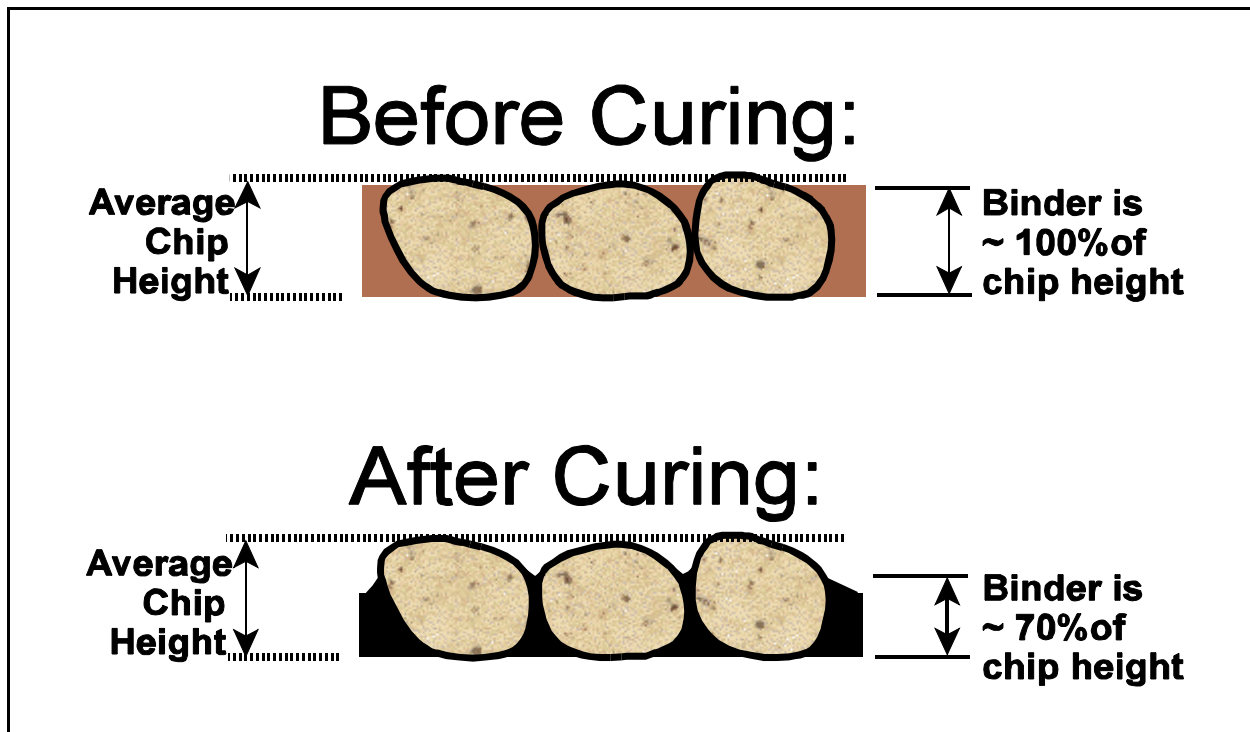


Figure 4.2. Change in volume after emulsion has cured.

Refer to Chapter 3 of this handbook for more details on 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 to be **70 percent filled with asphalt cement** for good performance on pavements with moderate levels of traffic.

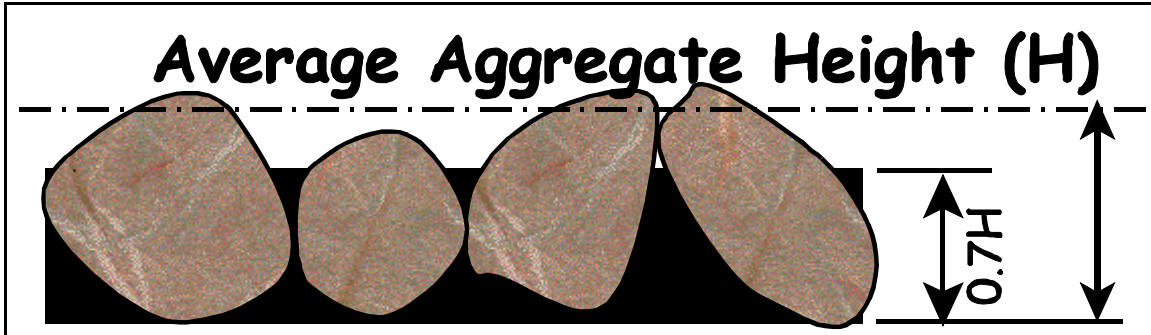


Figure 4.3. McLeod design: One-stone thick & Proper embedment

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 μ m
No. 200	0.0029 in.	75 μ m



Figure 4.5. Seal Coat Sieve Nest

Flakiness Index

The Flakiness Index (FI) is a measure of the percent, by weight, of flat particles. It is determined by testing a small sample of 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 plate 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 (9.5 mm).
- Slot 3: Material passing the 1/2 in. sieve (9.5 mm) but retained on the 3/8 in. sieve (6.3 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 of 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 wheel paths where traffic forces the flat chips to lie on their flattest side.

The Average Least Dimension is calculated as follows:

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

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 near 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:

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

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/ft³
- G = Bulk Specific Gravity of the Aggregate

S.I. Metric Units:

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

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/m³
- 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			Class B		Class C
		Granite	Quartzite	Trap Rock	Limestone	Red Rock	Pea Rock
Bulk Specific Gravity	Min.	2.60	2.59	2.95	2.40	2.50	2.55
	Max.	2.75	2.63	2.98	2.67	2.52	2.66
	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 2 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

Aggregate type		Class A			Class B		Class C
		Granite	Quartzite	Trap Rock	Limestone	Red Rock	Pea Rock
Percent Absorption	Min.	0.40	0.61	0.31	1.75	no data	1.14
	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

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

* 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

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

The inspector needs to be aware of these conditions 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 slight pocked, porous and oxidized surface.



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

McLEOD SEAL COAT DESIGN EQUATIONS

Once all of the lab testing is 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)
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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:

$$C = (1 - 0.4V)HGE \quad (5)$$

Where:

- C = Cover Aggregate Application Rate, kg/m²
- 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)

Binder Design Equation

Binder application rates are determined from the following equations:

U.S. Customary Units:

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

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, gal/yd² (based on existing surface, Table 4.6)
- A = Aggregate Absorption Factor, gallons/yd²
- R = Residual Asphalt Content of Binder, in percent expressed as a decimal.

S.I. Metric Units:

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

Where:

- B = Binder Application Rate, liters/m²
- 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/m²
- 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 5 of this manual. It has 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 (68 kg) sample of 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 Name	Sieve Opening		Percent Passing
	U.S. Customary	S.I. Metric	
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 μ m	1
No. 200	0.0029 in.	75 μ m	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 the 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.

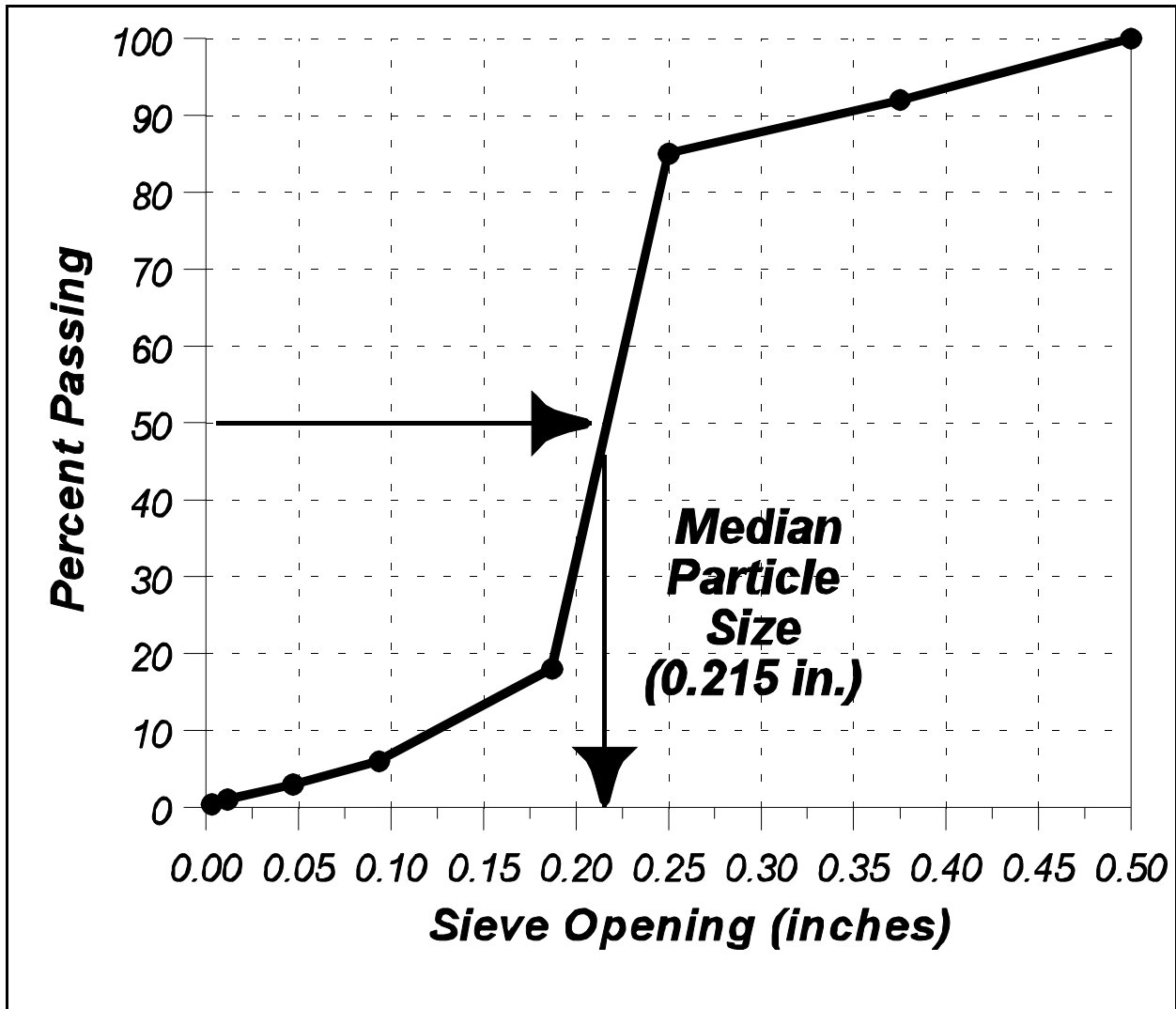


Figure 4.12. Gradation Chart for the Design Example showing the Median Particle Size.

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 in 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:

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

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:

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

S.I. Metric Units:

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

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

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

Loose Unit 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

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

S.I. Metric Units

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

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:

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

S.I. Metric Units:

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

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/ft ³	1,470 kg/m ³
Voids in the Loose Aggregate	0.46	0.46
Traffic Volume	500 - 1000 vehicles/day Use 5% whip-off	500 - 1000 vehicles/day Use 5% whip-off
Surface Condition	Slightly pocked, porous and oxidized	Slightly pocked, porous and oxidized
Bulk Specific Gravity	2.71	2.71
Aggregate Absorption	0.31 percent No adjustment needed	0.31 percent No adjustment needed
Residual Asphalt Content of the Binder	0.67	0.67

Cover Aggregate Application Rate

U.S. Customary Units:

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

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:

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

Where:

- C = Cover Aggregate Application Rate, kg/m²
- 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 over 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:

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

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, gal/yd² (based on existing surface, Table 4.6)
- A = Aggregate Absorption Factor, gallons/yd²
- R = Residual Asphalt Content of Binder, in decimal percent

Binder Application Rate for Wheelpaths:

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

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-wheelpath areas:

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

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

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

S.I. Metric Units:

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

Where:

B = Binder Application Rate, liters/m²

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/m²

R = Residual Asphalt Content of Binder, in decimal percent.

Application rate in the wheelpaths:

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

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

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

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

$$\text{Starting Application Rate in the Field} = \frac{1.46 + 1.12}{2} = 1.29 \text{ L/m}^2 \quad (24)$$

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.

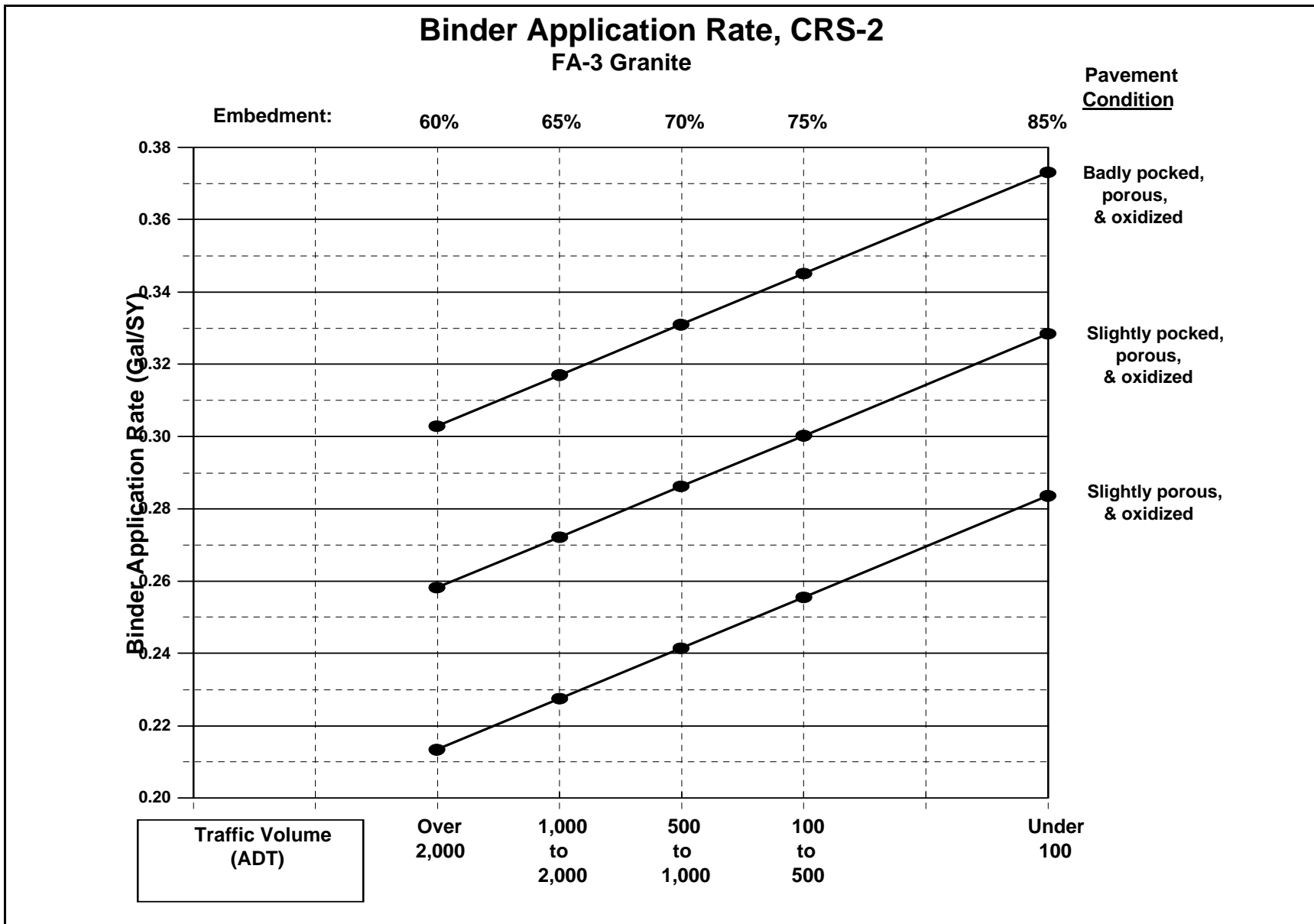


Figure 4.13. Example of a Binder Adjustment Chart