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Kansas Department of Transportation 2014 Chip Seal Manual

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A chip seal is a very effective thin surface treatment process used by maintenance managers to preserve existing asphalt pavements. The Kansas Department of Transportation (KDOT) 2014 Chip Seal Manual is a guide that provides guidelines, background and general information for the design, construction, and inspection of chip seals. This manual is intended for use by KDOT field engineers, laboratory personnel, construction inspectors, and contractor's estimators, supervisors, operators, and workers to provide procedures for the design of chip seals. The information, recommendations and best practices provided in this manual may refer to either: (1) learning the overall chip seal operation; (2) learning about the workings, maintenance, calibration and proper operation of equipment used in chip sealing; or (3) learning chip seal design procedures.

This manual consists of seven chapters. Chapter 1 is the introduction. Chapter 2 is about selection of chip seal. Chapter 3 discusses the materials for chip seal and the design process. Chapter 4 discusses surface preparation prior to chip sealing. Chapter 5 describes equipment inspection and calibration. Chapter 6 discusses the actual application process. Chapter 7 underlines the areas of concern during construction process.

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Final Report

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THE KANSAS DEPARTMENT OF TRANSPORTATION
TOPEKA, KANSAS

and

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PREFACE

The Kansas Department of Transportation's (KDOT) Kansas Transportation Research and New-Developments (K-TRAN) Research Program funded this research project. It is an ongoing, cooperative and comprehensive research program addressing transportation needs of the state of Kansas utilizing academic and research resources from KDOT, Kansas State University and the University of Kansas. Transportation professionals in KDOT and the universities jointly develop the projects included in the research program.

NOTICE

DISCLAIMER

Abstract

A chip seal is a very effective thin surface treatment process used by maintenance managers to preserve existing asphalt pavements. The Kansas Department of Transportation (KDOT) 2014 Chip Seal Manual is a guide that provides guidelines, background, and general information for the design, construction, and inspection of chip seals. This manual is intended for use by KDOT field engineers, laboratory personnel, construction inspectors, and contractor's estimators, supervisors, operators, and workers to provide procedures for the design of chip seals. The information, recommendations, and best practices provided in this manual may refer to either: (1) learning the overall chip seal operation; (2) learning about the workings, maintenance, calibration, and proper operation of equipment used in chip sealing; or (3) learning chip seal design procedures.

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Chapter 1: Introduction and General Principles

1.1 Rules of Interpretation and Authority

This manual for the most part is written in the imperative mood. This is in the same written style as the KDOT Standard Specifications for State and Road Construction, 2007. See subsection 101.1: Rules of Interpretation in these specifications for additional information. (KDOT Standard Specifications 2007)

This manual is intended to provide guidelines, background, and general information for the design, construction, and inspection of chip seals. The manual is intended for use by KDOT field engineers, laboratory personnel, construction inspectors, and contractor's estimators, supervisors, operators, and workers.

This manual provides procedures for the design of chip seals. If conflicts are found between this Chip Seal Manual and the Contract Documents, the Contract Documents will govern. In no case will the information provided in this Manual override requirements of the KDOT Contract Documents.

The information, recommendations and best practices provided in this manual may refer to either:

1. learning the overall chip seal operation;
2. learning about the workings, maintenance, calibration and proper operation of equipment used in chip sealing; or
3. learning chip seal design procedures.

KDOT lets all chip seal work to contract, thus the chip seal design, equipment, materials and labor to perform the work is the contract responsibility of the Contractor. The Contractor is responsible for the initial chip seal design with adjustments made during construction in conjunction with the KDOT Engineer. When this manual refers to checking, the actual duties may fall to either the Contractor employees or the KDOT engineer or inspectors, or both. The Contractor is ultimately responsible for delivering a final product in conformance with the terms of the contract.

1.2 Overview of Chip Seals

A chip seal is a very effective surface treatment process used by maintenance managers to preserve existing asphalt pavements. Two of the major asphalt pavement distresses, cracking and loss of friction are effectively addressed with the use of a chip seal. If cracks greater than ¼ inch are either sealed or filled, the chip seal binder will address the minor cracks, and the chips or aggregates provide a good friction surface. Chip seals also address oxidization, a normal hot mix asphalt (HMA) pavement aging process. Chip seals are a relatively inexpensive pavement surface treatment; however, they require a considerable amount of time and effort in planning in order to execute the work. Chip seals are often referred to as a seal coat, and the process of applying a chip seal, are often referred to as sealing.

The chip seal process is an application of a layer of Asphalt Cement (AC) or asphalt emulsion, referred to as the binder, covered with a layer of graded aggregate, referred to as the chips, to an existing paved surface. The chips are set by rolling the chips into the binder with a pneumatic roller, followed by brooming any loose chips from the surface. With proper planning, once the chip seal process has begun, the actual application moves rapidly.

In some cases the term seal may be used, and when used, is considered to be the application of a binder with or without the application of chips, and may or may not be blotted with sand.

KDOT is responsible for maintaining approximately 20,992 lane miles of asphaltic pavement on the Kansas State Highway System. KDOT's Pavement Preservation Program uses many different treatments for maintaining the asphaltic pavements on the State Highway System, chip seals are just one of the many pavement treatments used. KDOT, by policy, contracts most of the pavement preservation treatments. Selecting a pavement treatment takes into account many factors such as the age and condition of the pavement, the volume and type of traffic, and environmental issues, when selecting the type of surface treatment. The pavement preservation treatment selection process at KDOT is referred to as the Substantial Maintenance Program or pavement preservation program. The pavement treatment selection process for asphaltic pavements is not included in this manual.

The average effective life of a chip seal varies from four to eight years, however some positive affects remain for the entire life of the pavement.

1.3 Functions of Seal Coats

Chip seals are placed on existing asphaltic pavements as a pavement treatment in a preventative maintenance or pavement preservation program. Chip seals provide a relatively inexpensive permanent surface, protecting the pavement structure and driving surface, as well as the subgrade.

Applied to an asphaltic pavement surface, a seal coat provides a durable all-weather surfacing that:

- seals an existing asphaltic surface against the intrusion of air and water;
- enriches an existing oxidized or raveled surface;
- retards the deterioration of a surface showing early signs of pavement distress;
- provides good frictional characteristics;
- keeps moisture from penetrating the subgrade and pavement structure;
- delineates a shoulder from the driving lanes if different aggregates are used; and
- provides a uniform-appearing surface.

There are basically two components of a chip seal, an asphalt binder and aggregate or chips. The functions of the binder are to bond the aggregate particles to the underlying surface and to provide a waterproof seal. The function of the aggregate or chips is to provide surface friction between the vehicle tires and the pavement.

A chip seal provides no structural strength, but by preventing the intrusion of water, it enables the inherent strength of the pavement structure and subgrade to be preserved.

A chip seal is less beneficial to pavements showing evidence of traffic or load-related distresses associated with cracking (including alligator, fatigue and longitudinal wheel path cracking), and in these situations is considered a very short-term solution and is not considered cost effective.

Pavements showing load-associated distresses may require base repair or structural improvements, prior to application of a chip seal.

Chip seals applied to pavements showing signs of non-traffic load-associated longitudinal and transverse cracks have proven effective, if these cracks can be addressed with other treatments such as crack sealing or filling prior to the application of the chip seal.

The ride quality of a pavement is not improved significantly by the application of a chip seal. Pavement treatments such as overlays of various thickness, spot maintenance patches, microsurfacing, surface milling, or reconstruction are normally required to restore pavement ride quality.

Pavements demonstrating flushing or bleeding may be addressed with chip seals. The existing excess binder normally migrates through to the surface producing a slick surface or less tire-pavement friction. Altering (decreasing) the binder quantity applied to the pavement surface at flushing and bleeding locations, thus utilizing the existing binder, can improve the friction.

Pavements demonstrating rutting caused by subsurface or subgrade failure will not be improved with a chip seal. When deep ruts are encountered, (greater than ½ inch) perform other corrective treatments. Chip seals have been used on roadways with minor rutting (less than ½ inch).

Standard chip seals have been used successfully on low traffic volume roadways for many years. With the addition of polymers and use of lightweight aggregates, successful chip seals have been used on higher volume pavements. Approach the use of chip seals in urban areas where accelerating/decelerating traffic and frequent turning movements with caution. The linear forces in these actions may cause the chip seal to fail. In urban and residential areas, noise and surface texture becomes a factor in selecting a chip seal.

1.4 Factors Influencing Performance

There are many factors that must be performed correctly in order to have a quality chip seal project. Performance of chip seals is dependent on:

- construction techniques used;
- condition of Contractor’s equipment;

- skill and knowledge of Contractor’s employees;
- knowledge and training of inspection personnel;
- generally good structural condition of pavement;
- selection of the correct properties of the asphalt binder and the aggregates;
- application of the correct amounts of aggregate and binder;
- uniformity of application;
- development of adhesion between the chip seal and the existing pavement;
- development of a dense interlocking mosaic of stone;
- strength of the underlying base or condition of underlying pavement;
- amount and type of traffic; and
- environmental and drainage conditions.

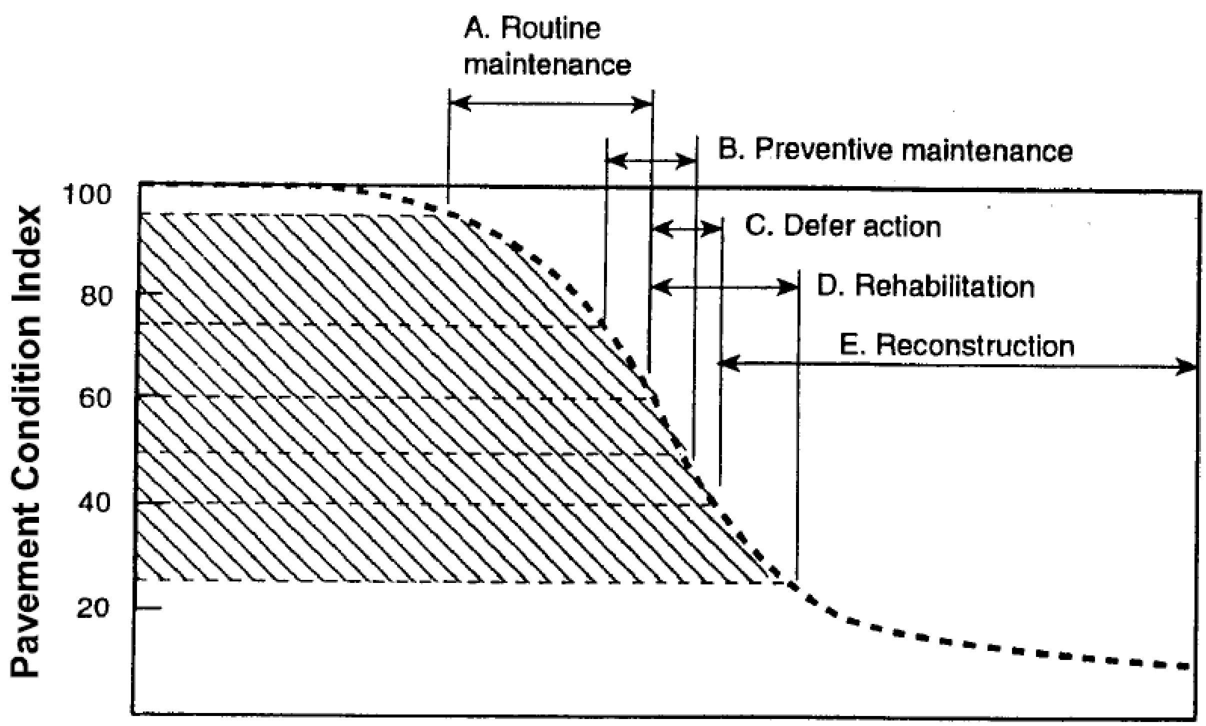
(Source: Ron Matteson)

FIGURE 1.1
A Good Chip Sealed Pavement

Chapter 2: Treatment Selection

2.1 Introduction

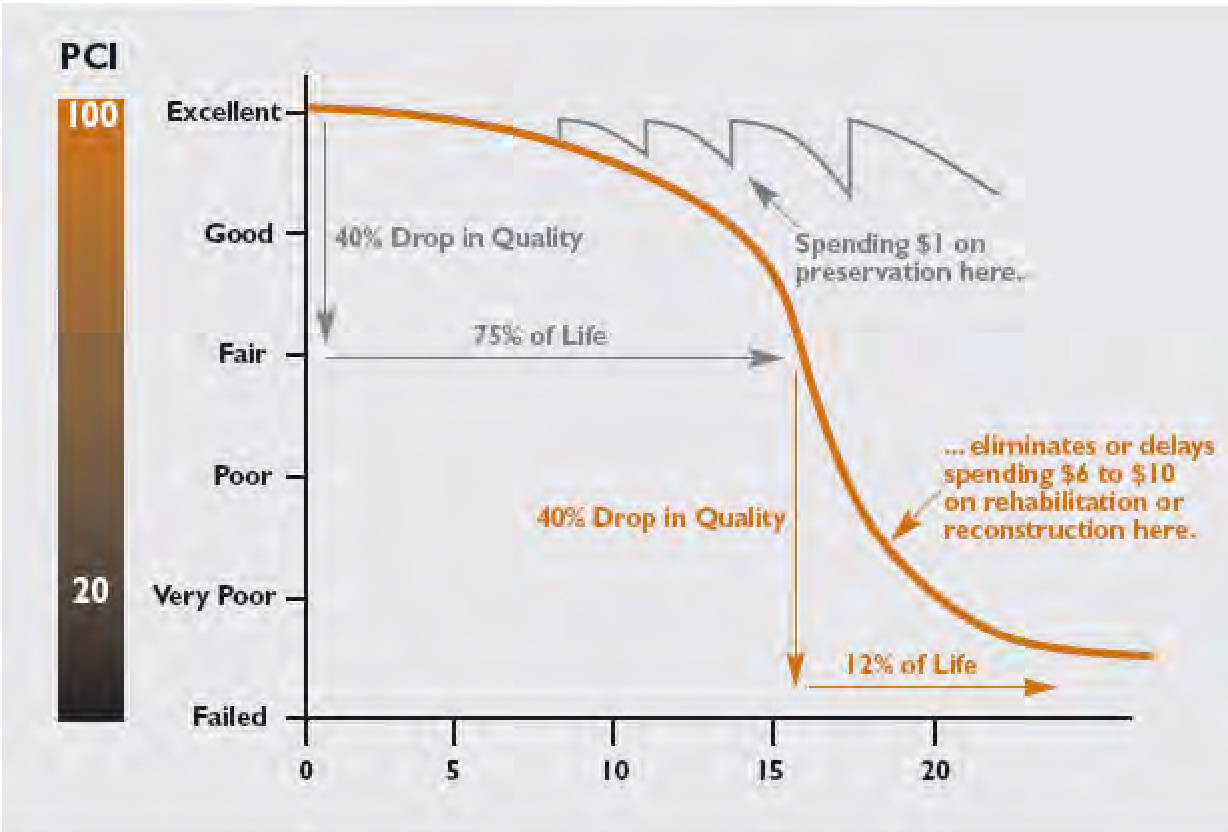
Factors responsible for pavement deterioration include traffic loading, weathering, aging, moisture, etc. According to AASHTO (2010) and TRIP (2010), if pavements are not treated in time, deterioration rates increase and pavements become candidates for heavy rehabilitation or reconstruction. They also mention timely application of maintenance treatments reduces overall life-cycle costs. Hicks et al. (2000) reported pavement treatments are cost effective when applied on pavements in good condition. Preventive maintenance, i.e. chip seal, slurry seal, etc. is applied to structurally sound pavements.



(Source: Hicks et al. 2000)

FIGURE 2.1
Pavement Condition and Required Treatments

Pavement condition changes with time and requires different types of treatments as shown in Figure 2.1. To ensure higher service life and retard pavement deterioration, routine maintenance, preventive maintenance, and minor rehabilitation are applied. If pavement is badly cracked, major rehabilitation is performed.

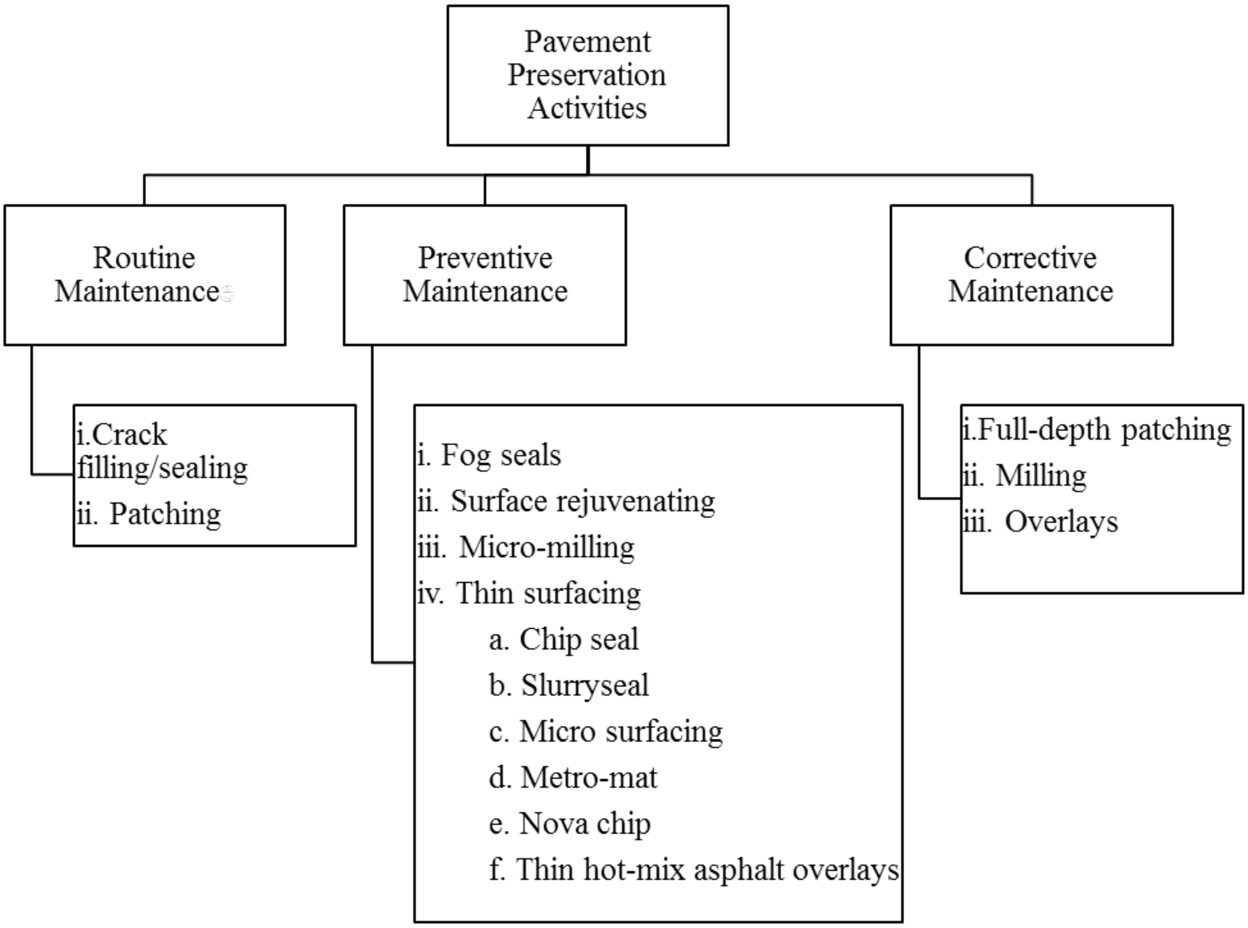


(Source: Galehouse et al. 2006)

FIGURE 2.2
Preventive Maintenance Concepts

Figure 2.2 shows timely application of preventive maintenance reduces costs. If pavement is treated in good condition at $1 per yd^2, it defers pavement deterioration. Delayed application however, can increase costs from $6 to $10.

Asphalt pavement preservation activities are divided into three major categories (Uzarowski and Bashir 2007) and are shown in the tree diagram in Figure 2.3.



(Source: Uzarowski and Bashir 2007)

FIGURE 2.3
Pavement Preservation Activities

Transportation agencies in the United States use chip seal to preserve flexible pavements (Gransberg and James 2005). The expected service life of a chip seal is five to seven years (Chen et al. 2003, Jackson et al. 1990).

2.2 Chip Seal Definition

Chip seal is a thin surface treatment of flexible pavement. The treatment involves spraying of binder, i.e. asphalt emulsion, followed by application of aggregates. It bridges minor cracks and does not allow water into existing pavement on which chip seal is applied (Gransberg and James 2005). Many states use chip seal as a preventive maintenance technique. Liu et al. (2010) noted “a total of 4,156 chip seal treatments were performed on 3,552 segments of 280 highways in Kansas from 1992 to 2006.” Chen et al. (2003) studied fourteen sites in Texas with preventative maintenance treatments, noticing that chip seal performance is highly satisfactory compared to the other techniques, i.e. thin overlay and slurry seal. Costs of these treatments were also compared in this study. Chip seal’s cost is lower than that of an overlay as shown in Table 2.1.

TABLE 2.1
Costs of Preventive Maintenance Treatments

Treatment	Cost per lane-mile
2-inch overlay	\$20,000-\$35,000
Slurry seal	\$7,000-\$10,000
Chip seal	\$7,000-\$10,000
Crack seal	\$700-\$1,000

(Source: Chen et al. 2003)

Although chip seals have been used for the last 90 years, a survey conducted by the National Cooperative Highway Research Program (NCHRP) shows that most states in the U.S. use an empirical approach to design a chip seal (Gransberg and James 2005). Chip seal is now applied on both low-traffic and high-traffic roads.

2.2.1 Types of Chip Seal

Chip seals are classified depending on “construction sequences, number of courses applied, and variations in nominal aggregate sizes” (Gransberg and James 2005):

a. Single chip seal
b. Double chip seal
c. Racked-in seal
d. Cape seal
e. Inverted seal
f. Sandwich seal
g. Geotextile-reinforced seal

2.2.1.1 Single Chip Seal

The concept of chip seal was developed based on single chip seal. A single chip seal involves applying a single layer of aggregates after applying bituminous binder, i.e. asphalt emulsion. Single chip seal is widely used for flexible pavements where no other situations exist that require a special kind of seal (Gransberg and James 2005). Figure 2.4 is a typical diagram of single chip seal.

(Source: Wood et al. 2006)

FIGURE 2.4
Single Chip Seal

2.2.1.2 Double Chip Seal

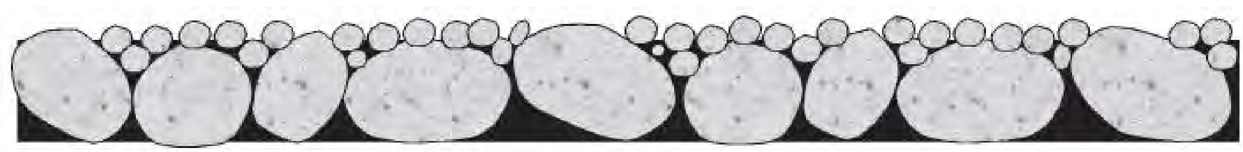
According to Gransberg and James (2005), a double chip seal consists of two layers of bituminous binder and aggregate application, where aggregates of the top layer are “about half the nominal size” of the bottom layer. Double chip seals provide enhanced performance to prevent water entrainment into pavement. As smaller particles are used in the second seal, traffic noises are also reduced. A double chip seal is stronger than a single chip seal and is typically used in roads with high-traffic volume (Gransberg and James 2005). Figure 2.5 shows a double chip seal.

(Source: Wood et al. 2006)

FIGURE 2.5
Double Chip Seal

2.2.1.3 Racked-In Seal

A racked-in seal is a special kind of chip seal typically applied in the areas of high turning movements. A layer of choke stone is applied after a single chip seal to prevent the loss of aggregates. Choke stones are about half the size of the aggregates used in the first application. This seal allows bituminous binder to cure fully by interlocking between the aggregates (Gransberg and James 2005). Figure 2.6 shows a typical diagram of a racked-in seal.

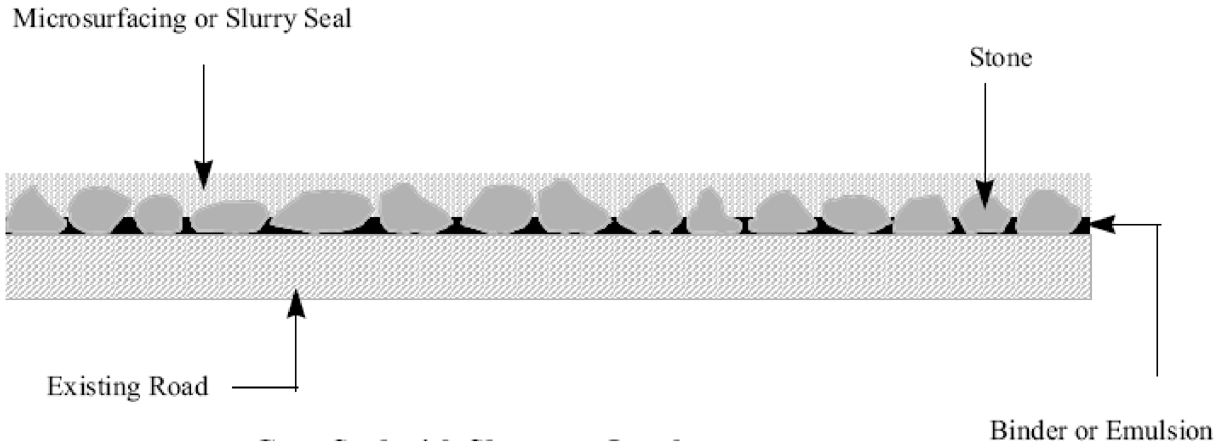


(Source: Wood et al. 2006)

FIGURE 2.6
Racked-In Seal

2.2.1.4 Cape Seal

Cape seal was invented in South Africa, and is named after Cape Town. It is a combination of a single seal and a slurry seal. Cape seal provides a “stable matrix” as the second application, i.e. slurry seal helps to dislodge the larger aggregate particles. Although South Africa uses larger than ¾-inch aggregate for the first seal, smaller-sized aggregates are used in North America for cape seal (Gransberg and James 2005). Advantages that cape seals provide include “a smooth, dense surface, one having good skid resistance and a relatively long service life” (Solaimanian and Kennedy 1998). Figure 2.7 shows a typical cape seal system.

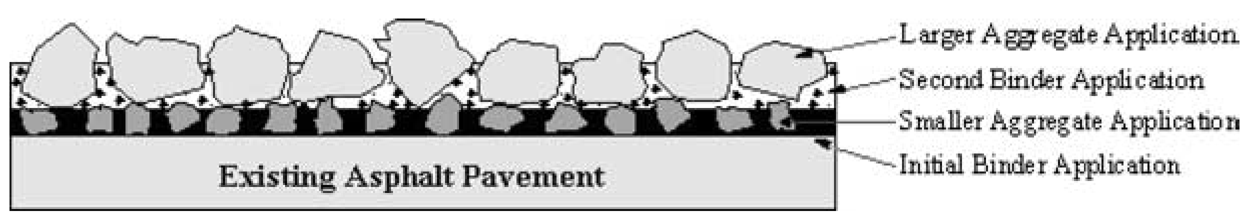


(Source: Solaimanian and Kennedy 1998)

FIGURE 2.7
Cape Seal

2.2.1.5 Inverted Seal

Inverted seal is a kind of double chip seal where smaller particles are applied for the first seal without any application of bituminous binder. When pavement shows bleeding, inverted seal is applied to correct this problem. Not only are inverted seals used in Australia for remedying bleeding in high-traffic roads, but it also reinstates "uniformity to surfaces with variation in transverse surface texture" (Gransberg and James 2005). Figure 2.8 shows a typical inverted seal system.

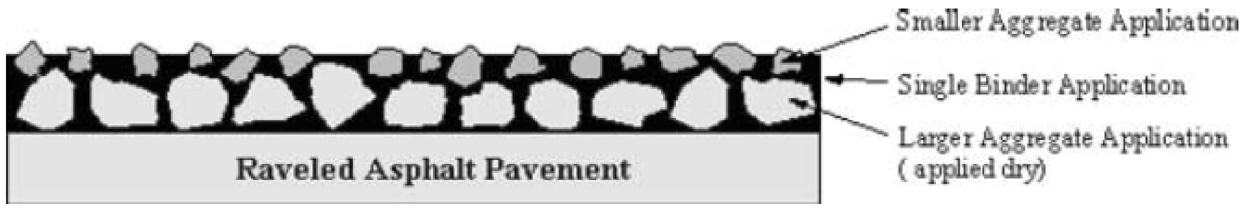


(Gransberg and James 2005)

FIGURE 2.8
Inverted Seal

2.2.1.6 Sandwich Seal

Although two layers of aggregates are applied in sandwich seals, only a single spray of asphalt binder is used in between them. These seals are used to correct "surface texture on raveled surfaces" (Gransberg and James 2005). Figure 2.9 shows a typical sandwich seal system.

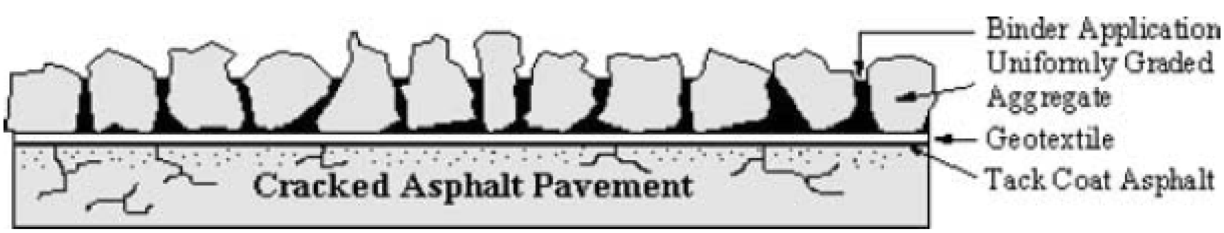


(Source: Gransberg and James 2005)

FIGURE 2.9
Sandwich Seal

2.2.1.7 Geotextile-Reinforced Seal

Conventional chip seals are not suitable for cracked road surfaces, which require high-cost rehabilitation or reconstruction. Geotextile-reinforced seals are applied in these cases. A geotextile fabric is placed on pavement surfaces with a light application of asphalt binder, and a single seal is applied on it. This kind of seal is successful to prevent reflective cracking. Geotextile-reinforced seals act as a "stress-absorbing membranes interlayer (SAMI) system" (Gransberg and James 2005). Figure 2.10 shows a typical geotextile-reinforced seal system.



(Source: Gransberg and James 2005)

FIGURE 2.10
Geotextile-Reinforced Seal

2.2.2 Benefits of Chip Seal

If chip seals are constructed properly on flexible pavements, they provide the following benefits (Gransberg and James 2005, Texas DOT 2004, California DOT 2008):

- prevents water from entering into the underlying pavement
- increases skid-resistant
- corrects dry or raveled pavement

- bridges minor cracks (<¼ in.) of existing pavement
- prevents deterioration of distressed-showing pavement
- defends pavement surfaces from degradation resulting from oil or chemical agents
- produces chosen texture
- provides an aesthetic, smooth, and uniform pavement surface
- offers good durability
- offer ease of construction

Aggregates and bituminous binder have different roles in chip seals. Bituminous binder acts as a binding agent among aggregate, and prevents water intrusion into the pavement base. Aggregates used in chip seals work against abrasion caused by vehicles, and provide surface texture and skid-resistant surfaces (Gransberg and James 2005, Texas DOT 2004).

In spite of these benefits, chip seals do not (Senadheera et. al 2006, Gransberg and James 2005)

- increase strength of existing pavement
- correct major cracks and weathered pavements
- explain reasons behind failure of a project
- offer an alternative to reconstruction

2.2.3 Project Selection for Chip Seal

Effectiveness of chip seals depends on structural strength of the pavement. Selection of projects for chip seals is governed by pavement strength and the level of distresses. Application of chip seals should be performed before significant pavement deterioration (Gransberg and James 2005).

Chapter 3: Chip Seal Materials and Design

3.1 Chip Seal Materials Selection

Chip seal materials selection includes deciding on the aggregate and asphalt binder type to be used. Normal or lightweight aggregates are used as cover material. Currently, application of asphalt emulsions as binder is more prevalent in chip seal construction.

3.1.1 Selection of Aggregate

According to Gransberg and James (2005), selection of chip seal aggregate is very important as it works against the wearing action of wheels. It governs selection of chip seal and binder types, and construction procedures. Performance of chip seals largely depends on particle cleanliness, durability, and wearing resistance. Selected aggregates should be such that they are able to give a skid-resistant surface, as well as transfer vehicle load to the underlying pavement layers. Although North America compromises on local aggregates by considering shipment costs, other countries, i.e. Australia and New Zealand, are more rigid about the quality of aggregates. They perform a cost analysis while selecting aggregates for chip seals. Aggregate and asphalt binder compatibility is also an important issue as both carry electrical charges on their surfaces (Gransberg and James 2005).

Factors affecting performance of chip seals, and which are considered during selection of aggregates, include (Gransberg and James 2005)

a. aggregate size and gradation
b. aggregate shape
c. dust-content
d. aggregate abrasion resistance
e. aggregate type

3.1.1.1 Aggregate Size and Gradation

Size of aggregate is important in chip seal design because it is a function of asphalt binder application rate (Gransberg and James 2005). Single-size aggregates perform best in chip seal by providing less variation in binder application (Wood et al. 2006; Gransberg and James

2005). Although larger particles provide a stable matrix, insufficient embedment of aggregate in the asphalt binder may cause windshield damage as well as increase in traffic noise. One-sized aggregates are not always practically available. Although graded aggregates are used for chip seals, aggregates “very close to one size” are used in chip seal to achieve uniform embedment (Gransberg and James 2005). Figure 3.1 and Figure 3.2 show chip seal with single-sized aggregate and graded aggregates, respectively. Table 3.1 shows KDOT’s gradation requirements of cover aggregates.

(Source: Wood et al. 2006)

FIGURE 3.1
Chip Seal Constructed with Single-Size Aggregates

(Source: Wood et al. 2006)

FIGURE 3.2
Chip Seal Constructed with Graded Aggregate

TABLE 3.1
Gradation Requirements for Aggregates for Cover Material

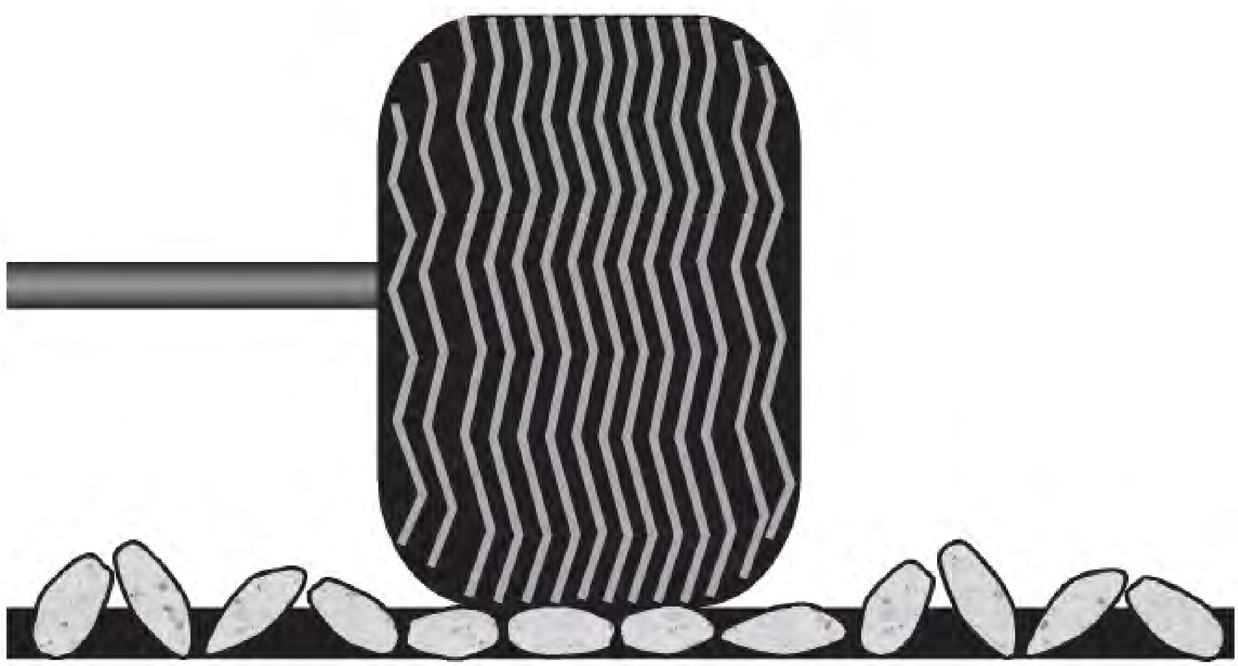
Type	Composition	Percent Retained-Square Mesh Sieves*							Minimal
		3/4”	½”	3/8”	No. 4	No. 8	No. 16	No. 50	Gradation Factor
CM-A	Sand-Gravel		0	0-20	30-100	85-100			
CM-B	Sand-Gravel		0	0-25		35-100		90-100	4.00
CM-C	Crushed Stone	0	0-12	40-100	95-100				
CM-D	Crushed Sandstone	0	0-5	15-35	70-100	95-100			
CM-G	Sand-Gravel or Crushed Sandstone		0	0-15	45-100	95-100			
CM-H**	Crushed Stone	0	0-5		40-100	90-100			
CM-J**	Sand-Gravel	0	1-20			30-100		90-100	
CM-K	Crushed Limestone	0	0-5	15-35	70-100	95-100			
CM-L-1	Lightweight Aggregate	0	0	0-10	10-40	85-100	95-100		
CM-L-2	Lightweight Aggregate	0	0-5	0-15	70-100	90-100			
CM-L-3	Lightweight Aggregate	0-15	0-60	65-100	95-100				

(Source KDOT Standard Specifications, 2007)

*After removal of all deleterious substances.
**Do not specify Types CM-H and CM-J for Federal Aid Projects.

3.1.1.2 Aggregate Shape

Aggregates shape affects performance of chip seals, and a cubical shape is preferred. Due to the action of traffic, aggregates turn onto their flattest side. Chip seals show flushing or bleeding if flat aggregates are predominately used for chip seal construction. When low rates of asphalt binder are used in chip seal with flat or elongated aggregates, these rates become insufficient for other particles, resulting in loss of aggregates (Gransberg and James 2005, Wood et al. 2006, Texas DOT 2004). Figure 3.3 shows chip seal with flat aggregates.



(Source: Wood et al. 2006)

FIGURE 3.3
Chip Seal with Flat Aggregates

Traffic action does not re-orient cubical aggregates. The possibility of uniform embedment of aggregate particles into asphalt binder is high with cubical aggregate, and also reduces occurrences of bleeding (Wood et al. 2006, Gransberg and James 2005). The Flakiness Index is determined by "testing a small sample of the aggregate particles for their ability to fit through a slotted plate." Low values of the Flakiness Index represent cubical shape (Wood et al. 2006; Texas DOT 2004). Angular aggregates face an adverse situation in highly "stopping or turning traffic" areas, whereas rounded aggregates are more susceptible to dislodgment (Gransberg and James 2005). Figure 3.4 shows chip seal with cubical aggregates.

(Source: Wood et al. 2006)

FIGURE 3.4
Chip Seal with Cubical Aggregates

3.1.1.3 Dust Content

Particles passing through a US No. 200 sieve are considered dust. Loss of aggregates from chip-sealed pavements increases if cover aggregates contain a significant amount of dust. In fact, dust acts as a barrier around the aggregate particles, hindering adhesion with the asphalt binder. Different roadway agencies have their own specifications for dust content in the aggregates, but most allow a maximum 2% dust as tabulated in Table 3.2 (Gransberg and James 2005; Wood et al. 2006). Figure 3.5 and Figure 3.6 show chip seals constructed with dusty aggregates.

TABLE 3.1
Maximum Dust Content

State	Maximum Percentage Passing No. 200
Alabama	1
Florida	3.75
Indiana	2
Kansas	2
Maryland	1
North Carolina	1.5
North Dakota	4
Ohio	3
Pennsylvania	2
South Carolina	0
South Dakota	2
Tennessee	1

(Source: Lee 2007)

(Source: Wood et al. 2006)

FIGURE 3.5
Chip Seal Constructed with High-Dust-Content Aggregates before Sweeping

(Source: Wood et al. 2006)

FIGURE 3.6
Chip Seal Constructed with High-Dust-Content Aggregates after Sweeping

By washing or precoating, the problem associated with dusty aggregates can be resolved. Here, precoating is defined as a light application of "a film of paving-grade asphalt or a specially formulated precoating bitumen to the aggregate" (Gransberg and James 2005). The Pennsylvania Department of Transportation used precoated aggregates; they seal pavements with precoated aggregates for pavements "carrying more than 1,500 average daily traffic" (Kandhal and Motter 1991).

3.1.1.4 Aggregate Abrasion Resistance

Abrasion resistance of aggregates is measured by the Los Angeles Abrasion test (ASTM C131-06, AASHTO T96, KTMR-25). Aggregates used for chip seals should be strong and durable so they can perform well against the wearing action of wheels. Aggregates with high abrasion values are not strong enough to withstand wear caused by vehicles, and more dust is produced which can cause vehicle damage as well (Texas DOT 2004). Table 3.3 shows KDOT's abrasion resistance requirements.

TABLE 3.2
Maximum Abrasion Losses of Cover Aggregates

Aggregate Type	Maximum Abrasion Loss Allowed (Percent)
Sand-gravel, gravel, or limestone	40
Sandstone	45
Lightweight	30

(Source: KDOT 2004)

3.1.1.5 Aggregate Type

Both natural and synthetic (artificially produced, i.e. expanded shale, clay, and slate) aggregates are used as cover materials for chip seals, though transportation agencies choose aggregates depending “on the availability and cost …within proximity to the project” (Gransberg and James 2005). New Zealand uses igneous or sedimentary rocks as production sources of chip seal aggregates, but aggregates produced from metamorphic rock show satisfactory performance in other countries (Transit New Zealand et al. 2005, Gransberg and James 2005). Table 3.4 tabulates different aggregates used for chip seal (Gransberg and James 2005). Natural gravels are predominant in North America, followed closely by limestone aggregates.

TABLE 3.4
Natural Aggregate Used for Chip Seals

Type	North America (%)	Australia, New Zealand, United Kingdom, South Africa (%)
Limestone	37	13
Quartzite	13	38
Granite	35	38
Trap Rock	13	25
Sandstone	10	25
Natural Gravels	58	25
Greywacke, Basalt	4	88

(Source: Gransberg and James 2005)

Lightweight aggregates are particles with “an apparent specific gravity considerably below that for normal sand and gravel” (Expanded Shale, Clay, and Slate Institute 1971). Table 3.5 shows bulk-density requirements of lightweight aggregates (ACI Committee 213).

Lightweight aggregates are successful as cover materials in chip seal. Application of lightweight aggregates is more prevalent in Australia, New Zealand, United Kingdom, and South Africa compared to the United States (Gransberg and James 2005).

TABLE 3.5
Bulk-Density Requirements of ASTM C 330 and C 331 for Dry, Loose, and Lightweight Aggregates

Aggregate size and group (ASTM C 330 and C 331)	Maximum density, lb/ft3 (kg/m3)
Fine aggregate	70 (1120)
Coarse aggregate	55 (880)
Combined fine and coarse aggregate	65 (1040)

(Source: ACI Committee 213)

Although lightweight aggregates are costly, they offer good skid resistance and reduce aggregate dislodgement (Gransberg and James 2005). Benefits of lightweight aggregates can be summarized in the following ways (Gransberg and James 2005, Martin 2003, Expanded Shale, Clay, and Slate Institute 1971):

- superior skid-resistance
- better aggregate retention
- reduction or elimination of windshield damage
- superior bonding with asphalt emulsion
- low content of dusts
- low transportation cost
- Drawbacks of lightweight aggregates are as follows (Gransberg and James 2005):
- costlier than normal-weight aggregates
- high water absorption

Lightweight aggregates can be obtained from natural sources, i.e. pumice, scoria, and volcanic cinders, but are produced mainly by industrial processes using shale, clay, and slate. Industrial by-products (slag, fly ash) are also used as raw materials for lightweight production

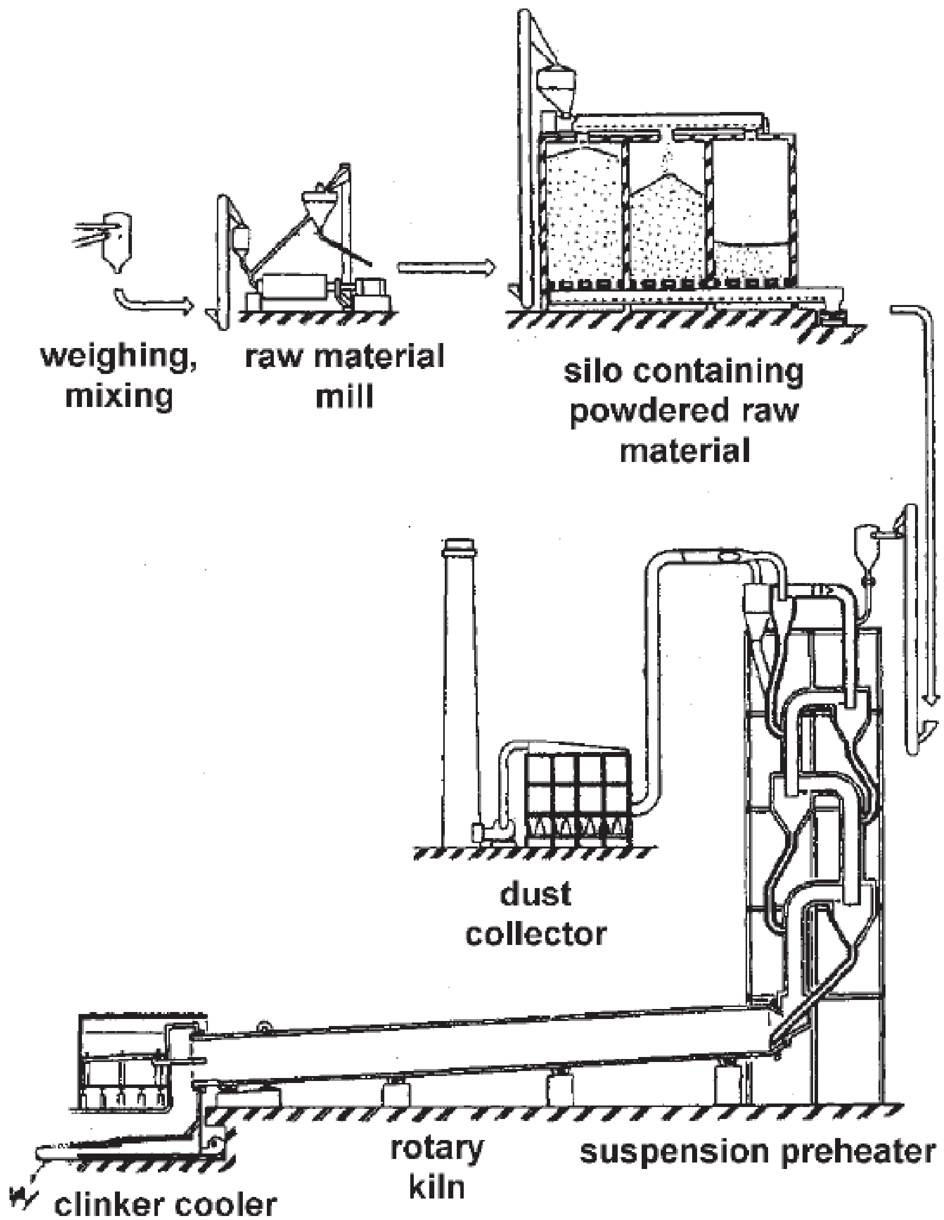
(Bush et al. 2006). Lightweight aggregates produced from calcined bauxite offer superior skid resistance (Transit New Zealand et al. 2005).

According to Chen et al. (2005), the following two requirements are needed in the rotary kiln during industrial production of lightweight aggregates. Moreover, these conditions are required to expand the particles:

a. Sufficient "glassed-phase formation," which helps to retain bloating gases; this "glassed-phase" occurs at a very high temperature (about 2,000ºF).
b. Gas-forming materials expand aggregate particles when the "glassed-phase" forms.

Different gasses are produced in the kiln during industrial lightweight aggregate production, which expands aggregate particles. Sulfur-dioxide (SO_2) is produced at a relative low temperature (750ºF). Clay minerals contain water, and dehydroxylation occurs at about 1,110ºF. Carbon-dioxide (CO_2) is produced at about 1,300ºF from "carbon-based compounds" and at about 1,560ºF from carbonates (CO_3^{-2}).

According to Chandra and Berntsson (2002), although two production methods (rotary-kiln and sintering) are available, the rotary-kiln method is widely used for lightweight aggregate production. In the rotary-kiln method, a 100 to 200-foot-long kiln with a five-degree inclination, similar to a Portland cement production kiln, is used. Raw materials (shale, clay, and slate) are supplied through the elevated end, and aggregates are cooled down at the lower end after passing through the hot kiln (Chandra and Berntsson 2002). Figure 3.7 shows typical diagram of lightweight aggregate production process by rotary-kiln method.

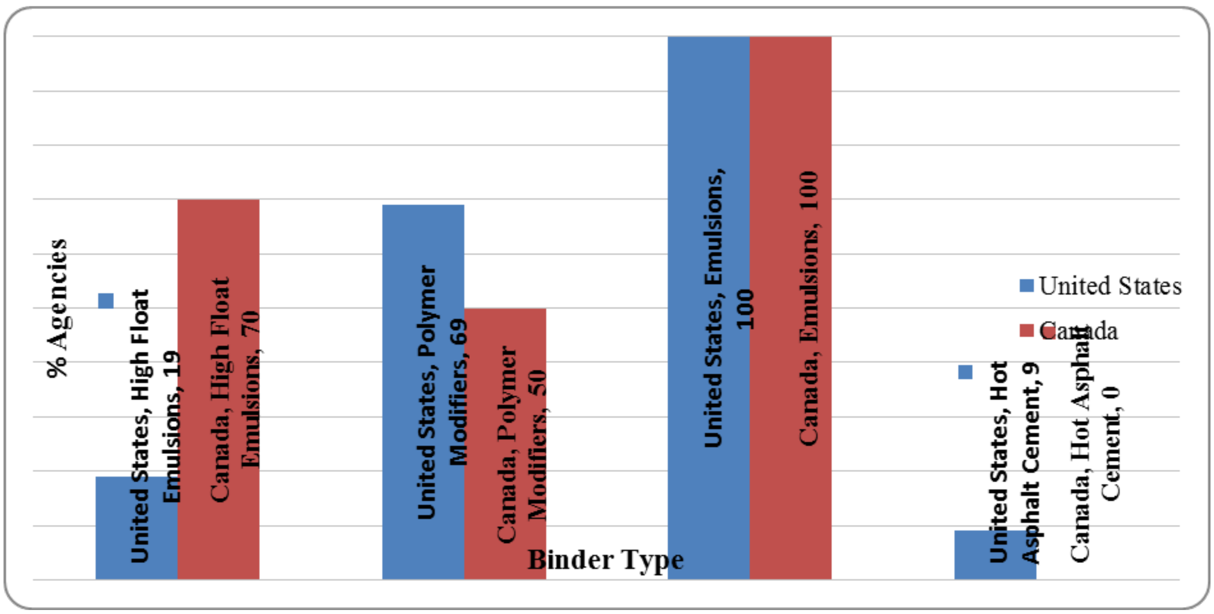


(Source: Reproduced from Chandra and Berntsson 2002)

FIGURE 3.7
Typical Diagram of Lightweight Aggregate Production by Rotary-Kiln Method

3.1.2 Selection of Asphalt Binder

Factors that govern the selection of asphalt binder include aggregate particles, existing pavement temperature, and weather conditions at the chip seal project sites. Selected asphalt binder should be such that it will not cause bleeding, as well as offer good adhesion to aggregate particles. Its viscosity should allow uniform application (Gransberg and James 2005; Texas DOT 2004). Mainly asphalt cement and asphalt emulsions are used in chip seal construction all over the world, though application of asphalt emulsion is more prevalent in the United States. Figure 3.8 shows usages of different binders used for chip seal in North America (reproduced from Gransberg and James 2005).

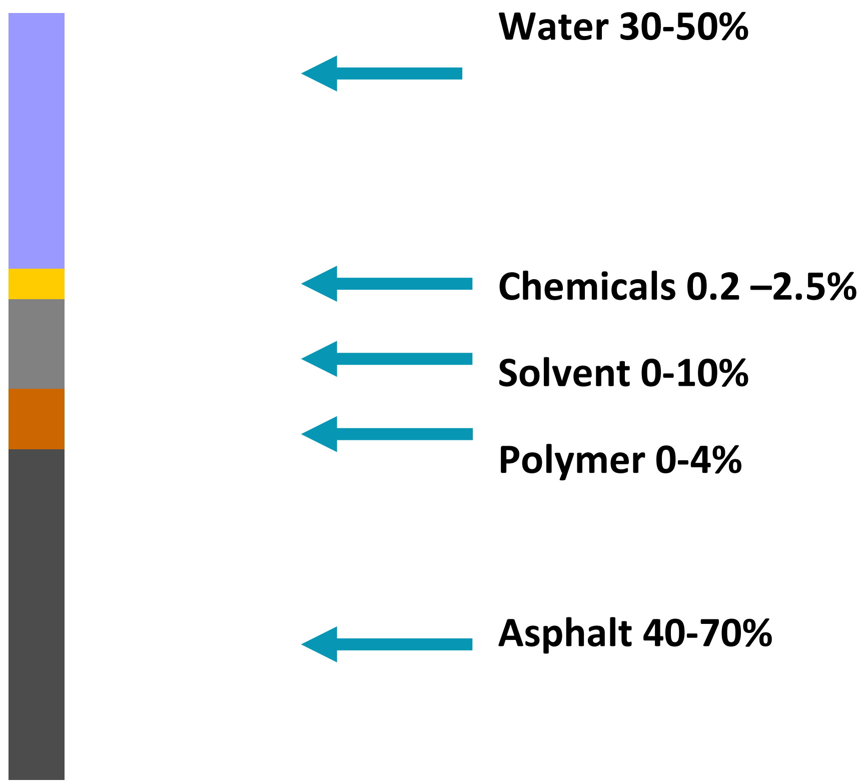


(Source: Reproduced from Gransberg and James 2005)

FIGURE 3.8
Asphalt Binder Used in Chip Seal in North America

Basically, asphalt emulsion is produced by an industrial process through mixing asphalt cement, water, and a specified emulsifying agent, which imparts charges to asphalt particles. Thus, asphalt particles in emulsion contain electrical charges, i.e. positive or negative depending on the emulsifying agent used in the production process (Gransberg and James 2005, James 2006).

Other than these three basic components, few other materials are also used in asphalt emulsion production, depending on requirements of the project. These components include calcium and sodium chlorides, adhesive agents, solvents, and latex. A typical recipe of asphalt emulsion is shown in Figure 3.9 (James 2006):



(Source: James 2006)

FIGURE 3.9
Typical Composition of Asphalt Emulsion

Benefits offered by asphalt emulsion can be summarized as follows (James 2006, Gransberg and James 2006):

- can be applied at relatively low temperature (about 140ºF)
- saves energy and has a lower negative environmental impact
- saves asphalt from oxidation
- offers ease of handling during construction
- particle charge ensures better bonding with aggregates
- reduces dislodgement of aggregates
- reduces bleeding and increases durability when polymer-modified emulsion is used

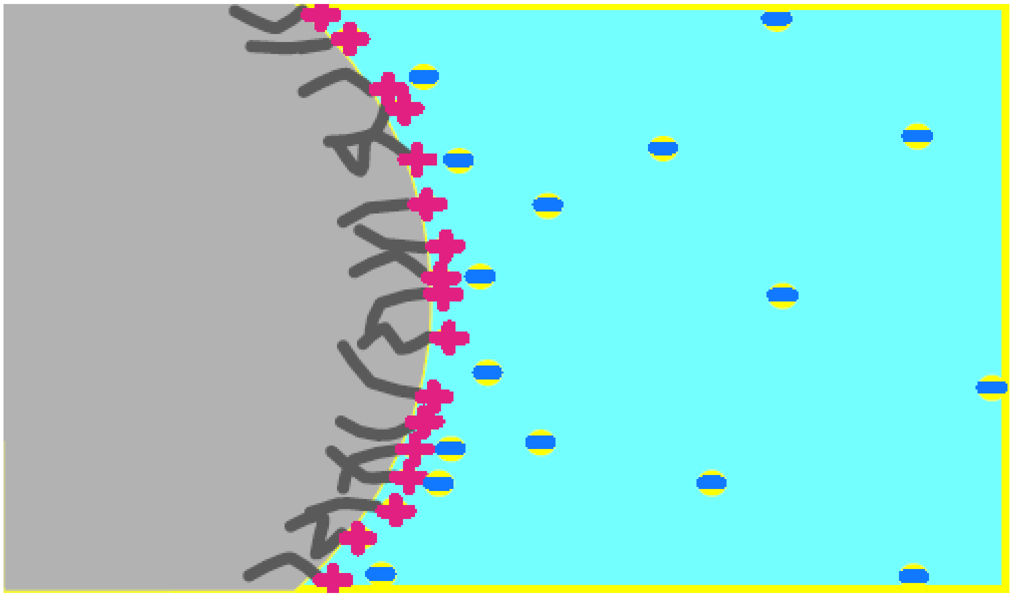
Table 3.6 shows the different types of emulsions used in the United States (Gransberg and James 2005). Kansas appears to be one of only two states that use CRS-1HP.

TABLE 3.6
Types of Asphalt Emulsion Used by Transportation Agencies in North America

Binder Type	U.S. Locations	Non-U.S. Locations
CRS-1	Nevada	None
CRS-1HP	Kansas, Nevada	None
CRS-2	Connecticut, Iowa, Maryland, Michigan, Montana, Nevada, New York, North Carolina, Oklahoma, Utah, Virginia, Washington, Wisconsin	Ontario
CRS-2H	Arizona, California, Texas	None
CRS-2P	Arizona, Arkansas, Alaska, Idaho, Iowa, Louisiana, Michigan, Minnesota, Mississippi, Montana, Nebraska, North Carolina, New York, North Dakota, Oklahoma, Texas, Washington, Wisconsin, Wyoming	New Zealand, Nova Scotia
HFRS	Alaska, Colorado, New York, Wisconsin	British Columbia, Manitoba, Ontario, Saskatchewan, Quebec, Yukon
HFRS-2P	Colorado, New York, North Dakota, Oregon, Texas, Wisconsin, Wyoming	Saskatchewan, Quebec

(Source: Gransberg and James 2005)

According to James (2006), ammonium compounds are used as emulsifying agents to produce cationic emulsion where nitrogen ions are gathered on the surface of asphalt particles. Thus, positive charges form on the surface of asphalt particles. He also indicates anionic emulsions impart a negative charge on the asphalt particles. Figure 3.10 shows positive ions of emulsifying argents surround the asphalt particles, while negative ions diffuse into water (James 2006).



(Source: James 2006)

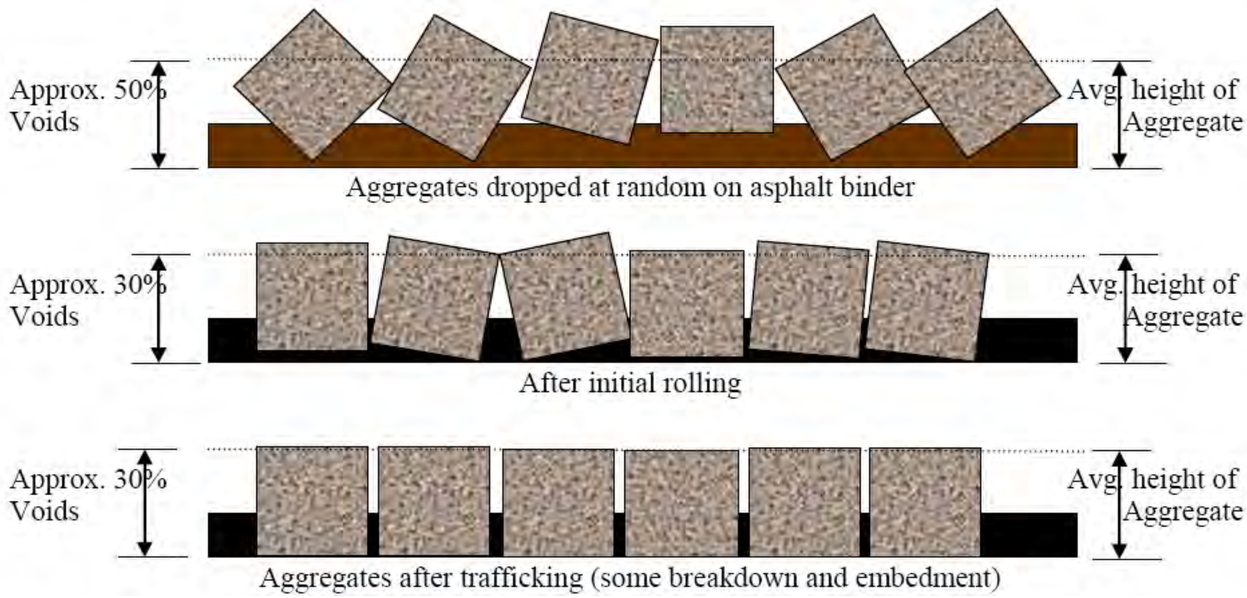
FIGURE 3.10
Formations of Positive Charges on Asphalt Particles

Breaking and curing stages associated with asphalt emulsion are very important. According to Gransberg and James (2005), separation of water from asphalt emulsion after application is known as "breaking." They also mentioned at the end of this stage, the emulsion's color turns to black. Several factors affect the breaking of emulsion, including emulsion composition, aggregate type, and temperature at the time of chip seal application. The process of strength gaining to form a stable matrix with aggregates is known as "curing" (Transit New Zealand et al. 2005).

3.2 Chip Seal Design Methods

Hanson first developed the chip seal design method in 1935, introducing the concept of partial filling of voids in aggregates. Later, other methods were developed based on Hanson's method. These include McLeod, Kearby, and modified Kearby methods. Another method developed by Transit New Zealand is known as the New Zealand chip seal method (Transit New Zealand et al. 2005).

Voids occur among loose aggregates when they are laid down in single layer. Hanson (1935) addressed partially filling these voids when they are applied for chip seal. He noted voids among the cover aggregate vary from 30% to 50% throughout the service life of the chip seal. Hanson's concept is shown in Figure 3.11.



(Source: Reproduced from Lee 2007)

FIGURE 3.11
Concept of Voids among Aggregate in Chip Seal

McLeod (1969) developed a chip seal design method which is applicable to both single and multiple layers of chip sealing. His method is based on two basic principles including aggregate and asphalt application rates. Aggregate application should be such that there will be a single layer of aggregate. Application rate depends on gradation, shape, and specific gravity. The most important issue he addressed is the asphalt application rate. He stressed a 70% filling of voids among aggregates. Asphalt application rate depends on a few factors including "aggregate "gradation, absorption and shape, traffic volume, existing pavement condition, and residual asphalt content of the binder" (Texas DOT 2004).

According to Gransberg and James (2005), the first chip seal design method in the United States was developed by Kearby. He introduced a nomograph to determine the required asphalt quantity. A number of design factors including thickness, aggregate embedment, and percentage of voids are required to determine appropriate binder rate from the nomograph (Kearby 1953). He emphasized using single-sized aggregates for chip seals.

Epps et al. (1974) modified the Kearby method as they found it does not estimate the quantity of asphalt normally applied for chip seals with lightweight aggregates. They introduced a curve in the nomograph for lightweight aggregates with more than 30% coating of aggregate. Epps et al. (1980) introduced two factors, traffic volume and pavement condition, to determine asphalt rate. A board test is used in the modified Kearby method to determine aggregate application rate. In this method, a ½-yd^2 board is covered by single-layer aggregates, and the amount of aggregate is determined.

According to the Seal Coat and Surface Treatment Manual (Texas DOT 2004), the following equations and procedures are used in the modified Kearby method to determine aggregate and asphalt application rates for chip seals:

The quantity of aggregates for chip seals is determined by Equation 3.1,

$$S = \frac{27W}{Q} \cdots\cdots\cdots\cdots \quad \textbf{Equation 3.1}$$

where S = designed aggregate application rate (yd^2/yd^3); W = dry-loose unit weight of aggregates measured from the unit weight test, (lbs/ft^3); and Q = amount of aggregates required to cover the board (lbs/yd^2).

According to this manual, asphalt application rate (for asphalt cement) is determined by Equation 3.2,

$$A = 5.61E(1 - \frac{W}{62.4G})T + V \cdots\cdots\cdots\cdots \quad \textbf{Equation 3.2}$$

where A = designed asphalt application rate, gal/yd^2 at 60°F; E = aggregate embedment depth determined using Equation 3.3; G = dry bulk specific gravity of the aggregate; T = traffic correction factor; and V = existing pavement surface condition factor.

$$E = ed \cdots\cdots\cdots\cdots \quad \textbf{Equation 3.3}$$

where d = average height of the chip seal, inch, obtained by Equation 3.4; and e = percentage of aggregate embedment.

$$d = 1.33 \frac{Q}{W} \cdots\cdots\cdots\cdots\cdots\cdots \quad \textbf{Equation 3.4}$$

where Q = amount of aggregate required to cover the board (lbs/yd^2); and W = dry-loose unit weight of aggregate measured from unit weight test, (lbs/ft^3).

Equation 3.2 is used to determine asphalt application quantity, but this rate is applicable for asphalt cement. Adjustment is incorporated in the modified Kearby method when asphalt emulsion is selected as the binder for chip seal. This adjustment is done using Equation 3.5,

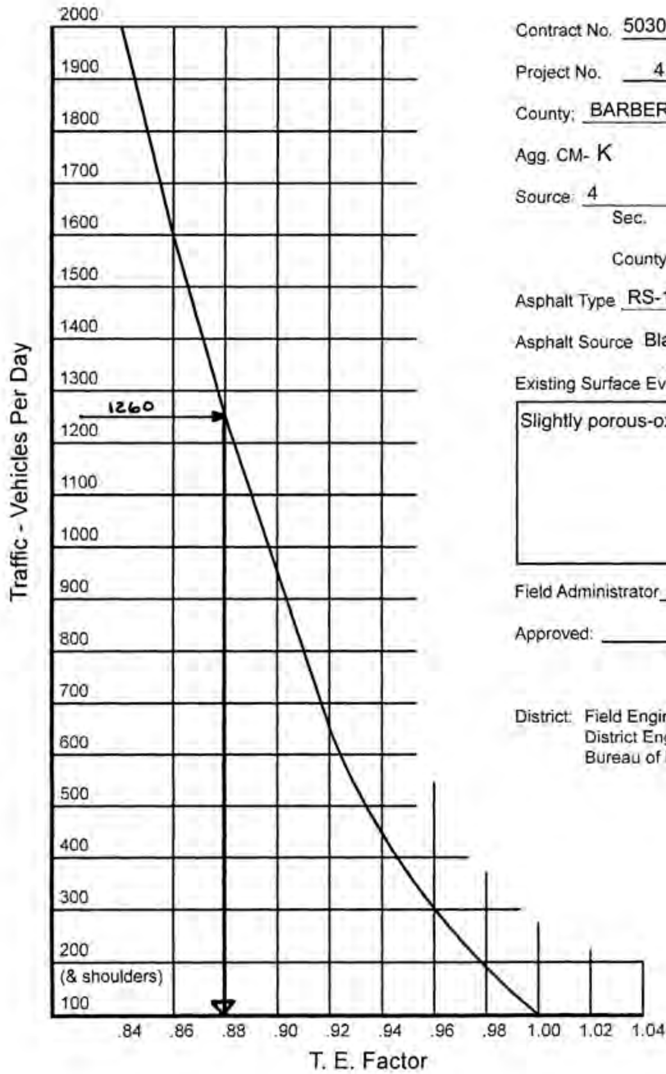
$$A_{recommended} = A + K\left(A_{theoretical} - A\right) \cdots\cdots\cdots\cdots\cdots\cdots \quad \textbf{Equation 3.5}$$

where $A_{recommended}$ = recommended asphalt emulsion application rate; A = designed asphalt application rate using Equation 3.2; and K = an adjustment factor depending on the chip seal construction season; $A_{theoretical}$ = A/R); R = percentage of residual asphalt content in asphalt emulsion.

Most chip seal design methods consider filling of 60-70% voids in aggregates, and the 2004 Seal Coat Design Algorithm assumes no aggregate loss will occur from chip-sealed pavement during the first winter season (Transit New Zealand et al. 2005). Houghton and Hallet (1987) mentioned the loss of aggregates in the winter season depends on voids in the aggregate. They showed aggregate stripping occurs while voids are less than 35%. This key point is used to determine asphalt application rate, which is sufficient enough to provide more than 35% voids in the winter season but no flushing in summer. This algorithm also includes the texture-adjustment factor. There are other adjustment factors, depending on the chip seal construction project, including soft substrate, absorptive surface, chip shape, and steep grades (Transit New Zealand et al. 2005).

The chip seal design procedure used by KDOT involves determination of aggregate and asphalt application rates. Cover material application rate is based on median particle size (M.P.S) of aggregates. Binder quantity depends upon chip size, traffic volume, and existing pavement conditions (KDOT 2004). Figures 3.12 and 3.13 explain this design method.

KANSAS DEPARTMENT OF TRANSPORTATION
ASPHALT SEALING DESIGN



Contract No. 503076295

Project No. 4 9298 01

County: BARBER

Agg. CM- K Qual. No. 90-8261

Source 4 (Sec.) 17S (Twp.) 21E (Range)

County Out of State

Asphalt Type RS-1H

Asphalt Source Black Gold, Inc

Existing Surface Evaluation:

Slightly porous-oxidized, some patches

Field Administrator ____________________

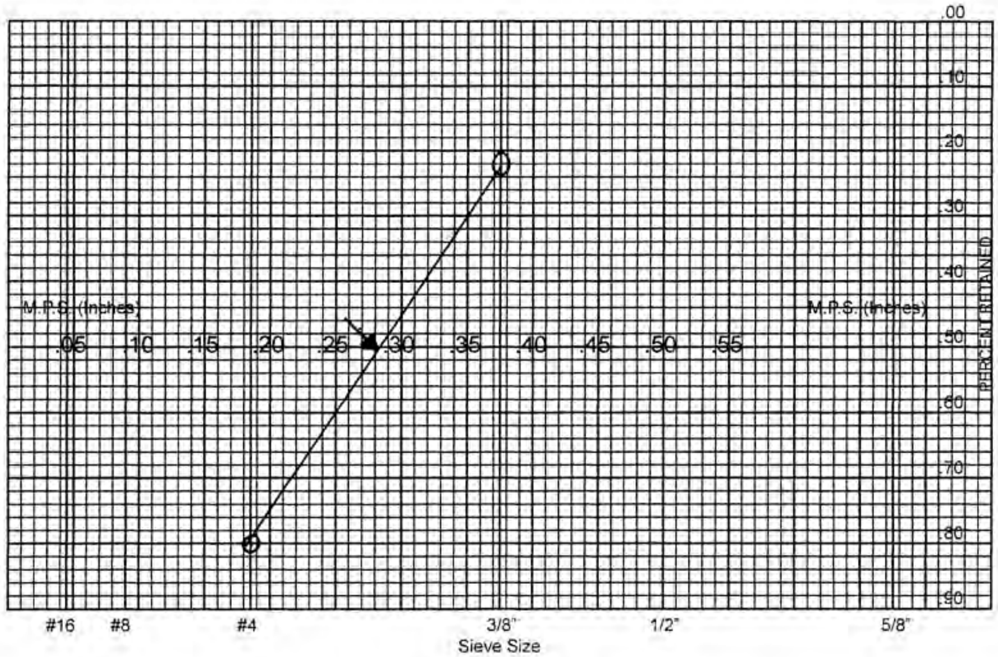
Approved: ____________________
District Materials Engineer

District: Field Engineer
District Engineer
Bureau of Materials & Research

Rev. 10-02 D.O.T. Form No. 683

(Source: Reproduced from KDOT 2004)

FIGURE 3.12
KDOT Chip Seal Design Method



Median Particle Size (M.P.S.) = 0.29 "   Traffic Count 1260 V.P.D.

T.E. Factor X 0.88 (From Graph)   (For traffic over 2,000 V.P.D., the T.E. Factor = 0.84)

Basic Residue Rate = 0.25 Gals. / Sq. yd.

Pavement Condition Adjust. = 0.02 Gals. / Sq. yd. (See Below)

Revised Application Rate, R_a = 0.27 Gals. / Sq. yd. (Residue)

Revised Application Rate, $R_e = \frac{R_a}{\%\ Residue} = \frac{0.27}{0.68} = 0.40$ Gals. / Sq. yd. Asphalt Binder

---

Aggregate Rate $A_{base} = \frac{36}{M.P.S.} = \frac{36}{0.29} = 126.32$ Sq. yd. / Cu. yd.

Theo. Max. Aggregate Rate, $A_a = A_{base}$ X (Factor) = 126.32 X 0.90

A_a = 113.68 Sq. yd. / Cu. yd.

CM-	Factor
A	0.70
D	0.90
E	0.94
→ K	0.90
L	0.90

Pavement Condition	Adjustment	
Flushed Asphalt Surface	– 0.03	Gals. / Sq. yd.
Smooth, Non-porous Surface	0.00	Gals. / Sq. yd.
Slightly Porous, Oxidized Surface	+ 0.02	Gals. / Sq. yd. ←
Slightly Pocked, Porous Surface	+ 0.04	Gals. / Sq. yd.
Badly Pocked, Porous, Oxidized Surface	+ 0.06	Gals. / Sq. yd.

(Source: Reproduced from KDOT 2004)

FIGURE 3.13
KDOT Chip Seal Design Method

KDOT Construction Manual Part IV contends the design values obtained in Figures 3.12 and 3.13 are based on the premise that the particles of aggregate have approximately the same height as their length and width. The use of excessively flat or elongated aggregate particles may necessitate a modification of the theoretical rates of application of both the cover material and the asphalt. The presence of an excessive amount of flat particles in the cover material would decrease the effective median particle size to some thickness below the theoretical, which would indicate a decrease in the rate of application of cover material and asphalt. If it can be assumed that the flat particles of cover material assume a flat position under rolling, it can be seen that the application of more cover material than the calculated quantity would only result in placing one particle of cover material upon another, and with the corresponding decrease in the rate of application of asphalt, the relationship of asphalt, aggregate and embedment would be out of balance, and the quantities calculated would probably not give satisfactory results. The calculated rate of application in the outlined procedure indicates the quantity of asphalt that is necessary to be permanently retained around the aggregate particles and above the existing surface to give satisfactory results. If cutback or emulsified asphalt is used, the calculated rate of application must be increased an amount equal to the diluent content of the cutback asphalt or the water content of the emulsified asphalt. The rate of application also must be adjusted to compensate for the old roadway surface condition. The recommended adjustments for pavement condition are shown in Figure 3.13. A blank design form is available in Appendix A.

3.3 Construction of Chip Seal

Chip seal construction includes the use of equipment (Gransberg and James 2005) — aggregate particles spreader, asphalt sprayer, pneumatic-tired roller, dump truck, and rotary broom.

Some precautions need to be followed before chip sealing. These include weather conditions and surface preparation. Asphalt emulsions used for chip seal require a high pavement temperature with low humidity (Gransberg and James 2005). Kansas performs chip seal applications from June to September (KDOT 2004). Surface preparation for chip sealing is very important. Patching, crack filling, leveling pavement surfaces, and sweeping to remove debris are also required for successful application of chip seal (Gransberg and James 2005).

Chip seal performance depends on accurate application of asphalt binder. Thus, it is necessary to calibrate and inspect the asphalt distributor (Gransberg and James 2005). Normally, asphalt emulsions are applied at about 140ºF. Aggregates are applied immediately after asphalt spraying. As noted earlier, chip seal success depends on proper embedment of aggregates into the applied asphalt emulsion applied; delayed application of aggregates hampers the goal. If the applied aggregate amount is more than required, loose aggregates will be dislodged. Rolling should be accomplished as soon as possible after aggregate spreading, using pneumatic-tire rollers. Performance and durability of chip seals is dependent on proper aggregate embedment by rolling (Gransberg and James 2005).

Excess aggregates need to be swept after the rolling operation. Proper traffic control is also required during and after chip seal application in accordance with the KDOT (2004) Construction Manual. Newly sealed roads need to be closed to regular traffic for four hours in the case of asphalt emulsions being used as binder. This time is reduced to one and one-half hours for polymer-modified asphalt emulsion. Distin (2008) noted that in South Africa, traffic is allowed a minimum of two hours before the outside temperature falls below 77°F.

3.4 Performance Measurement of Chip Seal

According to Gransberg and James (2005), both quantitative and qualitative approaches are used for performance measurement of a chip seal. They recommended both engineering-based and visual inspections be performed. Measurement of skid resistance and texture depth are engineering-based procedures. Skid resistance is a relationship of frictional force developed between wheel and aggregate particles and is measured by the ASTM E 274-06 test. According to this report, measurement of texture is performed using the sand patch method, using ASTM E 965-96, while qualitative measurement is performed by visual inspection.

Chapter 4: Pre-Seal Coat Activities

4.1 Overview

Chip seal projects, though considered to be simple, require a great deal of planning and careful preparation in order to achieve the maximum benefit. Numerous details must be worked out between the KDOT field engineer, project inspectors and the contractor. The Engineer needs the approximate date the Contractor plans to start the work and who will supply and deliver the materials. The Engineer must also arrange for the preconstruction conference. See details in Section 4.3.

The main preparatory stages for a chip seal project include:

- Repairs and patching existing pavement, see Section 4.2;
- Chip seal design and application rates, see Chapter 3.
- Preconstruction conference, see Section 4.3;
- Stockpiling, sampling, and testing aggregate, see Section 4.4;

4.2 Repairs and Patching Prior to a Chip Seal

Perform any repair work that the existing pavement requires, well in advance of chip seal work, ideally in the previous summer or fall. For some repairs, a portion of the roadway may need to be removed and replaced. Other repairs may involve a thin cold or hot mix maintenance overlay. A strip/spot seal coat or fog seal may be applied, which may reduce the amount of the future chip seal binder that is absorbed into the repaired area. Pavement repairs are usually accomplished by KDOT maintenance forces, however they may be done as a part of the chip seal contract.

4.2.1 Timing

There is no absolute time frame during which repair work must be accomplished. It is generally preferred all repair work be accomplished well in advance (perhaps eight to ten months) before applying the seal coat.

It is very important for the local maintenance personnel to know when chip seals are scheduled in order to have the repair work completed in advance of the chip seal. Preparation of the existing pavement prior to a chip seal helps assure a good final product.

When a cold mix asphalt repair is required, the further in advance of the chip seal, the better. The lead time allows the cold mix material time to cure, by allowing the volatiles time to evaporate. This may require performing the repairs during the fall of the previous year.

If a fog seal is needed on a repair area, allow time for the patch materials to completely cure before applying a fog seal. A fog seal is used to help hold the repaired area until the chip seal can be applied.

4.2.2 Types of Repairs

There are many different types of repairs that could be performed prior to a chip seal:

- **Milling.** Correct high spots in the existing surface may be accomplished by planning with either a heater planer or, more commonly, a cold milling machine. If the riding surface is rough these process will help improve the ride. Milling or heater planning is normally included with the chip seal contract, allowing the Contractor to coordinate the work.
- **Leveling.** Depressions may require leveling the surface with either a hot- or cold-laid asphalt mix. The sizes of this type of patch will vary, but ranges in size from a wheel path only a few feet long, or two full lanes wide and 50 feet or more in length.
- **Pothole Repair.** Repair all potholes in a permanent manner before the chip seal is applied.
- **Base Repair.** Repair any base failures before applying a chip seal. This generally requires removal and replacement with suitable material.
- **Edge Repair.** Raveled edges generally are dug out and replaced with new material. The goal is to replace the pavement edge to a stable condition and the roadway to its full width.

- **Crack Sealing.** Seal or fill cracks greater than ¼ inch, prior to the chip seal. If the quantity of cracks is large, the work of crack sealing or filling may be included in the chip seal contract. If there are just a few unsealed cracks, the KDOT maintenance forces may repair these cracks.

4.3 Preconstruction Conference

KDOT allows Contractors to tie projects, and it is not uncommon for one Contractor to tie all chip seal projects within a District. This practice results in a savings to KDOT as the Contractor can spread the fixed costs over a larger volume of work. KDOT may have one field construction office administer all of the tied chip seal contracts in a District, or have individual offices administer those projects within their Area.

Prior to any of the work, or prior to stockpiling aggregates, a preconstruction conference should be held. If multiple offices are involved, a joint conference may be used covering all the work in the District. The preconstruction conference is a time for the Contractor to explain their “game plan” and work out any details necessary to construct the chip seal projects. It also allows KDOT to discuss general procedures, and any special conditions or requirements in the Contract Documents.

4.3.1 Attendees

There is no specific rule as to who should attend the preconstruction meeting. If KDOT Maintenance forces are performing repairs in conjunction with the project, include the appropriate personnel in the meeting. The Contractor should be represented by the project supervisor, foreman, and any other supervisory personnel on the project. If traffic is expected to be a major factor, the personnel from both the Contractor and KDOT assigned to traffic control should attend.

4.3.2 Meeting Procedures and Objectives

KDOT Construction offices will follow established procedures for conducting preconstruction conferences. For the chip seal preconstruction conference, the following objectives should be included:

1. **Meeting All Personnel Involved.** The preconstruction conference allows the Contractor and assigned foreman and supervisors to meet the Construction Engineer, Chief Inspector, and the other project Inspectors. This is often the first time these two groups have ever met each other in person.
2. **Establish Working Relationship.** The preconstruction conference provides an opportunity to establish a harmonious, yet professional working relationship between key personnel involved in the project. KDOT and the Contractor personnel must to be able to work in harmony with each other. Due to the fast pace nature of chip seal work, it is extremely important to have open and honest communications at all times; otherwise the quality of the final product could be compromised. Maintain professionalism at all times.
3. **Define Responsibilities.** Identify the Contractor and KDOT chain of command or escalation ladder, in the event of project-related conflicts. Establish the method to resolve any conflicts that arise during the course of the project as rapidly as possible.
4. **Review Contract Documents.** The information in the Contract Documents is a binding contract. The Contract Documents must be understood by all parties. During the preconstruction conference, a discussion and understanding with everyone involved should result in few conflicts during construction. It is a good practice to try and anticipate potential problems and resolve them during the preconstruction conference when everyone is present rather than wait until encountered during the work.
5. **Define Work Schedule.** KDOT and the Contractor should agree on a work schedule, including hours and days to be worked, sequence of lanes to be sealed, when and how repair work will be performed and by whom.
6. **Material Sources (asphalt binder and aggregate).** Where will the Contractor’s materials be produced, and how will they be delivered to the project site? Depending on the Contract Documents, who and where will the materials testing be performed?

7. **Agree on Location of Aggregate Stockpiles (either at KDOT mixing strips, on right-of-way or off site).** It is important to know where the Contractor will stockpile the aggregates. Permission is required to place the materials on KDOT mixing strips or within the right-of-way. This should be coordinated with the local KDOT maintenance supervisor. Note: often the stockpile locations are established before the preconstruction see 4.4.
8. **Review Traffic Control.** Traffic control is critically important to ensure the safety of the traveling public and both the Contractor and KDOT personnel during construction. Discuss traffic handling methods, devices, signs, and barricades in detail. Address correct flagging procedures and delay times.
9. **Miscellaneous.** Discuss any other pertinent information concerning the project at this meeting. Both KDOT and Contractor representatives should leave the meeting with a full understanding of what is expected from each party on the project.

4.4 Stockpiling Aggregate

KDOT Standard Specifications allow the Contractor to stockpile aggregate to be used on the project on KDOT R/W at locations approved by the Engineer. For the sake of efficiency, most Contractors will elect to use KDOT mixing strips or R/W. For numerous reasons, the stockpiling of aggregate occurs prior to the formal preconstruction conference. When stockpiling occurs prior to the preconstruction conference, decisions as to location must be made and approved, prior to any actual stockpiling on the job site.

4.4.1 Supplier

Before submitting a bid on the project, the Contractor will have already received a tentative agreement from a supplier that the required materials will be made available. After the contract is awarded, the Contractor finalizes the agreement with the supplier, and identifies the supplier to the appropriate KDOT field office.

4.4.1.1 Aggregate Sampling and Testing

The Contract Documents identify the required material properties for the aggregate and binder, along with the appropriate test methods. Normally, the test methods are covered in the KDOT Construction Manual, while the aggregate graduation and quality requirements are included in the Contract Documents.

In the 2007 KDOT Standard Specification 106.1b: Quality Materials, it states:

1. Use only materials that meet the Contract Documents requirements. Unless specified otherwise, use new materials.
2. The Engineer or Inspector will inspect materials. The Engineer, Inspector, or Contractor will test the materials. See Subsection 106.3: Sampling, Testing, and Cited Specifications in the 2007 Standard Specifications.

- After inspection and testing, the Engineer or Inspector will approve or reject the materials at the source of supply, at the project site, or both;
- The Engineer or Inspector may reject materials at the project site even if the Engineer or Inspector previously approved the materials at the source of supply;
- The Engineer or Inspector may reject materials if at any time, the Engineer determines the materials do not meet the Contract Documents; and
- The Engineer or Inspector may reject materials during or after incorporation into the work, if the material does not meet the Contract Documents requirements.

The method and location of sampling materials should be consistent and uniform. The Engineer can retest accepted stockpile materials if the material shows visible changes, or does not conform to specifications.

4.4.1.2 Stockpile Locations

Normally, the Contractor proposes the stockpile locations to the project Construction Engineer for approval. If the use of the mixing strip will not interfere with KDOT operations, approval is generally granted. In some cases mixing strips are not in a good location, and the use of KDOT R/W becomes more beneficial. When approving the use of existing R/W, as a minimum, consider the following:

- Locate stockpile a minimum of 30 feet from roadway;
- Do not obstruct traffic or sight distance;
- Do not interfere with the access from abutting property;
- Do not interfere with roadway drainage; and
- Return stockpile location to the existing conditions, upon completion.

4.4.1.3 Contamination

Do not place the stockpiles in locations where they have the potential to become contaminated. Take precautions that clay, mud, soil and grass are not added to the stockpile. Contamination may occur when building the stockpile and when removing aggregate. Do not stockpile such that roadway drainage will cause the aggregate in the stockpile to become excessively wet.

4.4.1.4 Area Preparation

The Contractor may be required to prepare a stockpile area before the aggregate is delivered and stockpiled. Clean and level the stockpile area with equipment such as a dozer or motor grader, clearing debris, such as vegetation, rocks, and sticks. Apply appropriate storm water pollution prevention devices, when necessary. For these reasons, the use of the KDOT mixing strip becomes a good choice, as the surface is generally solid.

4.4.1.5 Proper Stockpile Techniques

Place the aggregate in the stockpile to minimize (or prevent) segregation and degradation. Use techniques such as one-dump high and benching to build proper stockpiles.

a. **Segregation.** Segregation is the separation of the different sized aggregate particles. Segregation results in one part of the stockpile containing only the coarser particles and another area containing only finer particles. Stockpile the aggregates uniformly, so that all samples taken from any area of the stockpile contain a complete range of aggregate sizes, and are within the graduation limits specified in the Contract Documents.

The best technique is to dump the truckload adjacent to the previous pile, keeping the larger particles from rolling. Never place stockpiles in a high cone-shaped heap, as segregation is very likely to occur. See Figure 4.1 as an example of good stockpile building.

b. **Degradation.** Degradation is the breaking down of individual aggregate particles, resulting in a finer gradation of the aggregate than when delivered to the stockpile. Degradation commonly occurs from improper operation of the front-end loader, either at the quarry or when loading the haul truck. The more often the aggregates are handled, the more likely degradation may occur. The goal for both the Contractor and KDOT should be to handle the aggregate as little as possible.

FIGURE 4.1
Properly Placed Aggregate Stockpiles

Chapter 5: Equipment Inspection and Calibration

5.1 Introduction

Inspectors and the Contractor's equipment operators must be familiar with and knowledgeable of the capabilities and limitations of the equipment used in a chip sealing project. Equipment must be properly calibrated, well-maintained by the Contractor, and functioning correctly in order to produce a successful chip seal. In this Chapter, many of the checks are the responsibility of the Contractor; however the Inspector must be aware of the checks and verify they have been completed. This chapter provides basic information for the following typical types of equipment used in chip sealing:

- Rotary broom
- Asphalt distributor
- Aggregate spreader
- Haul trucks
- Rollers
- Front-end loader
- Heater and storage unit

5.1.1 General Provisions for Inspection

The Contractor and KDOT Construction Engineer should coordinate the starting date of the project, and set a date and time for the equipment to be assembled, inspected and calibrated. Expect a minimum of half a day for equipment inspection/calibration. Perform the inspection/calibration the day before the work begins. Trying to accomplish equipment inspection/calibration the same day the chip seal is scheduled to begin leads to a hurried operation, often resulting in overlooking important details.

5.1.2 Equipment Data

The project equipment list should include the date of inspection, equipment manufacturer's date, manufacturer's name, model number, Contractor's equipment number if used, serial number or other identifying features. The inspector's diary should include any required or routine adjustments resulting from the inspection, noting the completion of required adjustments, and lastly, if correct, that the piece of equipment is found to be acceptable.

5.1.3 Inspecting for Leaks

Visually inspect all equipment used on the project for leakage of any substance that might: contaminate the asphalt (binder), aggregate, or adhesion of the chip seal to the existing pavement surface. These primary fluids include fuel (both diesel and gasoline), hydraulic fluid, engine coolant, crankcase oil, and transmission fluid; however, others may be involved.

Inspecting for leaks is extremely important, not only before the project begins, but continually as the project progresses. If a leak is detected in any piece of equipment, remove the leaking equipment from the roadway until it is repaired.

5.1.4 Safety

Follow the manufacturer's safety procedures for inspection/calibration and operation of all equipment. Follow safety precautions and procedures for any equipment used for transporting, storing, or applying asphalt materials. Heating asphalt materials other than emulsions constitutes some degree of "risk or danger" and must be respected. The most sensitive are cutback asphalts, due to the highly flammable solvents used. Exercise care to prohibit open flames to come in contact with the asphalt or the gases from these materials. When asphalt cement is involved, the major safety concern is related to the high material's temperature. Asphalt cement at 300°F can cause very severe burns. Do not stand near the asphalt distributor during heating and/or during operation, unless necessary. Keep a copy of the Material Safety Data Sheet (MSDS) for the products being used, in the asphalt distributor.

5.2 Rotary Broom

It is necessary to clean the existing pavement of debris before applying the binder to the existing surface. Proper cleaning helps achieve an adequate bond of the binder to the pavement. Prior to opening the chip seal to traffic, broom the finished surface to remove excess aggregate particles. Use power rotary brooms for these operations. An example of a rotary broom is shown in Figure 5.1. A vacuum sweeper or street sweeper is another example of a broom which may also be used to clean the pavement.

FIGURE 5.1
Rotary Broom

Use self-propelled, four-wheeled rotary brooms, capable of operating in both forward and reverse. Equip with a bristle brush capable of being raised, lowered, and rotated horizontally. The bristle brush on a rotary broom is shown in Figure 5.2.

FIGURE 5.2
Rotary Broom Brush

5.2.1 Safety Markings

The rotary broom operates well ahead of the rest of the equipment. This puts it in a very vulnerable position, due to the creation of dust and the exposure to traffic. Check safety markings, lights, and flags on the broom for the safety of the traveling public, as well as the sweeper operator.

5.2.2 Bristles

Equip the brush with nylon or fiber bristles, or a combination of nylon and steel bristles. Check the bristles to verify they are in a workable condition. Check the full width of the brush for even wear of the bristles. If the bristles are worn unevenly, too much pressure is being exerted in one spot while not making contact in another. If there is a visible unevenness, replace the bristle assembly.

5.2.3 Brush Controls

Check the brush to see that it can be raised or lowered, and rotated horizontally. Use a brush capable of discharging debris, or aggregate to either the left or right. Equip with rotating brush controls that promptly start and stop the rotating brush.

5.2.4 Older Model Brooms

Many older model brooms have a separate hydraulic cylinder at each end of the broom, which raise and lower the brush assembly. These cylinders are operated with individual controls. The two cylinders may not exert even pressure, thus one end of the broom may exert greater pressure on the pavement, while the other end barely contacts the surface. When older models are used on the job, watch for uneven pressure at opposite ends of the brush and adjust to more uniform pressures. Newer models should not have a problem, as they are manufactured with single controls.

5.3 Asphalt Distributor

The asphalt (binder) distributor (referred to as the distributor) is the most complex piece of equipment required in all sealing type operations. A distributor is a truck-mounted, calibrated, insulated tank, with numerous special purpose attachments. It is necessary to operate all of the many components of this piece of equipment properly at all times. The major components of a distributor are considered to be:

- Asphalt tank
- Heating system
- Circulating and pumping system
- Filter screens
- Spray bar
- Hand sprayer
- Controls and gauges

A typical asphalt distributor is shown in Figure 5.3.

FIGURE 5.3
Asphalt Distributor

5.3.1 Asphalt (Binder) Tank

Distributor binder tanks vary in size from 500 to 2000 gallons. Most Contractors performing chip seals prefer the larger tanks to minimize starts and stops. The tank is insulated to assist holding the heat, and maintain the desired temperature. Asphalt cement temperatures for chip seals are commonly well over 300°F. If the tanks were not well insulated, the binder would cool quickly near the skin of the tank and could harden to unworkable levels.

For each distributor, provide a current "calibration certificate" issued by KDOT personnel and according to KDOT requirements. (See 5.3.2 for more details) The distributor "calibration certificate" indicates the tank has been calibrated determining the accuracy of the tank's capacity and a correlation with the volume measuring stick (referred to as the stab stick). The "calibration certificate" is considered valid as long as there is no reason to suspect that any major modifications have been made to the distributor tank.

Before chip seal operations begin, verify the tank is clean, or if there is binder from a previous project that it is the same as the binder to be used on the project. It is necessary to prevent contamination or commingling of different types of binder. Use extreme caution to avoid chemical or physical reactions occurring when different binders are inadvertently used in the same tank.

5.3.2 Distributor Tank and Stab Stick Calibrations

Though a stab stick from another state or the manufacture may come with the distributor, KDOT requires the tank volume to be calibrated by KDOT personnel and a new stab stick made. Have the KDOT District Materials Lab calibrate the tank of any new or first-time use distributor before beginning any sealing operation for KDOT. Once the tank is calibrated, the KDOT District Materials Lab will issue a certification for the distributor, to be carried in the distributor at all times. The Contractor is responsible to make arrangements for the tank calibration with the District Materials Engineer in the District where the first usage of the distributor will occur. The Contractor should schedule the calibration at least two weeks before intended usage. Additionally, the District Materials Lab will mark a stab stick to be used with the specific distributor, with the blank provided by the Contractor (See Section 5.3.2.1: Materials). The field office Inspector should check the distributor certification verifying the tank has been calibrated when the distributor arrives on the project.

Two KDOT personnel are required to perform the calibration. The calibration will require a certified scale within in reasonable distance to weigh the distributor before starting calibration and after the tank has been filled with water. The calibration location must have an area large enough and level enough to accommodate the distributor in a level condition, and the availability of water from a normal outside water faucet.

5.3.2.1 Materials

The Contractor must furnish an aluminum or stainless steel blank, a minimum of ¼ x 1 ¼ inch and 1 foot longer than the tank and manhole (See 5.3.5 for description) depth. The blank stab stick should not bend easily when standing vertically. KDOT will furnish a certified water meter capable measuring in gallons, and files or tools for marking the Contractor-furnished stab stick.

5.3.2.2 Tank Condition

After making arrangements for the calibration, the Contractor must deliver the clean tank with an inside condition free of asphalt or emulsion from previous usage to the location agreed to by the District Materials Engineer. Visually inspect the inside of the tank prior to beginning calibration procedure.

5.3.2.3 Calibration Procedure.

1. Prior to starting the calibration process, it is best to add some water and blow the tank to be sure the tank and application system is empty.
2. Weigh the distributor empty on certified scales.
3. Place the distributor in position near the water source, and make sure the distributor is level. Some distributors have a built in level, and for those that do not, a carpenter’s level will suffice.
4. Hook up the water meter with the outlet hose placed in the bottom of the tank, but with the outlet end of the hose not near the location where the stab stick will be placed or interfering with any floats for outside meters.
5. Find the location where the volume of asphalt will be measured generally through the manhole hole, which should also be along the lines of the center of the distributor tank. The location should have easy access. Always place the stab stick plumb, and mark the top of the manhole hole on the stab stick to make sure it is always returned to the same position.

6. Pour approximately 5 gallons of emulsion into the tank to aid in reading the water level on the stab stick after water has been added. Pull the stab stick and mark as zero.
7. Start filling the tank with water running through the calibrated meter. Once started, do not stop the water flow or change the rate of filling the tank.
8. After 25 gallons of water has been added, pull the stab stick and quickly mark with a file or metal marking tool and return the stab stick to the tank. The mark does not have to be large, but clear enough that when finished it can be seen. See step 13 below.
9. Repeat pulling the stab stick and marking after every 25 gallons of water has been added until the distributor tank is full. Depending on the size of the tank this may take quite a long time (Example at 5 gal/min and a 2000 gal tank it will take 6 ½ hours).
10. When the tank is full, discontinue filling and remove the hose, making sure no water is siphoned from the tank.
11. Take the distributor to the certified scale and get the weight full of water.
12. From weight tickets, compute the weight of water. Convert to gallons to check that the meter and the actual amount by weight are close (plus or minus 10 gallons). Do not forget the 5 gallons of emulsion added for marking.
13. KDOT personnel will take the stab stick and formalize the marks, noting the gallons generally with the number stamped in at 100 gallon intervals, and a star at the 25 gallon intermediate points. Additionally, the KDOT personnel will reference the stab stick to the distributer. Note: the stab stick will be completed a few days after the actual calibration. See Figure 5.4.
14. KDOT personnel will make a paper tape of the stab stick and keep for future reference in case the stab stick is destroyed or lost.
15. Complete the KDOT paperwork, placing the original in the distributor truck.

(Source: Courtesy: AusStab)

FIGURE 5.4
Taking Reading with a Calibrated Stab Stick on the Top of a Tanker

5.3.3 Baffle Plates and Flues

In order to stabilize the load while the distributor is in motion, the inside of the tank contains two or three baffle plates. The baffles are especially critical as a constant spray pressure is necessary for uniform application of the binder. The tank will have one or two flues or heat ducts running lengthwise of the tank. The flues allow heat to be conducted into the center of the tank. Even though the tank is insulated, some heat loss will occur. Using a burner system in combination with binder recirculation within the tank, the binder may be heated and held at a selected temperature. Figure 5.5 shows the baffles and flues running through the distributor tank.

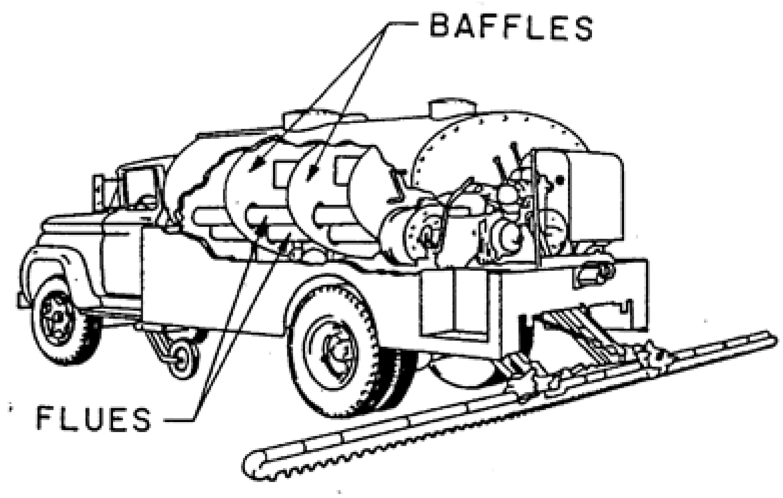


FIGURE 5.5
Baffles and Flues inside Distributor Tank

5.3.4 Thermometer

Equip the tank with a thermometer having a range from below 100°F to at least 400°F. Dial or mercury thermometers mounted into the tank are acceptable. A dial-type thermometer mounted outside the tank connected to a thermocouple that is mounted inside the tank is also acceptable. Check thermometers for accuracy through the full range of the thermometers. Using a sample of binder, record the temperature using a separate thermometer, then compare the results with the thermometer attached to the distributor tank.

5.3.5 Manhole

A manhole opening at the top of the tank covered with a heavy, hinged lid with fastener is used in filling the tank, and permits visual inspection of the tank and its contents. The manhole may be opened to measure the amount of asphalt in the tank using the calibrated “stab stick”. The measuring process is called “stabbing the tank” and is described in 6.10. Figure 5.6 shows the manhole cover from the top of the tank.

FIGURE 5.6
Manhole Cover on Distributor

5.3.6 Vent

All distributor tanks are equipped with a vent. The vent location varies with the manufacturer. For safety reasons, take care to make certain the distributor is always parked where there is adequate crosswind to prevent an accumulation of fumes (from the vent) to come in contact with the burner flame.

5.3.7 Distributor Heating System

Binder application temperature is a critical factor in the success of a chip seal. To maintain a constant temperature, a heating system is necessary. Each manufacturer will have a unique heating system. The heating system is judged on performance (ability to keep the binder at recommended temperature), rather than a specific heating system design.

5.3.7.1 Burners

Burners are fueled with either propane or diesel, and are located at the rear of the distributor. Burners are mounted and positioned to allow the flame to be directed into the flues passing through the tank. See Figure 5.7 for a typical configuration.

Check the tank heater unit for starting and operation. Each burner should operate independently to allow either one to be used alone or simultaneously. Use adjustable burner flames to regulate the amount of heat being directed into the flues. Verify the fuel lines and burners are free of fuel leaks.

FIGURE 5.7
Burners and Flue

5.3.7.2 Heating

The need and amount of heating is dependent on the following:

- Type of binder being used;
- Ambient air temperature;
- Length of time the binder will be in the distributor prior to being sprayed on to the roadway; and
- Whether the distributor is filled directly from a jobsite heated storage tank, or has been hauled to the project site in an insulated transporter.

Often emulsions are used for a chip seal and are applied (referred to as shot or sprayed) from 120 to 160°F. When applying asphalt cement as a binder, application temperatures may range from 275 to 325°F. Application temperatures for cutback asphalts are from 125 to 275°F. Apply cutbacks at 25 to 50°F below their respective flash point. For each binder type, refer to recommended heating and application temperatures. (See Table 601-1: Asphalt Application Temperature in the 2007 KDOT Standard Specifications.)

5.3.8 Distributor Circulation and Pumping System

Equip all distributors with a power-driven pump to apply (spray) binder under pressure onto the roadway surface. Secondarily, the pumps provide a binder circulation system. There are two systems commonly used to supply pressure to the spray and circulation system. One system uses a separate engine, normally mounted at the rear of the tank supplying power only to the pump. The other system uses power from the truck engine to operate the pump, this system is referred to as a hydrostatic distributor system.

5.3.8.1 Function

The pump provides power to perform the following functions:

- Circulate the binder throughout the tank. Circulation of the binder is necessary to prevent the binder from burning if it remained next to the flues for an extended period, and prevents the binder from remaining near the outside of the tank long enough to cool and harden.

- Circulate binder through the spray bar and return unused binder back into the tank, preventing binder from remaining in the spray bar long enough to cool, harden, and clog the spray nozzles.
- When work is completed, pump unused binder out of the distributor.
- Pump binder from one storage tank to another. (It may be used as an auxiliary pump to transfer asphalt from one tank to another)
- Fill or load the distributor tank. If a storage tank, heater unit, or transporter unit is not equipped with a pump, the distributor spray pump may be used to fill the distributor tank.

5.3.9 Filter Screens

Most distributors have filter screens in the main piping between the tank and the spray bar. These wire-mesh filters prevent particles of burned asphalt, (a component of the binder) or impurities from entering the spray bar and clogging the spray nozzles.

Occasionally remove these filter screens and clean with diesel fuel, or burn off the particles with a torch. This prevents a blockage of the flow of binder, allowing it to flow under full pressure to the nozzles.

5.3.10 Distributor Spray Bar

The spray bar and nozzles regulate the amount of binder applied on the roadway and generate the spray pattern. Figure 5.8 shows a typical distributor spray bar.

FIGURE 5.8
Distributor Spray Bar

Typically, the spray bar used on chip seals may be adjusted from 10 to 16 feet wide, using extensions (generally in 2 foot increments).

The bar is composed of a series of evenly spaced (every 4 inches) spray nozzles along the bar. The spray bar contains a return line for continuous circulation of binder through the bar. Some models are equipped with shut-off valves on each nozzle, allowing closing a few spray nozzles for spraying irregular areas. Figure 5.9 shows the nozzles on a typical spray bar.

FIGURE 5.9
Nozzle on Spray Bar

5.3.10.1 Hinged Bar

Most spray bars are hinged at each end, allowing the end to be folded up when moving between locations. For safety and logical reasons, never drive the distributor in traffic with the ends extended, as they will extend beyond the sides of the truck. The ends of the bar may be attached to the truck with chains. These chains help support the ends of the bar when they are in the spray position. Figure 5.10 shows the spray bar ends folded up.

FIGURE 5.10
Hinged Spray Bar

5.3.10.2 Spray Nozzles

Nozzles are manufactured with different size openings to permit different application rates of binder. All nozzles on the spray bar should be from the same manufacturer. Do not mix nozzle type or sizes on the spray bar, as different manufacturer's nozzles produce different spray patterns, and deliver different amounts of binder to the pavement surface. When nozzles become damaged or worn, it is best to replace all the nozzles on the bar.

Distributor nozzles are designed to spray a fan-shaped pattern, rather than a circular spray. Viewed from the top, they would appear as shown in Figure 5.11. Viewed from behind the distributor, they would appear as shown in Figure 5.12. Some distributors are equipped with a second spray bar, called a wheel path bar which is controlled with a separate computer.

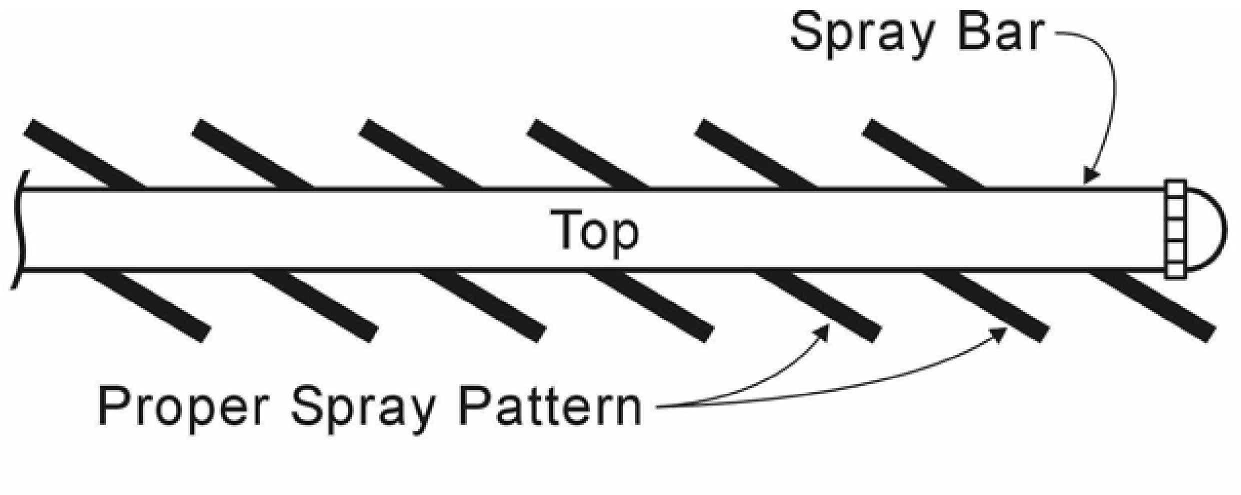


FIGURE 5.11
Spray Bar

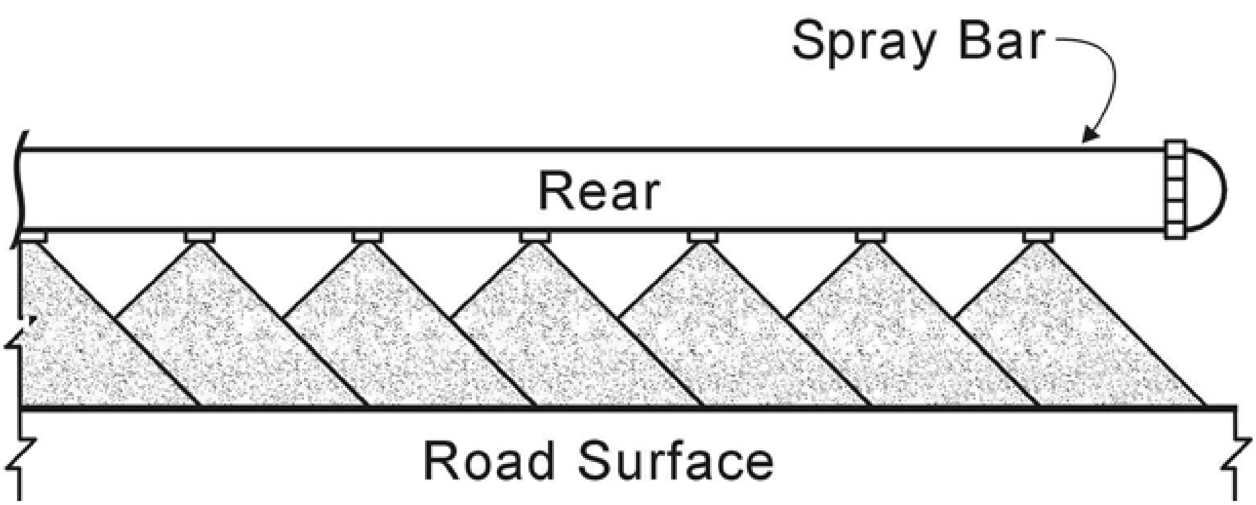


FIGURE 5.12
Spray Bar

5.3.10.3 Inspecting the Spray Bar

The spray bar should be raised and, if possible, rotated outward in order to inspect the nozzles. The nozzles are critical to obtain uniform binder coverage. Maintain the nozzles in good condition and properly orient to achieve consistent binder coverage across the width to be sealed. Typically nozzles are of brass and can easily be gouged or otherwise damaged, which will negatively affect spray pattern. See Figure 5.13.

FIGURE 5.13
Spray Bar Rotated Outward

Typically check the spray bar for the following:

- **Spray Bar Ends.** Check the ends of the bar to determine if they can be raised and lowered. Check the method for securing the ends in the raised position. (Most models are equipped with a chain device to secure the ends when raised).
- **Bar Position.** The bar should be straight when the ends are lowered. Check straightness in all directions. Spray patterns will be distorted if the bar is not straight.
- **Hoses, Joints and Pipes.** Check for leaks in any of the hoses, joints and pipes. If binder leaks onto the pavement when the distributor is not spraying, a puddle of binder will form. (This type of spill is difficult to clean up, and may result in too much binder at that location, which will bleed through the cover aggregate).

- **Spray Bar Width.** Check the width of the spray bar. Determine the proper amount of extensions and nozzles have been installed to cover the required width.
- **Spray Bar Height.** Check the height of the spray bar. Park the distributor on a flat, level surface, with the spray bar in the lowered position. Measure height from the bottom of the nozzles to the pavement surface. Take measurements at various points across the width of the spray bar to verify the height is constant. Set the height according to the manufacturer's recommendations. Measure first with the tank empty, and again when the tank is full. Corrective action is required if more than 1 inch difference occurs. (This will prevent a change in the overlap of the fan pattern between the beginning and end of a shot).
- **Spray Nozzles.** Spray nozzles are mounted every 4 inches along the width of the spray bar. Equip with the correct number of nozzles for the width being sealed. When a variable spray rate is required, check the nozzles to see that they are the proper size and in the correct location. If more than the required numbers of nozzles are present, close any extra nozzles. To achieve a straight, sharp edge of binder coverage, use a deflector nozzle at the ends of the spray bar. (Do not allow the end nozzle to be turned perpendicular to the spray bar axis in an attempt to get a sharp edge. This action will cause too much binder to be placed at the edge, and robs the next nozzle of the overlap normally provided by the end nozzle).

5.3.10.4 Nozzle Angle

Set nozzles to the proper angle according to the manufacturer's specifications. (Depending on the manufacturer, the angle is usually between 15 to 30° as shown in Figure 5.14). In order to avoid distortion of the spray pattern, set all nozzles at the same angle. Equip every distributor with a tool used to accurately set the proper angle.

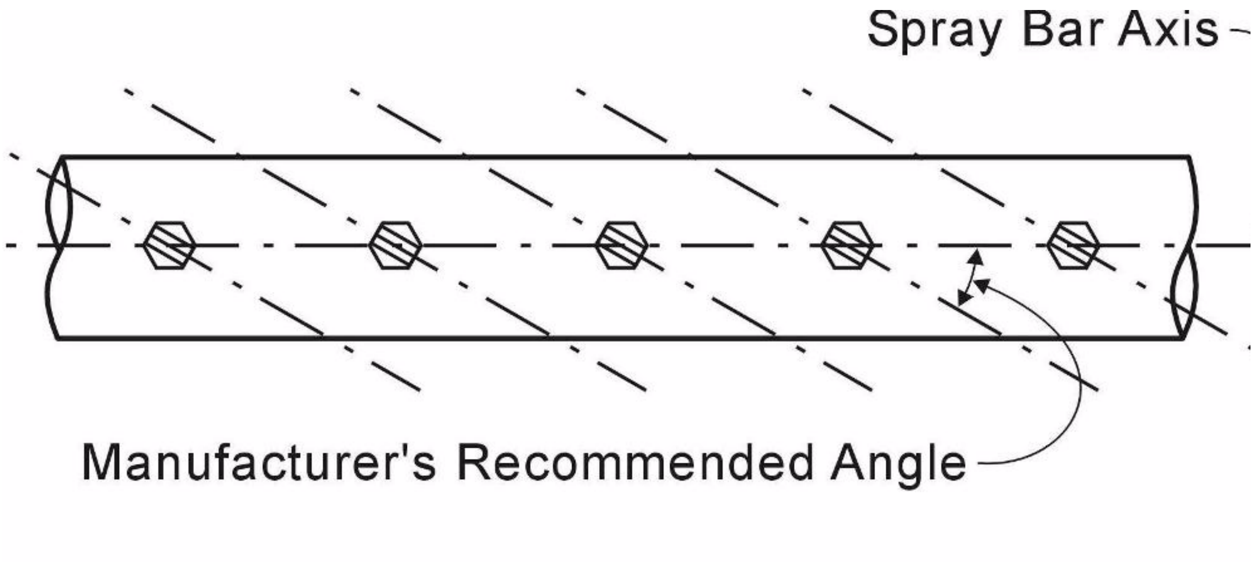


FIGURE 5.14
Manufacturer Recommended Angle

The proper spray pattern or coverage depends directly on the exactness of the nozzle angles. If not set correctly, the fan pattern can be distorted as shown in Figure 5.15.

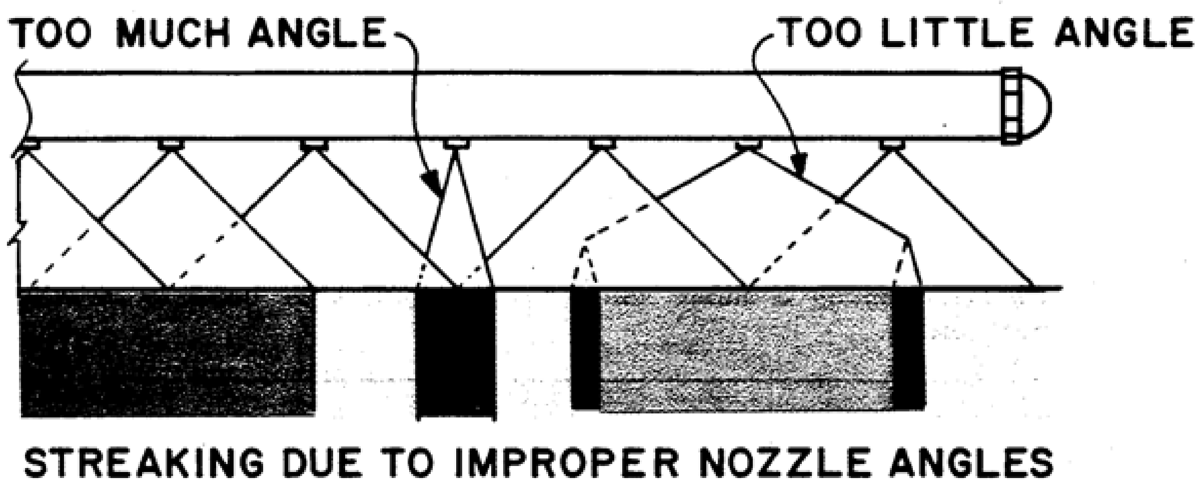


FIGURE 5.15
Effect of Incorrect Nozzle Angle

5.3.10.5 Fan Width

Once the nozzle angle is set, the height of the spray bar is critical to obtaining a correct and uniform spray pattern. The bar height above the surface of the roadway determines how wide the fan spreads. The desirable coverage is a triple lap as shown in Figure 5.16, and is achieved at a spray bar height of 12 inches.

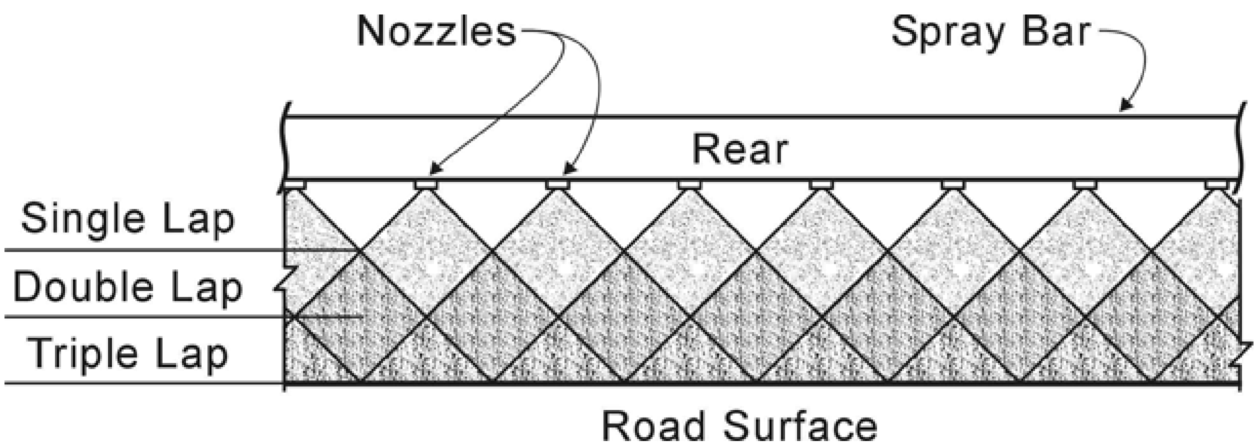


FIGURE 5.16
Various Binder Spray Pattern

Standard truck springs compress under a heavy load, and flex back to an arch when the load is removed. If a distributor had standard springs, the spray bar would change height as the binder is shot onto the pavement. The beginning of the shot would have triple lap coverage, but the lap would increase as the spray bar height increases, causing streaking.

Most distributors are equipped to either prevent the springs from compressing under a load, or prevent them from arching back when the tank is near-empty. Some manufacturers stabilize the bar position with a compressed air system. The best results occur when the spray bar remains at a constant height, whether the tank is full or empty.

For a Contractor’s quick check of the fan width, back the distributor onto a flat area and place one or two layers of brown paper under the spray bar. Turn the spray on momentarily making certain to turn it off as quickly as possible. This will not give an exact representation of the fan widths, but will quickly reveal any problems with the spray pattern. For a more conclusive look, spray a short test strip (20 to 30 feet). This will usually reveal any nozzle problems.

5.3.10.6 Nozzle Output

The amount of asphalt being sprayed out of each nozzle will vary. A quick nozzle output can be performed using 4 inch diameter by 8 inch high concrete cylinder mold (referred to as bucket) to ensure each nozzle is spraying within the correct tolerance.

Buckets for the bucket test must be shaped so they will fit under the nozzles side-by-side. Concrete cylinder molds as shown in Figure 5.17 may be used for this check.

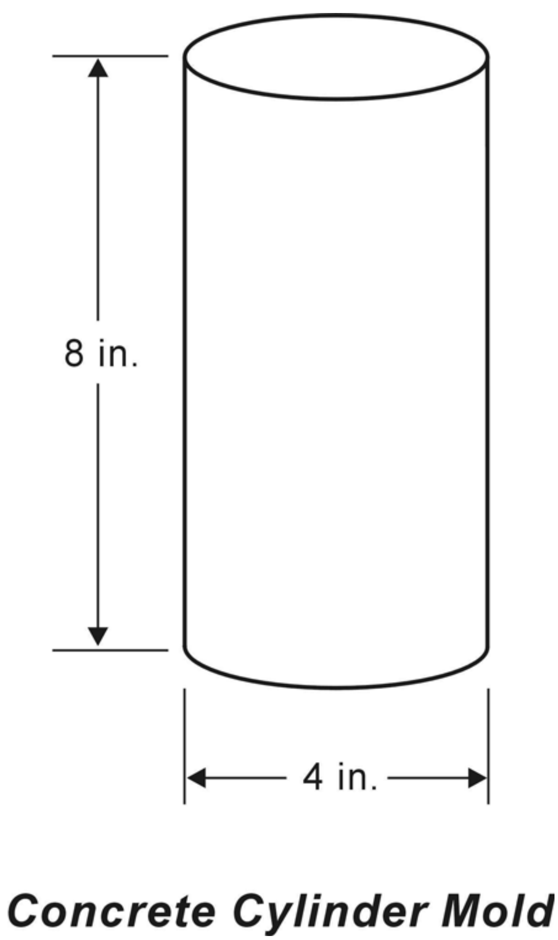


FIGURE 5.17
Concrete Cylinder Mold

The distributor should be moved off the test area to perform this check because it requires blowing out the nozzles. If asphalt or emulsion is used for the check, it should be heated to the temperature at which it will be applied. Water may be used for this check on new and empty distributor tanks. Before the check is made, turn on the spray bar for a short period of time to make certain none of the nozzles are clogged. If all nozzles are working, proceed with the check. If any nozzles are clogged, remove and clean them, or take them out of service.

Place buckets under each nozzle to catch all of the flow from each nozzle, as shown in Figure 5.17. Set the pump pressure or speed to match the application rate for the asphalt or emulsion. When the containers are all in position, turn the sprayer on briefly to fill the containers to about ¾ full. There should be no more than a 10 percent variation in the weight of the contents between each bucket.

If water is used for this check, make sure all water is removed from the distributor tank after checking the spray bar. Adding hot asphalt will cause water in the tank to be converted to steam, resulting in foaming or an explosion, which may result in injuries. The asphalt tank is likely to overflow via the manhole.

5.3.11 Hand Sprayer

Equip distributors with a hand sprayer for use in irregular-shaped areas inaccessible to the spray bar. A typical hand sprayer is shown in Figure 5.18. Most hand sprayers have a shut-off valve located on the handle. Judge the amount of binder applied to the irregular areas by trial and error. Generally, too little may be better than too much, as additional binder may be applied if deemed necessary.

FIGURE 5.18
Hand Sprayer

5.3.12 Distributor Controls and Gauges

The distributor is intended to deliver a uniform and precise amount of binder onto and throughout the length of the roadway. There are a number of gauges and controls used to achieve this consistency.

5.3.12.1 Thermometer

A thermometer is used for monitoring binder temperature. Most are located in a well in the side of the tank. Different manufacturers use different types of thermometers. See thermometers in Asphalt (Binder) Tank, Section 5.3.1.

5.3.12.2 Volume Gauge

Many tanks are equipped with a volume gauge, as shown in Figure 5.19. These are used as a tool for the operator to know when the tank is getting close to empty. The volume gauge is not applicable for chip seal work or payment, as the start and stop points are defined. See Section 6.6 Setting the Asphalt (Binder) Shots.

FIGURE 5.19
Volume Gauge

5.3.12.3 Pump Pressure or Rate

All distributors utilize a power-driven pump to spray binder under pressure onto the roadway, and to circulate the binder through the tank and spray bar to maintain a uniform binder temperature. Some distributors measure the pump pressure in pounds per square inch (psi) in the lines. This method requires a conversion chart supplied by the manufacturer, which converts the psi into gallons per minute (gpm) dispensed at the spray bar. Other distributors measure the pump rate directly in gallons per minute increments. In either case, the accuracy of the gauge is extremely important, as the pressure applied directly influences the amount of binder being delivered to the roadway. If the pressure is too low, the binder will streak, and the spray pattern will be uneven. If the pressure is too high, the binder may atomize, and the spray pattern becomes distorted. It should be noted a high wind, often occurring in Kansas, will magnify the ill effects of incorrect pressures.

Operate the pump at the highest pressure possible without atomizing the binder. The ideal pressure or pump rate is determined through field trials. Once the ideal pressure is determined, continuously operate the pump at that rate or pressure.

Newer distributors are computerized so that the desired binder application rate may be set by the operator and any changes in speed or pressure are automatically adjusted. Some older model distributors require the adjustment of the pump pressure as the truck speed varies.

5.3.12.4 Digital-Measuring Instrument (DMI)

KDOT requires that a vehicle be equipped with a calibrated digital-measuring instrument, accurate to plus or minus 6 feet per mile. Verify that no modifications have been made that might affect the accuracy of the measuring instrument since calibration. Check the accuracy of the DMI, by running a known measured distance and compare. A minimum of ½ mile is recommended.

5.3.12.5 Valve Control

The valve control simply turns the sprayer on and off. The distributor operator must be able to turn all spray nozzles on and off simultaneously and instantaneously. This is a simple task in a computerized distributor, and can be accomplished from inside the cab with a switch on the control panel.

For older model distributors at the beginning and end of a shot, the distributor passes over paper, which masks the pavement to form a straight, sharp start and stop line. Pass over the masking paper on both ends of the binder shot at spraying speed. Turn all nozzles on or off in the split second that the distributor passes over the masking paper.

On newer model distributers the use of paper may not be required as the starting and stopping of the spraying is quick enough to produce a true clean line. If the joint is unacceptable, the operation can revert to the paper method. See Section 6.8 Placing Paper Joints for additional details.

FIGURE 5.20
Distributor Controls

A computerized distributor may be operated by one operator. When manual operations are used, two operators will be required. On manually operated distributors, the driver lines up the machine, and keeps it on line and at the correct speed, while the spray operator works the valve control, and on some models, sets the pump motor speed and monitors pump pressure.

These two people are required to work as a team. The skill and care of the operator will affect the outcome of the project.

5.4 Aggregate Spreader

The aggregate spreader generally referred to as the “spreader” or “chipper” is used to distribute aggregate evenly over the film of binder applied by the distributor. KDOT specifications require aggregate spreaders to be self-propelled and have a continuous feed feature. A common type seen on a chip seal project is shown in Figure 5.21

FIGURE 5.21
Aggregate Spreader

The spreader receives aggregate from a haul truck which dumps the aggregate into a receiving hopper at the rear of the spreader. The aggregate is delivered by internal belts to another spreading hopper located at the front of the spreader. Gravity spreads the aggregate evenly across adjustable gates, allowing the required amounts of aggregate to be applied to the previously applied binder.

The major components of the aggregate spreader are as follows:

- Truck hitch
- Receiving hopper
- Belt conveyors
- Spreading hopper
- Discharge gates
- Discharge roller

The spreader distributes cover aggregate (chips) accurately and uniformly over the entire width and length of the area being chip sealed. The individual components of the spreader will be described further in this section.

Visually inspect the spreader, looking at the overall condition of the power train, to detect evidence of leaks in the engine and transmissions.

5.4.1 Truck Hitch

Back the haul truck up to the spreader. A coupling on the spreader engages the rear of the haul truck, quickly and securely locking the haul truck and spreader. Likewise, easily and quickly releasing the hitch. Placing the haul truck in neutral gear position the spreader will pull the haul truck. Do not push the haul truck with the spreader.

Visually check the hitch and coupling for broken and bent parts. Determine if the locking mechanism is working properly, by hooking and disengaging a truck to the spreader. Have the spreader operator manipulate the release to verify it will disengage the truck effectively.

5.4.2 Receiving Hopper

The function of the receiving hopper is to receive the aggregate from the haul truck. After the haul truck and spreader have been coupled, the haul truck bed is raised and aggregate is dumped into the receiving hopper. At the bottom of the receiving hopper, there are openings through which the belt conveyors pass in a continuous loop. A rubber shield prevents aggregate from piling up on the belt, being carried ahead of the receiving hopper, and being spilled onto the ground. Verify this shield is not torn or missing, to function properly.

Visually check the receiving hopper for overall condition. There should be no holes or large gaps that would allow aggregate to fall through to the road surface. Equip the conveyor belt system with rubber, neoprene, or fabric cowling (or flaps) around it to prevent aggregate loss. There should be a flap on top of the receiving hopper to obtain a tight fit against haul trucks as the aggregate is being dumped into the receiving hopper.

5.4.3 Belt Conveyors

There are two belt conveyors, which transport the aggregate forward to the discharge hopper. These can be seen on each side of the photo in Figure 5.22. Use belts in good condition and not frayed so no aggregate spills over the sides onto the roadway.

Check that the operator has control of the conveyors speed. Verify the speed is variable, in order that the amount of aggregate reaching the front hopper can be increased or decreased as needed.

Keeping the conveyor belts tight will keep them from sagging, which could cause a loss of aggregate.

FIGURE 5.22
Aggregate Conveyor

5.4.4 Spreading Hopper

The discharge hopper receives the aggregate from the belt conveyors and distributes it laterally in the discharge hopper. The aggregate falls over a scalping device which may consist of either a series of bars or a coarse mesh to separate any large rocks, dirt clods, or weeds from the aggregate.

Equip the scalping grate to cover the entire top of the hopper. This grate keeps large clay balls and other foreign matter out of the aggregate. Check the hopper to determine that it is clean and free of aggregate particles from a previous project. Check for holes or cracks in the hopper, where aggregate can fall through, causing a ridge or row of excess aggregate.

Check the exterior of the discharge hopper for damage. A spreader may have been driven over a large rock or other object, damaging the lower front corners. Roller bearings are held in a casing in this section of the hopper. Damaged roller bearings may cause the roller to wobble, resulting in an uneven flow of aggregate.

5.4.5 Discharge Gates

On the bottom of the discharge hopper there is a series of discharge gates operated by the spreader operator. Each gate can be opened or closed individually, or all at the same time. Check to see that the gates are adjusted to fully close and open uniformly. When the spreader is dispensing aggregate, judge whether the adjustment is correct.

5.4.6 Discharge Roller

Some spreaders have a roller at the bottom of the discharge gates which spins to deliver a more even flow of aggregate onto the binder. This roller (see Figure 5.23) helps provide a uniform amount of aggregate to be spread laterally across the pavement.

Visually examine the discharge roller, checking for mud or other debris that may be caked on its surface. Stretch a string line from end to end of the roller to be certain it is not warped. Examine the end bearings of the roller for excessive wear, by turning on the roller, and checking for wobble or noise from the bearings.

FIGURE 5.23
Discharge Roller

5.4.7 Wheels and Tires

With the spreader in motion, observe the wheels for any indication of wheel wobble or excessive toe-in or toe-out. Any of these conditions will cause the tires to scuff the aggregate. The spreader is the first vehicle to drive over the freshly placed aggregate, and when the spreader's tires pass over the aggregate, the aggregate particles will be in unarranged positions. Scuffing by the spreader's tires may shove the aggregate sideways rather than straight downward. Scuffing appears as a dark, ragged-looking strip, causing asphalt to be picked up on the tires of the pneumatic rollers.

Check the tires for any gouges that might adversely affect the aggregate arrangement.

5.5 Haul Trucks

The cover aggregate (also known as "chips") are stockpiled in advance of the project. Generally, the Contractor will store the aggregate in the immediate vicinity of the project in order to shorten the haul distance between the stockpile and the spreading operation.

End-dump type trucks are generally used to transport the aggregate and dump it into the spreader receiving hopper. The haul truck may be either tandem-axle or single axle trucks, as shown in Figure 5.24.

FIGURE 5.24
Haul Truck

5.5.1 Size

Truck bed size is an important factor and is expressed in cubic yards. Single-axle trucks carry approximately 6 cubic yards, while tandem-axle trucks carries between 12 and 14 cubic yards. It will be necessary to measure and calculate the capacity of each individual haul truck bed. Often the capacity is increased by adding boards at the top of the sides. Do not exceed the gross weight of the vehicle for the tag and axial limits.

5.5.2 Condition

Verify all trucks are free from leaking fuel, crankcase or transmission oil, engine coolant, and hydraulic fluid. These fluids leaking onto a fresh seal coat may prevent proper bonding of the binder and aggregate. Legally register all trucks, abide by the weight restrictions and equip with appropriate safety equipment.

5.5.3 Hoist

Equip all trucks with an operating hoist mechanism in order to smoothly dump the load into the receiving hopper of the spreader unit. Verify the hoist mechanism is free of hydraulic leaks.

5.5.4 Tailgate

Hinge the tailgate at the top of the bed and be able to chain closed at the bottom, as shown in Figure 5.25. The chaining prevents the aggregate from spilling out until the tailgate is unlatched. As the bed is raised, check the tailgate locking mechanism. Lock the chain securely when the bed is in the down position, and unlock as the bed begins to rise.

FIGURE 5.25
Tailgate Latch

5.5.5 Hitch

Equip all haul trucks with a hitch that is compatible with the one on the spreader. The spreader tows the haul truck as the aggregate is being emptied into the spreader receiving hopper.

5.5.6 Identifying Trucks

The Inspector must be able to identify each individual haul truck in order to determine the quantity of material delivered to the roadway. Based on truck bed measurements and calculations, each haul truck delivers a known amount of material when properly loaded.

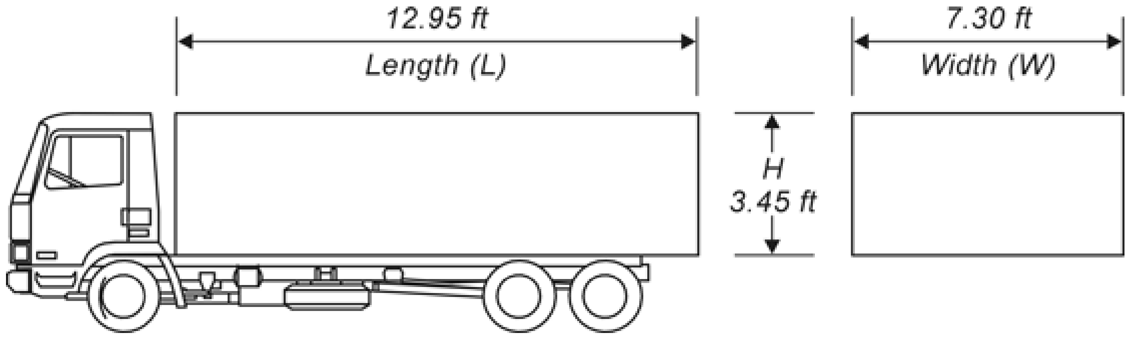
5.5.6.1 Bed Measurements and Calculations

Determine the volume of each truck bed. KDOT pays for aggregate by the cubic yard placed on the roadway. The number of full loads per haul truck placed times the volume of the individual truck is used to determine the pay quantity of aggregate.

Ideally, all trucks used on the project would have the same capacity to easily compute the volume of aggregate being placed. Normally, there will be a mix of truck sizes making it necessary to track each truck used. There is no particular truck size that is best.

The length (L), width (W), and height (H) of the inside of the truck bed should be measured to the nearest 0.05 feet as shown in the example below. These three measurements are multiplied to obtain the volume in cubic feet. This product is then converted to cubic yards by dividing by 27 as shown in Figure 5.26 and Equation 5.1.

Example: Volume of Truck Bed (V):



(Source: TxDOT)

FIGURE 5.26
Truck Bed Measurement

$$V = \frac{L \times W \times H}{27}$$

$$V = \frac{12.95 \times 7.30 \times 3.45}{27}$$

V= 12.08

V= 12.08 CUYD, round to 12 CUYD **Equation 5.1**

5.5.6.2 Volume of Truck Bed with Deduction of Hydraulic Ram Cover

Some trucks have the hydraulic ram recessed into the bottom of the truck bed. If the trucks have this configuration, deduct the volume of the housing from the total volume of the truck bed, as shown in the example below.

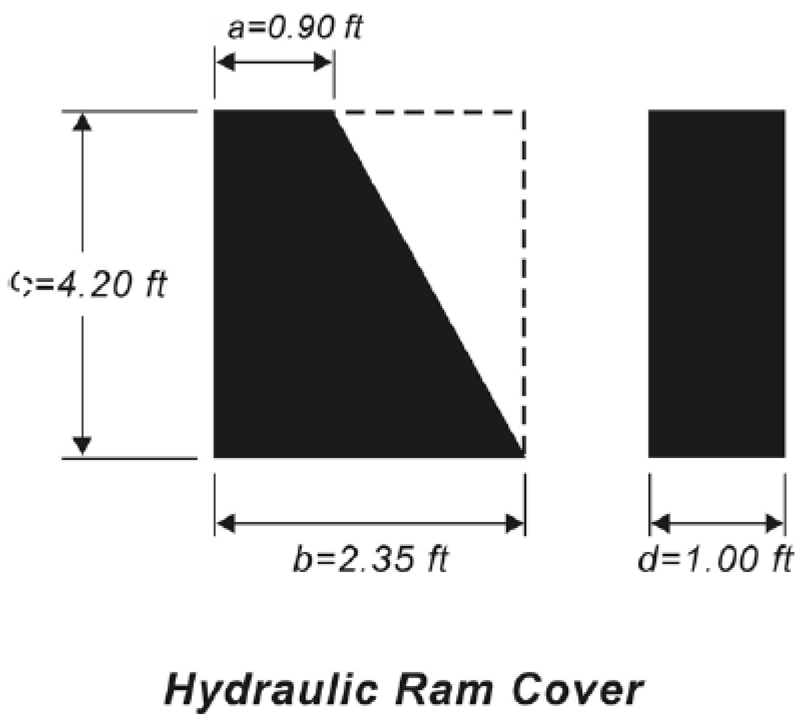


FIGURE 5.27
Hydraulic Ram Cover

Volume of Hydraulic Ram Cover (VHRC)

$$VHRC = \frac{a+b}{2} \times c \times d/27 = 0.25 \text{ CUYD}$$

Net Volume of Truck Bed NV = Truck Bed Volume (See previous example) – VHRC = CUYD, round to 1/2 CUYD

NV = 12.08 – 0.25 = 11.83 CUYD

Round to 12 CUYD **Equation 5.2**

5.6 Rollers

After aggregate is placed on the binder, pneumatic rollers are used to orient the aggregate in its flattest dimension and seat it firmly into the binder. A steel-wheeled roller is not used as the flat, steel drum crushes the aggregate, especially when lightweight aggregate is used. If the old pavement is rutted, a steel-wheeled roller tends to bridge over the ruts, failing to seat the aggregate in the low spots or wheel paths.

5.6.1 Pneumatic Rollers

Pneumatic rollers operate on rubber, air-inflated (pneumatic) tires. Figure 5.28 shows a pneumatic roller type used for chip sealing. Use self-propelled pneumatic rollers, capable of operating in both forward and reverse.

FIGURE 5.28
Pneumatic Roller

5.6.2 Weight

The project Contract Documents will specify the required weight for pneumatic rollers. The specifications for pneumatic rollers require they be capable of ballast loading, and to uniformly vary the total vehicle weight from 9,000 pounds to 18,000 pounds. Generally, wet sand or aggregate is used for ballast.

5.6.3 Weight Certification

Manufacturers publish the gross weights of their rollers, using water and wet sand as ballast. If either of these materials are used and the ballast tanks are full, this meets the manufacturer's roller weight. If the Contractor uses different material, such as aggregate for ballast, or the ballast tanks are not full, the weight is unknown; weigh to verify the minimum requirements. If there is any doubt, have the roller weighed in accordance with the Contract Documents. Obtain a weight ticket from a certified scale.

5.6.4 Contact Pressure

Contact pressure exerted by each tire is a function of the following combination of factors:

- Total weight of the roller with ballast
- Number of tires on the individual roller
- Tire size and ply rating
- Tire inflation pressure.

The 2007 KDOT Standard Specifications, or latest version, require a minimum contact pressure of 45 pounds per square inch (psi) of tire contact area. As a minimum, use smooth-surfaced tires.

5.6.5 Tire Inflation

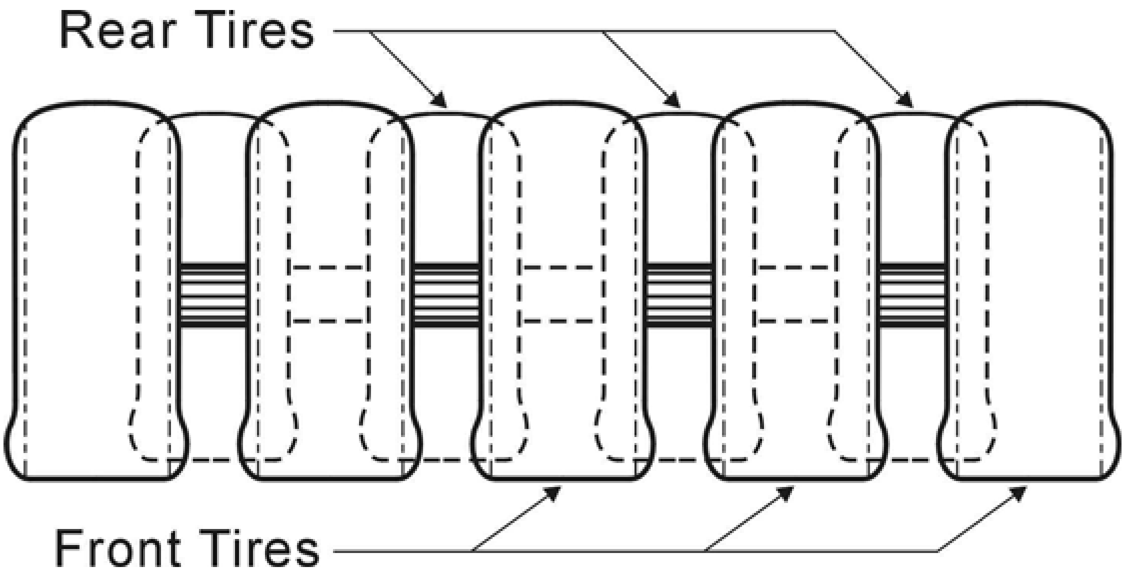
Equip the roller to provide a uniform compression under all wheels. 2007 KDOT Standard Specifications, or latest version, require that all tires be inflated so there is less than 5 psi variation within all tires.

5.6.6 Number of Tires

Normally, pneumatic rollers have a minimum of nine tires. Most are manufactured with five wheels on the front and four on the rear. The rear wheels are the drive wheels, while the front wheels are the steering mechanism.

5.6.7 Area of Coverage

Light rollers should cover an area approximately 60 inches wide on each pass. Offset the rear tires to provide coverage of the areas between the front wheels as shown in Figure 5.29.



(Source: TxDOT)

FIGURE 5.29
Pneumatic Wheel Configuration

5.6.8 Wheel Wobble

Do not allow rollers to operate if the wheels wobble. Wheel wobble can displace the aggregate. If any wheel is not operating smoothly, remove the roller from the roadway until it is repaired.

5.6.9 Smooth Operation

Operate the roller smoothly when turning and stopping. If the brakes or drive train are faulty and cause jerking or excessive vibration when stopping or starting, remove the roller from the roadway until it is repaired. If any of the wheels are out of alignment, it may cause “scuffing”. Do not permit any of these conditions on the project.

5.6.10 Medium-Weight Rollers

Heavier rollers may be specified for various reasons. The information for all pneumatic rollers, in general, is the same except for heavier rollers the weight, number of wheels, contact pressure and width are greater. The weight can be changed by adding from 23,000 pounds to

50,000 of ballast. Use a minimum of seven wheels, with contact pressure of 80 pounds per square inch (psi) or more. The effective rolling width should be approximately 84 inches.

5.6.11 Tire Pressure

Tire pressure is a critical item for all pneumatic rollers. If one tire is soft, it will not seat the aggregate as firmly as the other tires, and this could result in the aggregate in that path stripping away under traffic. The variation in the pressure should not exceed 5 psi within the group of tires; the correct tire pressure is a function of these variables.

- Gross weight of the roller and ballast;
- Number of tires on the roller (Either seven or nine are required for medium-weight rollers. Most rollers used on seal coats have nine);
- Tire size and ply rating; and
- Check the required ground contact pressure. In general these will range from 45 psi to 90 psi. These are the minimum amounts; higher contact pressures may be allowed.

5.6.12 Inspection Checklist

Visually inspect all rollers to be used on the project for the following:

- Check overall condition of the equipment;
- Check for presence for leaks of any kind;
- Tires should be smooth (no tread pattern);
- All tires should be the same size and ply rating;
- The rollers should start and stop smoothly. Brakes should not “grab”;
- The roller must be self-propelled, and operate in both forward and reverse;
- There should be no wheel wobble, since this will scuff the cover aggregate;
- Check tire stability on turns. If there is unusual scuffing, it may mean a bad bearing or king pin, which might not be detectable when the roller is moving in a straight line;

- Roller tires should have no gouges that would alter the contact pressure of the tire; and
- Certify the weight.

5.7 Front-End Loader

Front-end loaders are used to move aggregate from the stockpile into the haul truck. Figures 5.30 shows a typical front-end loader. Front-end loaders are for the Contractor's benefit only. The most important aspect of the front-end loader is the way it is operated.

FIGURE 5.30
Front-End Loader

5.7.1 Visual Inspection

Make a quick visual inspection for leaks and safety. Before beginning loading of haul trucks, view inside the loader bucket to verify it is free from any substance which might contaminate the aggregate. Check for any fluid leaks that may contaminate the aggregate. It should be very unlikely for contamination to occur as the loader should never be on top of the stockpile.

5.8 Heater and Storage Unit

On large projects, the Contractor may utilize an asphalt heater and storage unit. The binder is hauled from the source by truck and pumped directly into the heater and storage unit. When ready to apply the binder to the pavement surface, the binder is pumped either into another transporter or directly into the distributor.

There are many standard storage and heater units in use. A unit may combine a heating and circulating system, or it may use an insulated tank with a separate heater unit utilizing interconnected piping.

The goal of the unit is to have binder available near the project site and at the correct application temperature.

5.8.1 Temperature

Store the binder at the specified temperatures, generally at slightly higher temperatures than temperatures at which the binder is applied. The binders used in chip seals are stored at the following approximate temperatures:

- Asphalt cement 325 to 400°F
- Cutback asphalt 150 to 200°F
- Emulsions 150 to 170°F

The upper temperatures shown are the maximum allowable storage and heating temperatures. The heating and storage unit requires a continuous recording thermometer to closely monitor the temperature of the binder.

To achieve the desired results, it is necessary to spray binders at the temperature specified in the Contract Documents. There is a correct viscosity-temperature relationship for each different binder. Maintain the temperature near the required binder spraying temperature in order for the binder to be near the correct viscosity for spraying.

The heater unit operator must clearly understand the importance of the viscosity-temperature relationship.

5.8.2 Safety

Knowing the flash point (temperature at which ignition could occur) of the binder being used is critical. Never assume someone has taken care of safety issues involving heating of the binder. The flash point is extremely critical with cutback asphalts. For example, RC-250 has a flash point of 80°F and it is recommended to be applied between 125 and 180°F. There is some danger when working with temperatures within these ranges, and precautions should be taken.

When using asphalt cement, danger exists around the heater and storage units. Storage tanks, pipes, and valves are extremely hot. Take precautions to ensure that any part of the heater and storage tank unit that might be touched is insulated.

Take care when obtaining a sample of asphalt cement, as hot asphalt cement (350°F) can easily splatter. Wear proper safety clothing, and use safety equipment when working around hot asphalt cement.

5.8.3 Storage Tank

Inspect storage tanks for cleanliness and the presence of conditions that would allow for the contamination of the binder. There should be a continuous-recording thermometer on the tank, recording any fluctuations in asphalt temperature.

5.8.4 Heater

The heater unit may be a part of the storage tank, or a separate unit consisting of a smaller tank with pump and heater.

It should have a burner that can be regulated to alter the intensity of heat. Direct the flame into the flues, similar to the arrangement in a distributor. Circulation of the binder material through the heater unit to prevent the asphalt from burning next to the flues and from sticking (from cooling) near the outside of the tank is necessary.

5.8.5 Pump Unit

Check the pump unit for proper operation. The primary concern is to verify that the pump and associated piping protects the binder from contamination. Configure the unit so no dirt or fuel can enter the piping or pump unit.

5.8.6 Heater Unit Location

The location of the heater unit is the Contractor's responsibility; however, give safety considerations as to the location of the unit.

If the heater unit is situated in the vicinity of the aggregate stockpile, separate it far enough away to prevent contamination of the aggregate such as binder being spilled around heater units. It is best that the heater be situated well away from the aggregate stockpiles.

5.8.7 Recording Thermometer

When the project begins, the Inspector must pick up the record card from the continuous recording thermometer each day. A new card is installed when the old one is removed.

5.8.8 Manifest

Check the transporter's manifest before it is unloaded to make certain the binder in the transport truck is the correct type, and weight tickets are provided for the project. The manifest is the Contractor's responsibility, but can delay the project if the wrong material is applied. Retain a copy of the manifest of each load of binder delivered to the project.

5.8.9 Contamination

Guard against contamination from previous asphalt loads. Check for possible contamination during off-loading to the heater unit.

Chapter 6: Chip Seal Application Process

6.1 Overview

For chip seal projects there is a definite sequence of events necessary to accomplish the project goals. A full lane width chip seal operation is fast moving requiring both the Contractor and KDOT personnel to understand the process, open and honestly communicate, and work together. To understand the application of a chip seal, this chapter includes activities and responsibilities of the Contractor and KDOT personnel. Both the Contractor and KDOT personnel must be aware of each other's responsibilities and activities. In this chapter, the chip seal operation or placement is broken into activities in the normal sequence of events. It should be recognized the individual activities are overlapping throughout the operation.

If any of these descriptions conflict with the KDOT Standard Specifications or Special Provisions, the Standard Specifications or Special Provisions will prevail. The following activities are recognized:

- Weather conditions
- Traffic control
- Cleaning the pavement
- Setting rock coverage areas
- Setting the binder (asphalt) shots
- Checking the loader operation
- Placing paper joints
- Shooting the binder (asphalt)
- Stabbing the asphalt distributor
- Spreading the aggregate
- Timing for aggregate application
- Rolling the aggregate
- Patching or hand work
- Intersections and irregular shapes
- Brooming excess aggregate
- Opening to traffic

- Temporary or permanent pavement markings
- Cleanup.

To properly cover a chip seal surface treatment, the Inspectors (generally three people) must be trained and thoroughly understand the specifications and the intent of the specifications. Likewise the Contractor's personnel must be skilled, knowledgeable and understand the specifications and the intent of the specifications.

For both KDOT and Contractor, considerable planning is involved. For example: strategic placement of the aggregate stockpiles to ease loading haul trucks and control or eliminate aggregate contamination is vital to the quality of the final product. During actual placement of the materials, coordinating the delivery of the binder material with proposed production will enhance the smooth operation of the project. During the process of chip sealing, Contractor personnel and KDOT personnel must know why and what each other will be doing, as well as sharing any potential problems or proposed changes. Though many believe chip sealing is a simple process, due to the speed of operation, everyone must be operating smoothly in order to meet the full benefit of the chip seal.

6.2 Weather

During placement, proper weather conditions are necessary for a chip seal to function as planned. When performing a chip seal there are many outcomes that are related to a change in the weather conditions, most of which are undesirable. Comply with the KDOT Standard specifications or special provisions for acceptable weather conditions.

The best conditions for applying a chip seal or surface treatment occur when temperature is high, humidity is low, and there is little or no wind. These conditions in Kansas are most likely to occur from May through October. See the KDOT Standard Specifications or Special Provisions for seasonal limitations based on the type of binder specified in the Contract Documents. When starting too early in the spring, both temperature and wind problems are likely to be encountered; too late in the fall could result in lower temperatures, which decrease the time available to properly set the aggregates. Contractor and KDOT personnel must pay attention to both the short-term and extended weather forecast. In most cases it is best not to risk continuing operations if there is a potential for negative weather conditions.

6.2.1 Temperature

The KDOT Standard Specifications require seal coats be placed at minimum ambient air and pavement temperatures based on the type of binder specified in the Contract Documents. In all cases, do not attempt apply chip seals when the ambient air temperature is below 60°F and falling. If polymer-modified asphalt cement is used, apply when the air temperature is above 70°F and rising. Refer to the standard specification for minimum pavement surface temperatures based on the type of binder being used. When wintertime work is allowed, the Engineer will approve the air and surface temperature for the binder application, however additional effort will be required when accomplishing the work.

During the summer months, roadway temperatures are commonly 90°F or higher by 9 a.m. Therefore, temperature is normally not a problem. Check the surface temperature every morning before any binder is shot. This can be accomplished by placing a surface contact type of dial thermometer on the roadway, or by using a surface reading electronic thermometer. Take the temperature reading under conditions typical of those in which the binder will be shot.

6.2.2 Humidity

Sealing works better regardless of binder type used when humidity is lower. High humidity can leave an invisible film of moisture on the roadway surface, which may hinder the asphalt from properly bonding with the pavement surface. When emulsions are used, the emulsion breaks slower in high humidity. It is best to apply seals when the humidity is 50% or lower. During times of high humidity, when asphalt cement is used, which is shot at much higher temperatures, steam may be observed rising as the hot asphalt comes in contact with the moisture on the roadway surface. As steam is trapped under the asphalt, small bubbles form and break as the air and moisture work their way to the asphalt surface. Allow the moisture to escape before applying the aggregate.

6.2.3 Wind

When the wind is blowing, it can be both advantageous and disadvantageous. If an emulsion is used, a gentle wind of constant velocity can accelerate the breaking of the emulsion, allowing traffic on the roadway sooner. During variable or strong winds, it can distort the asphalt distributor’s fan pattern as the binder is applied. This may lead to streaking and uneven distribution of the binder. The Contractor may install a shield in front of the spray bar to minimize wind effects on the spray pattern.

Wind may blow binder onto passing vehicles. It is particularly important to be careful of wind direction when applying modified asphalt cements. Small irregular strings of asphalt are blown around, and appear almost invisible until they land on a light-colored vehicle. Sequence the operation to minimize the effects of blowing asphalt.

6.2.4 Rain

Do not perform chip sealing during rain. If rain is in the vicinity and/or predicted for the area, consider suspending operations. If an unexpected shower arises during operations, shut off the distributor immediately, and continue placing aggregate until all shot binder has been covered. This area should receive extra rolling and be carefully watched after opening to traffic. If loss of aggregate or streaking occurs, consider resealing the affected location. After suspending operations due to rain, wait until the pavement has completely dried before resuming.

6.3 Traffic Control

The safety of the traveling public must be a major and continuous concern of the KDOT inspection staff and the Contractor’s work force. Due to the importance and need to move the chip sealing operation during the day, there should be one Contractor employee assigned the responsibility for traffic control.

Traffic control includes activities such as, erecting signs and barricades, placing traffic cones, flagging, and moving all traffic control devices as the chip seal operation progresses. Properly install all required traffic control devices before beginning the sealing operation. Conform to the details shown in the Contract Documents or those required in the Manual on

Uniform Traffic Control Devices (MUTCD). Due to the fast-paced movement of the sealing operation, keeping the traffic control up with the sealing operation is a continual process.

6.3.1 Pre-Positioning Traffic Control Signs

Locate and mark the position for traffic control devices (signs) in advance for quick installation when placement occurs. Prior to workers or equipment being moved onto the roadway, cover signs until they become effective and remove as soon as possible when no longer needed. Have the traffic control and flagging operations in place and operational before moving any equipment onto the roadway. When stopping traffic, keep the delay to the traveling public to a minimum, and do not exceed the time allowed by the Contract Documents.

6.3.2 Displaying Signs

As a minimum check, prior to closing a lane, review the following traffic control items:

- Signs in good condition;
- Signs in the proper sequence;
- Signs leading up to the work are placed the correct distance, height, and spacing per the Contract Documents;
- Signs clearly visible to motorists;
- Signs positioned correctly so the devices do not pose an obstacle to traffic; and
- Signs secured from the effects of wind

6.3.3 Traffic Cones

Traffic cones are typically used to route traffic around the seal coat work area. See Figure 6.1.

Check traffic cone placement for:

- Proper sight distance prior to lane closure;
- Proper spacing and taper lengths; and
- Cones are placed outside the operating path of the asphalt distributor and aggregate spreader.

FIGURE 6.1
Traffic Cones in Position

6.3.4 Flaggers

Flaggers are vital to the safety of motorists and workers in the work zone and obviously are required on any two lane roadways. All flaggers are required to be properly instructed and have a copy of the “KDOT Flagger Manual.” Check that the flagger is using: proper equipment, attired properly, using correct signals, and can verbally explain the situation to vehicle operators. When flaggers are used at opposite ends of the work zone, be sure they have adequate communication devices, and that the devices are used properly. If the flaggers are not properly performing their duties, promptly correct.

6.3.5 Pilot Vehicle

A pilot vehicle is often used on two lane roadways as the flaggers at opposite ends of the work zone cannot see each other. Additionally, the pilot vehicle helps to maintain slower speeds, and keeps the traveling public off the newly placed chip seal through the work zone. Correctly place and mount all required signing on the pilot vehicle, as required by the Contract Documents.

6.3.6 Repositioning Traffic Control Devices

As work progresses, and as sections of the new chip seal are opened to traffic, appropriate traffic control devices and flaggers need to be repositioned. Determine the frequency of repositioning at the pre-construction conference, or by the onsite field crew before beginning work. Once work begins, it may become necessary to reconsider when repositioning should occur. When a field adjustment is necessary, communicating to all parties is important. Once the flaggers and appropriate traffic control devices have been repositioned, check as though it is the first time the traffic control has been used on the project. When stopping traffic, keep the delay to the traveling public to a minimum, and do not exceed the time allowed by the Contract Documents.

6.3.7 Intersections

When chip seal operations cross intersections, control the cross traffic. Take care to prevent cross traffic vehicles from crossing the binder, prior to spreading and seating the aggregate. This may require positioning an additional flagger at the intersection.

6.3.8 Multi-lane Roadways

On multi-lane and high volume roadways, arrow boards may be used to move traffic into the adjacent lane rather than flaggers. Comply with the Contract Documents as to placement and operation of arrow boards or other approved traffic control devices.

6.4 Cleaning the Pavement

For good results in any chip sealing project, the initial step is a good cleaning of the existing pavement to be sealed. The cleaning process begins with a sweeping or brooming of the pavement to be sealed. Perform the brooming operation in advance of the binder application, but not so far in advance that the pavement will become dirty before the binder is applied. Cleaning includes removal of any vegetation and soil on the pavement edge. Make sure there is adequate and uniform pressure applied across the length of the rotary broom head.

It is noted the sweeping operation itself will generate considerable amounts of dust. Consider the safety of the traveling public and Contractor and KDOT personnel when brooming the existing pavement.

The sweeping operation should never delay the sealing operation, but should not be so far in advance that the roadway becomes dusty before the sealing operation begins. If conditions are very dusty, locate the sweeping operation to not be more than one or two binder shots ahead of the asphalt distributor (See Section 6.6 for definition of binder shot).

Additional sweeping may be required where dirt or dust is tracked or blown onto the pavement from side roads, private access roads or other dirt and dust generating conditions. In some cases, hand sweeping may be required. In Kansas, during certain times of the year, dust from adjacent fields may be a considerable cause of dust, thus sweeping will have to be completed just prior to the shooting of the binder material.

The choice of cleaning equipment is the Contractor’s option. Though rarely used, the Contractor may employ a “Street Sweeper”.

6.4.1 Safety During Sweeping Operations

Due to the normal sequence, sweeping occurs at a considerable distance ahead of any other sealing equipment used on the project. Equip the broom or sweeper with appropriate warning devices. Install the required traffic control devices during sweeping operations; remembering sweeping is a very fast moving operation.

Traffic does not always stay in the designated lane or on the proper side of the traffic cones. Traffic may enter the roadway from a private drive or side road. Everyone working on the project must stay alert for unexpected traffic.

During sweeping operations, the sweeper may create so much dust that visibility is reduced, when this occurs, flaggers may be required.

6.4.2 Sweeping Pattern

Under most conditions the sweeper will require two to three passes to adequately clean a 12-foot lane. The preferred method is for each progressing pass to move toward the shoulder with the broom pushing the debris toward the shoulder. It is always best to broom the debris away from traffic and with the wind. Take into account the wind conditions which may dictate the sweeping pattern.

6.5 Setting the Rock Spot

A rock spot is the area covered, at the desired aggregate (chips) application rate, by one predetermined size truckload of aggregate. The area of the rock spot is calculated in advance and marked either on the pavement with paint or on the side of the road with flags. If the project has been stationed and marked, the length of the rock spot can be computed and the length converted to stations.

Set rock spots at the start of a project, in order for the Contractor to calibrate the spreader application rate, determining that the correct aggregate rate is being applied. If the aggregate runs out before reaching the marker at the end of the rock spot, the rate is too heavy, likewise if there is aggregate remaining at the end of the rock spot, the rate is too light. This is based on the theory that the truck is carrying a known quantity of aggregate. Measure and calculate the volume of the truck bed (See Section 5.5.6.1) prior to loading the aggregate. It is especially important that the aggregate be leveled in the truck bed, in order to determine the true volume of aggregate being placed on the rock spot.

6.5.1 Calculating the Length of Rock Spot

The aggregate application rate is specified as 1 cubic yard (CUYD) of aggregate for a set number of square yards (SQYD) of roadway. For example: 1 CUYD aggregate per 125 SQYD of pavement would be an application rate of 0.008 CUYD/SQYD.

Calculating the length of a Rock Spot: Assume that the lane to be sealed is 12 feet wide, and the haul truck is filled with 14 cubic yards of aggregate with a desired application rate of 1 CUYD/125 SQYD.

Area of Rock Spot	14 CUYD x 125 SQYD/CUYD = 1,750 SQYD
Length of Rock Spot	(1750 SQYD x 9 SQFT/SQYD)/12 FT = 1,313 LNFT

(CUYD=cubic yard, SQYD=square yard, FT=feet, LNFT= linear feet)

The distance from the start of the aggregate application to the intended end would be 1,313 LNFT. The goal is to apply the aggregate to exactly 1,313 linear feet of 12 ft wide pavement. If the actual distance is less than 1,313 linear feet, too much aggregate is being applied, and if greater than 1,313 linear feet, too little aggregate is being applied. In actual practice, it is best to be slightly long (some material remaining in the truck bed) rather than short of the distance the volume of aggregate was to be applied.

6.5.2 Marking the Rock Spots

Rock spots are generally set for each individual haul truck, and the length will vary depending on the capacity of each individual haul truck. Using a calibrated Digital Measuring Instrument (DMI), begin at the start of the first placement of aggregate with the DMI set at zero. Drive down the roadway until the DMI reads the calculated length, as determined in "Calculating the Length of the Rock Spot." Stop and mark the end of the rock spot. A good practice when setting the distance of the rock spot is to use a different color paint or flags for marking the length of the rock spots and binder shots. (See Section 6.6 for binder calibration checks.) If adjustment to the aggregate application rate is needed, remark an area, change the application rate setting on the spreader, and repeat the process. The process of making adjustments to set the correct aggregate application rate requires repeating the process a number of times. If an electronic DMI is not available, the use of a measuring wheel or chain is acceptable to determine the length of the rock spot. As noted if the project has been stationed the rock spots for different haul truck volumes can be computed and related to the actual station. It is a good practice to check application rates often during the actual sealing operation, thus having the project stationed makes this easier and more practical.

6.6 Setting the Asphalt (Binder) Shots

An asphalt (binder) shot should be equal to the length of a specified number of full rock spots, however it is limited by the size of the distributor. For example, one binder shot should equal 1, 2, or 3 full rock shots, not 1.7 rock shots. Marking binder shots in advance provides a way to check the binder application rate. Calculate the area of the binder shot in advance, and mark the length with a specific colored paint on the existing pavement or a specific colored flag on the side of the roadway. Note binder shots generally are greater than one rock spot. If the project has been stationed the length of the binder shot can be determined and related to the appropriate station. Having the project stationed allows for checking the binder application rate during actual project operations on a daily or frequent basis verifying the proper operation of the distributor.

6.6.1 Asphalt Application Rate

The binder application rate shown on the plans or Contract Documents is intended solely for estimating contract quantities. The actual application rate (also known as the “spraying rate” and “shooting” and often used interchangeably) will be determined based on several design variables (See Chapter 3).

If the designed binder application rate is determined to be 0.36 gallons per square yard, spray this rate from the distributor. When using emulsions and the asphalt residual to be applied is 0.36 gallons per square yard, this becomes the residual amount of asphalt desired and NOT the amount to be shot from the distributor. The water added at the emulsion plant and any dilution water added at the project site will need to be accounted for, in order for the designed asphalt residual to be applied.

Emulsions consist of asphalt cement, water, and an emulsifying agent. After spraying the emulsion on the roadway, the water evaporates (the emulsion breaks), leaving only the asphalt cement. Different types of emulsions contain different amounts of asphalt, water and emulsifiers. Typically, an emulsifying agent and water are 35 to 40% of the total emulsion.

Example: An emulsion is to be applied at a residual rate of 0.25 gallons per square yard. If the emulsion delivered to the project contains 60% residual asphalt, apply it at a rate of 0.42 gallons per square yard (0.25/0.60). The percentage of residual asphalt for any emulsion may be found on the emulsion delivery ticket, or obtained from the District Materials laboratory or the emulsion supplier. If the same emulsion used in the example and delivered to the project was diluted 50% it would require an application rate of 0.84 gallons per square yard (0.25/0.60)/0.50 to have a residual asphalt amount of 0.25 gallons per square yard.

6.6.2 Distributor Capacity

When setting the binder shots, consider the capacity of the distributor tank. Never completely empty the distributor tank at the end of a binder shot. Emulsions foam more than other types of binders, thus the operator should stop spraying binder before the foam is reached. Assuming a 2,000 gallon distributor is used, when shooting emulsions it is a good practice to leave at least 200 gallons in the distributor at the end of the shot, or 100 gallons if Asphalt Cement is used. Maintaining the recirculation of the remaining binder through the spray bar reduces the chance that the thin film of asphalt remaining inside the pipes and spray nozzles will harden due to cooling.

6.6.3 Calculating the Length of Binder Shot

Base the binder shot length on “full rock spots” distances, which is governed by the number and bed size of trucks available. Example, assume one 12-foot wide section of roadway is to be chip sealed with Asphalt Cement at 0.36 gallons per square yard, using a 2,000-gallon distributor, and all haul trucks have the same calculated capacity of 14 cubic yards.

Desired Asphalt Cement Rate	0.36 gal/SQYD
Distributor Capacity	2,000 gal
Area of Rock Spot	1,750 SQYD (calculated in Section 6.5.b.1)
Length of Rock Spot	1,313 LNFT (calculated in Section 6.5.b1)
Gallons AC per Rock Spot	0.36 gal/SQYD x 1750 SQYD = 630 gal/rock spot
Rock Spots per AC Shot	2,000 gal (distributor capacity)/630 gal/rock spot = 3.2 rock spot

Note: Shot length should be in full rock spots and should leave at least 100 gallons of AC in the distributor.

Gallons per Asphalt Shot	3 full rock spots x 630 gal/rock spot = 1890 gal
Gallons Left in Distributor	2000 – 1890 = 110 gal (greater than 100 gal, OK)
Length of Asphalt Shot	3 full rock spots x 1,313 LNFT = 3,939 LNFT

In the above example, the capacity of all haul trucks was equal. In actual practice, each haul truck will be different, requiring adding the actual haul truck capacities to be used and working backward. If the three haul trucks to be considered had the following capacities: 14 CUYD, 12 CUYD, and 11 CUYD or a total capacity of 37 CUYD are to be considered. Using the same application rates as shown in the example above, 37 CUYD of aggregate will cover 3,468 LNFT of 12-foot wide pavement (37 CUYDx125 SQYD/CUYDx9 SQFT/SQYD/12 ft=3,468 LNFT) 3,468 LNFT would require 1,665 gal of asphalt for these three haul trucks (3,468 LNFTx12Ft/9 SQFT/SQYDx0.36 gal/SQYD=1,665 gal) Note these examples show using AC. When using emulsions, change the rate to compensate for the amount of water in the delivered emulsion and any dilution water. (See 6.6.1 for emulsions adjustments)

6.6.4 Marking the Binder Shot

Using a calibrated DMI, start at the beginning of the first shot. Set the DMI at zero. Drive down the roadway until the DMI reads the calculated length of binder shot. Stop and mark the end of the binder shot, using a different color marking than used for the rock spots. These markings may be paint on the roadway surface, or a wire flag placed in the adjacent soil. Reset the DMI at the end of each binder shot, and repeat the process. Mark each shot to know where to set a joint, or place paper joint. (See Section 6.8. Placing Paper Joints.) If the project has been stationed, the location can be converted to the stationing rather than actually measuring them at the time of application.

Note: Do not apply binder to the roadway without the haul trucks loaded and in place behind the distributor and aggregate spreader. Load the haul trucks with enough aggregate to cover the binder shot area. Coordinate and match the production rate of the distributors, spreaders, and rollers. See Section 6.13 for additional information on matching production rates with rollers.

6.7 Checking the Loader Operation

The loading of aggregate, from strategically placed stockpiles, into the haul trucks, becomes an issue affecting the success or failure of a chip seal application. Often the operation of loading trucks is overlooked because it is somewhat removed from the center of activity. It is best to check the operation early in the project and periodically perform spot-checks.

6.7.1 Loader Operation Checklist

Some potential areas of concern are:

- **Gradation.** Graded aggregate tends to segregate when stockpiled. Finer particles tend to sift between the coarse particles, causing the stockpile to show an increase of coarse particles near the top and outside. Note: this may not be a major problem as many of the gradations being used today utilize a “single size” aggregate. Take a representative sample of aggregate from the bucket load. The loader bucket should penetrate the stockpile near the bottom and deep enough into the stockpile that when raised, will have a full range of the aggregate gradation. The representative sample may come from more than one loader bucket. (Follow KDOT Construction Manual for stockpile sampling requirements)

- **Contamination.** The loader operator usually tries to use the entire aggregate stockpile. In doing so, the bucket often scrapes too close to the bottom of the stockpile, allowing clay balls, soil or grass to be picked up along with the aggregate. Do not use aggregate containing contaminants. If there is grass, clay, or soil detected in the spreader box, correct the loader operation immediately.
- **Degradation.** Avoid degradation of the aggregate. Do not operate any equipment in such a manner that causes the wheels to roll over any of the stockpile. These wheel loads will cause larger pieces to be crushed into smaller particles changing the aggregate gradation.
- **Full Trucks.** Fill every haul truck to its predetermined calibrated level. Over or under filling affects the amount the Contractor delivers and is paid for. Any irregular filling affects the application rate. Uniformity is the key to success for a quality chip sealing application.
- **Excessive Dust.** Excessive dust will affect the project, and is detrimental to the performance of the seal coat. If dust in the stockpile is a problem, it may be reduced by lightly sprinkling the stockpile with water. This procedure is only recommended when emulsions are being used.

6.8 Placing Paper Joints

Create a straight and sharp joint at the beginning and end of each binder shot. This is accomplished by placing heavyweight paper perpendicular to the centerline for the width of the lane to be sealed.

6.8.1 Equipment

Placing paper joints usually requires two Contractor personnel. This paper joint crew needs a small load of aggregate, shovels, push brooms, and a large roll of heavyweight brown paper or other similar material (36 to 48 inches wide).

6.8.2 Beginning of Binder Shot

At the beginning of a binder shot, a strip of paper is placed across the full width of the lane to be sealed, and held in place with a small amount of aggregate spread over the paper. Note: For new or inexperienced distributor operators, a larger masking may be necessary. This may be accomplished by increasing the number of full width paper strips placed, making sure to overlap each paper strip 2 to 3 inches. When placing aggregate to hold down the paper, keep the aggregate out of the wheel path of the distributor. Sweep away aggregate spilled onto the pavement surface where the binder will be shot.

Place the distributor and distributor bar over the paper strip such that the beginning of the shot will be started with the binder being shot onto the paper strip as the distributor starts to move. When the distributor passes over the end of the paper strip, the binder shot onto the pavement will be shot in a very straight line. Remove the paper and anchoring aggregate as soon as the distributor has started the shot. See Figure 6.2 for a typical paper joint being placed.

6.8.3 End of Binder Shot

At the end of the binder shot, place another paper joint. Placement is just like the beginning joint, except that the rear edge of the paper is placed on the mark for the end of the binder shot. (See Figure 6.2) The distributor spray bar is turned off as the spray bar passes over the paper. The goal of both joints is to leave a straight edge perpendicular to the center line of the pavement. When the paper is removed, this should have been accomplished.

If all the chips are to be placed on the binder shot before beginning the next shot, the aggregate spreader should pass over the end of the binder shot. Clean any chips from the next binder shot, and set the paper on the newly placed chips for the next binder shot. If more than one distributer is being used and the goal is to have a longer binder shot, see Section 6.8.4.

(Source: TXDOT)

FIGURE 6.2
Placing a Paper Joint at Beginning of Shot

The setting and placing of paper joints may not be required if the Contractor's distributer is a newer model. With newer distributors the application rate is held consistent by automatically adjusting the pump pressure with speed, and starts and stops of the spray bar occur very quickly leaving a sharp well defined transverse line. If the distributor cannot leave a satisfactory joint line, use the paper joint method.

6.8.4 Subsequent Asphalt Shots with Multiple Distributors

When multi distributers are being used allowing a continuous operation, the binder should be continuous; however, some form of a joint is required. When the first distributor has completed a binder shot, pull the paper joint to the side for proper disposal. Before beginning the next binder shot, spread aggregate over the fresh binder where the paper joint is to be placed. Place enough aggregate over the binder to keep the binder from coming in contact with the paper. Placing the aggregate over the binder is done by hand. Take care when performing this operation that enough material has been place to keep the paper from becoming in contact with the binder. On top of the hand-placed aggregate, start another paper joint over the aggregate to form a starting joint for the next shot. Clean all excess aggregate from the unsealed pavement to preserve a clean, sharp end. Position the edge of the paper exactly above the end of the asphalt shot, as shown in Figure 6.3. Once the joint paper has been set, position the distributor, and begin the next binder shot. The process can be continued throughout the day.

With the use of the newer distributors capable of making a clean transverse joint at the start of a binder shot, setting the paper joint can be eliminated. Back the second distributor into place and start the application of binder, holding any overlap to an absolute minimum (0 to 3 inches).

(Source: TxDOT)

FIGURE 6.3
Paper Joint in Place at Beginning of Second Shot

6.9 Shooting the Binder

The binder is placed on the pavement surface using the distributor which is a complex piece of equipment. For a smooth operation, use calibrated equipment (See Section 5.3) in good working condition, and follow the manufacturer's operational procedures.

6.9.1 Distributor Preparation

Heating binder materials constitutes some element of hazard, with the exception of emulsions. Due to the highly volatile solvents used, cutback asphalts are the most hazardous. Do not allow open flames to come in contact with the cutback asphalt or the gases released from hot cutback asphalt. When using asphalt cement (AC), the major safety concern is related to the high temperature of the binder—300°F plus asphalt cement will cause severe burns if coming into contact with human skin.

Before changing from one type of binder to another (for example, the previous binder was an AC and the new binder will be an emulsion) used in the same distributor, thoroughly flush or clean out the previous used binder from the system. This minimizes contamination of the new binder, and enhances safety of the distributor operation. When changing from emulsion to AC, it is a good practice to not fill the distributor tank more than half full for the first two or three binder shots. This will help to minimize foaming and possible overflow via the tank manhole. When emulsions are left in the spray bar and asphalt cement will be used next, there is the potential to cause sufficient foaming in the tank when the hot asphalt cement is circulated through the spray bar. Removing the remaining emulsion will help reduce the amount of foaming. Switching from cutback asphalt to AC can create a potential explosive hazard. Exercise extreme caution removing as much cutback asphalt as possible before adding the AC will reduce the hazardous situation.

Fill the distributor from the heater unit, a booster tank, an asphalt storage tank, or a transporter as shown in Figure 6.4.

FIGURE 6.4
Transfering Asphalt from a Transporter to a Distributor

When the distributor is full, record the number of gallons in the distributor tank. Use the stab stick to measure the amount of material in the distributor tank, as described in 6.10. Check the binder temperature in the distributor to determine that the binder is within the recommended application temperature range. When the temperature is low, light the heater unit burners, and start the pump to circulate the binder through the pipes. Circulate the binder through the entire system, especially the spray bar, in order for the spray bar to be brought up to temperature. Increase the pump speed to determine if the correct pressure is set for the binder application. This is extremely important on the first shot of the project and on the first shot each morning.

6.9.2 Blow the Nozzles

Check the nozzles to see that they are all working properly by "blowing the nozzles." Perform the blowing of the nozzles by moving the distributor completely off of the pavement and onto a flat surface. Use the following to check the nozzles:

- Bring the temperature of the binder to the correct shooting temperature.
- After the binder reaches the correct temperature, place, one or two layers of joint paper under the spray bar.
- Turn the sprayer on momentarily to "blow out" the nozzles.
- While spraying, visually check all nozzles to make certain no nozzles are clogged and the spray pattern looks correct.
- Remove and clean any clogged nozzles with an appropriate solvent.
- After cleaning any nozzles, repeat the blowing of the nozzles, again checking for clogs and the spray pattern.
- Visually check the spray system for leaking binder.
- When all nozzles are working correctly and there are no apparent leaks, the distributor may be moved into position at the beginning of the asphalt shot.

6.9.3 Check Spray Bar Height

To check the spray bar height above the pavement before applying the binder to the pavement, refer to Section 5.3.10.3. Once the check has been made, the distributor should stand by until all final checks are completed, before beginning the shot.

6.9.4 Final Equipment and Paper Check

Make a final check that all equipment is in position and ready to perform before allowing binder to be applied to the pavement. Items to consider are:

- Loaded asphalt distributor;
- aggregate spreader;
- required number of filled haul trucks are in position; and
- all rollers are in position and ready to go.

If a chip seal patching crew will be used on the job, they should be ready to follow the haul trucks as closely as possible.

Install the paper joint in place at both the beginning and end of the shot. Use an adequate paper width for the distributor being used and the skill of the operator. See Section 6.8. Position the distributor spray bar over or slightly behind the paper joint for the beginning of the binder shot. This will enable the spray bar nozzles to be opened on the paper joint at the beginning of the binder shot. Figure 6.5 shows the correct position for the distributor.

(Source: TxDOT)

FIGURE 6.5
Correct Starting Position over Paper Joint

6.9.5 Transverse Alignment

Visually check the transverse alignment when the distributor is in position over the paper joint. Set the end nozzle directly over the line, for the operator to use as a guide. As soon as the transverse alignment is correct, the operator should set the guide bar so that alignment is in position over the reference line.

6.9.6 Applying the Asphalt (Binder)

After all the checks have been made, including stabbing the distributor (See Section 6.10), begin the application of binder. Closely observe the early part of each shot to see that the fan pattern is correct and all nozzles are spraying properly, and especially evenly. Visually inspect the binder applied on the roadway for any variations in coverage. The binder shot should appear as a uniform sheet of asphalt material across the entire width of the shot. Check for the following items:

- any streaking;
- ridging;
- puddling; and
- flowing of asphalt material off the roadway.

If any variations are observed on the surface, immediately stop the operation and make the necessary corrections.

After completion of the binder shot, stab the distributor as described in Section 6.10, and check the application rate.

6.9.7 Timing for Aggregate (Chips) Application

Apply aggregate to the binder as soon as possible, without causing the rocks to turn over, or the binder to be picked up on the spreader, haul trucks, or roller tires. The aggregate spreader should follow closely behind the distributor. Refer to Section 6.11 for additional information on aggregate spreading.

6.9.8 Additional Distributors

On some projects, more than one distributor may be used. The use of additional distributors allows for a more continuous operation, but does require more coordination and vigilance on the part of the Contractor and Inspectors. When using more than one distributor, perform the same checks on all distributors.

6.10 Stabbing the Distributor

Before and after each distributor load of binder is sprayed, stab the distributor tank. The term “stabbed” refers to using a calibrated measuring stick to measure the amount of binder in the tank before and after the shot, in order to determine the amount of binder used. When performing strip/spot seal coat work, stab the distributor before and after all work is completed, or at the end of the day. When using a computerized distributor for strip/spot seal coat, obtain the asphalt quantity from the gauges on the equipment, and stab for verification and payment purposes.

For KDOT, payment of binder is by weight. Stabbing and recording amounts of binder used, verifies the application rate.

6.10.1 Determining Asphalt Application Rate

For payment purposes, stabbing the distributor is important. It is also important for each shot to determine the average binder application rate. With the information gained, adjustments in application rate may be made from shot to shot. Use the following procedure to stab the distributor and compute the application rate:

- Stop the distributor on a level spot immediately before and after the binder shot.
- Before stabbing, level the distributor tank as much as possible.
- Some distributors have a level attached to the tank. If not, use a 3- to 4-foot carpenter's level.
- Clean the stab stick in order for the level of asphalt to be easily read.
- Open the tank manhole cover and insert the stab stick through the manhole, into the tank, holding it as near vertical as possible.
- Carefully lower the stab stick down through the asphalt until touching the bottom of the tank.
- Remove the stab stick from the tank.
- The number of gallons is read at the top of the line covered by binder. Note: On some distributors, the stab stick itself may not be graduated and must be held against a graduated scale mounted on the side of the tank.
- Wipe the stab stick clean, removing all binder to ready the stab stick for the next measurement.
- For KDOT, calibration of the stab stick is performed by the District Materials Engineer. (See Section 5.3.2 for additional details of the "stab stick".)

Example:

Area of binder shot	5,625 SQYD
Gallons before binder shot	2,000 gal
Gallons after binder shot	225 gal
Gallons used for binder shot	2,000 – 225 = 1,775 gal
Average application rate	1,775 gal. Used/5,625SQYD = 0.32 gal/SQYD

Compare actual to desired application rate and adjust as necessary.

6.11 Spreading the Aggregate

Position all equipment in place before applying the binder shot. This includes the required number of loaded haul trucks to cover the binder shot in position behind the aggregate spreader, and all rollers in place and ready to begin. When using a patching crew operation, they should be ready to follow the haul trucks as closely as possible. For spot chip seal work, a dump truck tailgate spreader may be used to spread the aggregate rather than a self-propelled aggregate spreader.

6.11.1 Aligning the Spreader Box

As the distributor begins to apply the binder shot, move the aggregate spreader to within a few feet of the starting point. While the joint paper is being removed, the aggregate spreader operator should align the aggregate spreader to match the binder shot width. After the spreader is in position, make sure all of the necessary discharge gates are open to provide complete coverage of the binder shot. Close any gates that would make the application wider than the binder shot width.

6.11.2 Truck Hookup

Once the aggregate spreader operator is ready, the hookup and start of the process begins as follows:

- Back the waiting haul truck up to the aggregate spreader, and stop slightly short of coming in contact with the aggregate spreader. This allows the aggregate spreader operator to back the aggregate spreader into the truck, so the hitches connect. Some Contractors may use a spotter to verify a correct connection has been made.

- Place the haul truck transmission in neutral, allowing the spreader to tow the haul truck backwards as the aggregate is spread.
- Release the haul truck tailgate latch upon a signal from the spreader operator. The truck bed is raised allowing the aggregate to begin filling the receiving hopper. On a signal from the spreader operator, the haul truck driver must lower the bed to prevent the hopper from overflowing.
- Safety is all importance and an often overhead power lines are overlooked. With the truck bed up the potential to encounter a power line increases. The spreader operator and all other crew members and inspectors should be on the lookout.
- When the aggregate begins to pour into the receiving hopper, engage the conveyor belts. The aggregate should begin to flow into the discharge hopper and distribute across the discharge gates.
- When both the receiving and discharge hoppers are nearly full, the spreader operator, signals the truck driver to lower the truck bed to stop the flow of aggregate into the spreader.

6.11.3 Test Strip

Note: this step may be done off the road or on the pavement, just prior to the area to be sealed.

Before any binder is applied, a short test strip may be applied on bare pavement to visually confirm uniform aggregate coverage. If a test strip is to be used, the aggregate spreader operator may disengage the truck hitch and have the truck move away from the spreader, allowing the spreader operator to test the equipment for a few feet without the truck being attached. There should be enough aggregate in the aggregate spreader to run approximately a 50-foot test strip. Correct any gates not functioning properly. Once the spreader gate settings are correct, and the equipment is functioning properly, terminate the test. Remove any loose aggregate from pavement caused by the test strip. KDOT does not routinely perform test strips on the roadway, but may load and operate the spreader off site to verify operations.

6.11.4 Spreading the Aggregate

With the haul truck and aggregate spreader connected, the spreader and truck move forward. The aggregate spreader operator should open the gates just before reaching the beginning of the binder shot. While moving, the truck operator, with signals from the spreader operator, should raise the bed enough to keep the receiving hopper full until the haul truck bed is empty.

For best results, apply aggregate on any type of binder, as soon as possible, without the rocks rolling over, or the binder being picked up on aggregate spreader, haul truck, or roller tires. The aggregate spreader should follow closely behind the distributor. Refer to Section 6.12 for additional information on the proper time to begin spreading the aggregate.

When the haul truck bed is empty, give a signal to lower the truck bed. This will allow the truck to separate from the aggregate spreader without causing the tailgate or rear of the truck bed to strike the top of the receiving hopper.

Continue moving the spreader forward, while the haul truck bed is being lowered. The operator should release the truck when the tailgate and haul truck bed have cleared. Most hitches can be released without stopping the spreader.

The aggregate spreader must eventually stop to hook up to the next haul truck. After stopping the aggregate spreader, back it up a few feet to allow the next haul truck to link up. Repeat the process until the end of the binder shot is reached. If the equipment is calibrated and operated correctly, the last haul truck should run out of aggregate when the aggregate spreader reaches the end of the binder shot. (See Section 6.11.5.)

6.11.5 Rock Spot Marker

After hooking up with the second haul truck and resuming the spreading, the spreader should pass the marker for the end of the first rock spot. The end of the first rock spot should be slightly farther than the second truck hookup, due to some aggregate remaining in the aggregate spreader from the first truckload. If the aggregate spreader passes the first rock spot marker before the first truck is empty, the aggregate application is too thin. If the second truck is hooked up more than 25 feet before the first rock spot marker, the aggregate application is too heavy. In either case, adjust the gate openings accordingly. It is important to make sure the haul trucks are loaded with the correct amount of aggregate, as too light or heavy haul truck loads may cause the missing of the rock spot.

6.11.6 Visual Checks

Perform visual checks throughout the day, as settings may change for any number of reasons. The Inspector should be in position to have a good view of the aggregate application as it leaves the discharge hopper. Observe the following conditions:

- A thin “curtain” of aggregate should be dropping through the gates.
- The curtain should be uniform across the entire width of the discharge hopper.
- The curtain of aggregate should be only one aggregate particle thick, and light should be easily seen through the curtain.
- Any dark streams indicate a gate may be open too wide.
- Any unusually light streaks indicate not enough aggregate is being released.
- If the aggregate appears to be stacking on the binder as it is placed, it is being applied too heavily.

Additional checks of the aggregate spreader operation are:

- Visually check the scalping grate on top of the discharge hopper.
- There should be a steady flow of aggregate passing through scalping grate.
- An accumulation of clay balls, grass, or rocks on top of the scalping grate indicates the loader operator may be picking up contaminants.

Check the aggregate application behind the aggregate spreader for:

- contaminants such as grass, mud balls;
- streaking of thin or thick rows of aggregates; and

- thick and thin alternating streaks running transversely (a ripple effect), indicates that the spreader speed is too high.

Check the tires on the aggregate spreader and the haul trucks for binder (and aggregate) sticking to them. If sticking is occurring, immediately correct it. The following conditions may cause tires to pick up binder:

- Aggregate is rolling over causing binder to be exposed to the tires. This can be caused by not using enough binder to hold the aggregate, or by applying too much aggregate. Refer to Section 6.12 for more information on the best time to begin spreading the aggregate.
- Too much binder is being applied.
- A puddle of binder may have leaked or spilled onto the pavement without cleanup, prior to aggregate application.
- One of the discharge gates on the aggregate spreader may have momentarily clogged, preventing the aggregate from covering the binder.
- Failure to use deflector nozzles and overlapping the shot in the second lane causes an excess of asphalt.
- Detouring or cross road traffic being on the fresh chip seal too early may cause aggregate pickup.
- Construction and other traffic accelerating, turning, and braking abruptly on the fresh seal can dislodge aggregate.
- Accelerating quickly may cause a tire to spin because of the soft binder and unrolled aggregate.
- Turning quickly may cause the aggregate to roll over, exposing some of the binder.
- Braking suddenly may cause the wheels to lock and shove aggregate.
- These situations can occur with any binder, but are most likely to occur when using asphalt emulsions.
- Improper tire inflation pressures on construction equipment and vehicles.

If any of the above situations occur, repair before rolling. Clean tires immediately and correct the condition before the situation worsens.

6.11.7 Recording Truck Loads

The Inspector must accurately document the number of truck loads of aggregate placed on the roadway. Use a haul truck identification tally sheet and record the number of loads per truck per day. If the haul trucks are being weighed, keep a copy of the delivery ticket. Using volume for aggregate application and calibration, it is important to be sure the haul trucks are loaded as near as possible to the computed volume. KDOT pays for aggregate by the cubic yard, therefore an accurate load count is important.

6.12 Timing for Aggregate Application

Determining the proper time to begin applying aggregate on fresh binder is a decision requiring knowledge and experience. The desired situation is to apply the aggregate as soon as possible after the placement of the binder. This section will look at some best practices being performed.

6.12.1 Immediate Aggregate Application

For best results, apply aggregate to emulsified asphalt or hot AC immediately after application of the binder to the pavement. This requires the aggregate spreader to follow closely behind the asphalt distributor. Applying the aggregate while the binder is in a very liquid condition maximizes aggregate embedment depth and aggregate-to-asphalt adhesion. Good embedment and adhesion enhance the quality of the chip seal. As emulsions break or cure, the residue is deposited up the sides of the aggregate particles, and a meniscus is formed as shown in Figure 6.6. These conditions will not occur with cool AC or an emulsion after it breaks.

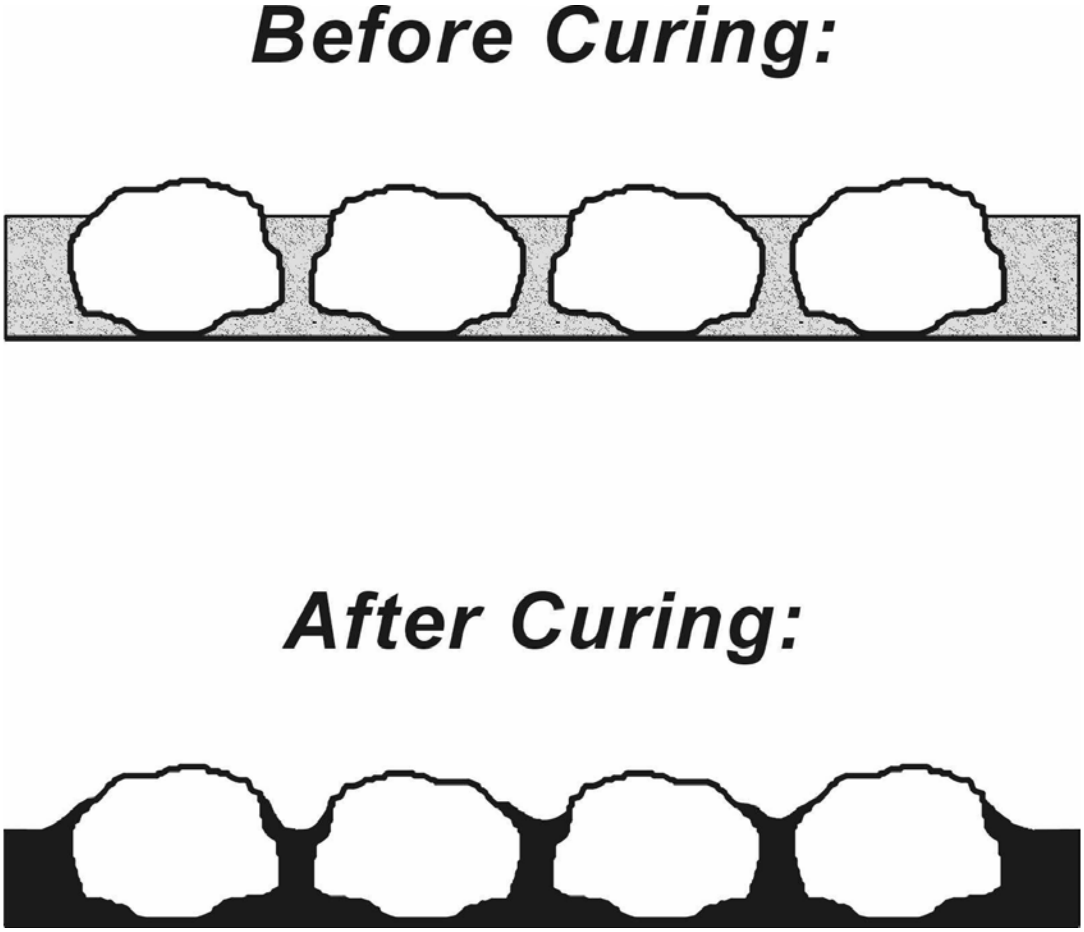


FIGURE 6.6
Decrease in Volume after Emulsion Has Cured

High embedment depth minimizes shelling, especially when the chip seal experiences rain or cold weather shortly after placement.

When applying emulsions for chip seals, some crews want to wait until the emulsion begins to break before applying the aggregate. Likewise, when applying hot AC, some crews want to wait until it cools before applying the aggregate. This is done because when applying the aggregate to the fresh emulsion or hot AC, the aggregate particles may strike the pavement surface and bounce or roll forward often coming to rest with a coating of asphalt on the upper surface of the aggregate particle. Subsequent aggregate seating using a pneumatic roller may pick up some of those aggregate particles with a sticky asphalt coating, thus creating a problem during the rolling process.

Waiting for the emulsion to break or the AC to cool too much before applying the aggregate may result in some undesirable subsequent circumstances:

- The occurrence of very low embedment depth.
- When emulsified asphalts begin to break, particularly polymer-modified emulsions, they often form a skin on the surface. This skin prevents adequate embedment of the aggregate particles into the emulsion layer reducing aggregate-to-asphalt adhesion. Allowing AC to cool before applying aggregate cause's similar problems.
- Low aggregate embedment depth and poor adhesion present the potential for shelling, or the loss of aggregate that should be adhering to the existing pavement. This condition is often observed when seal coats are placed late in the season, or just before rains or cool weather begins.

In order to offset the potential for aggregate shelling, the emulsion or AC application rate is often increased, when there is concern about shelling. The increase in rate of binder application is more noticeable near the end of the sealing season. The excess binder may appear as flushing during the following summer.

Aggregate roll-over is **not** a result of low viscosity of the emulsion or hot AC. Aggregate roll-over is generally caused by the forward motion (horizontal velocity) of the aggregate particles when they strike the pavement surface. An often used solution may be a strategically located “striker plate” fastened to the aggregate spreader at an angle designed to redirect the aggregate so it falls straight downward onto the pavement surface without bouncing or rolling forward. The desired result is for the aggregate particles to have no forward motion during application. With a striker plate in place and finding the ideal forward speed of the aggregate spreader, and operating at the ideal forward speed, the aggregate should drop straight down. Some newer model aggregate spreaders are designed to apply the aggregate with no forward momentum, eliminating the problem.

6.13 Rolling the Aggregate

Immediately after applying the aggregate to the binder, roll with self-propelled pneumatic-tired rollers meeting KDOT equipment requirements (See the latest publication of Division 150: Equipment of the 2007 KDOT Standard Specifications). Do not use steel-wheeled rollers unless ordered by the Engineer, as they can crush the aggregate. Complete the initial rolling within 5 minutes after application of the binder. Utilize a minimum of three rollers or enough rollers to cover the entire placement width in one pass (one direction) within 5 minutes. Rolling should be in a staggered pattern making a minimum of three complete passes. During cooler air temperatures, additional rolling may be necessary. If rollers are unable to keep up with the spreader, stop binder application until rollers catch up, or furnish additional rollers.

The asphalt distributor controls the overall production rate, since no other piece of equipment can function prior to the distributor applying the binder. Therefore, to achieve a high standard of quality, the spreader and roller operations must be able to keep pace with the production of the distributor. The number of rollers, the rolling time, and keeping pace with the distributor are critical for a successful chip seal.

6.13.1 Rolling Pattern

The rolling pattern used for chip seals is dependent upon the number and type of rollers. For a 12-foot wide binder shot, typically three or four pneumatic rollers are involved. Provide a minimum coverage with three complete passes which consists of three forward, three in reverse, and the final pass forward extending into the first pass of the next section to be rolled. It is better to have the rollers operating continuously rather than sitting idle, as more rolling is better, unless aggregate degradation occurs. Set the speed of the rollers to minimize aggregate displacement.

When three or four pneumatic rollers are used, stagger the rollers in an echelon pattern. The lead roller is usually on the inside, and each of the others offset approximately one-third the roller width. See sketch in Figure 6.7 illustrating the echelon pattern and Figure 6.8.

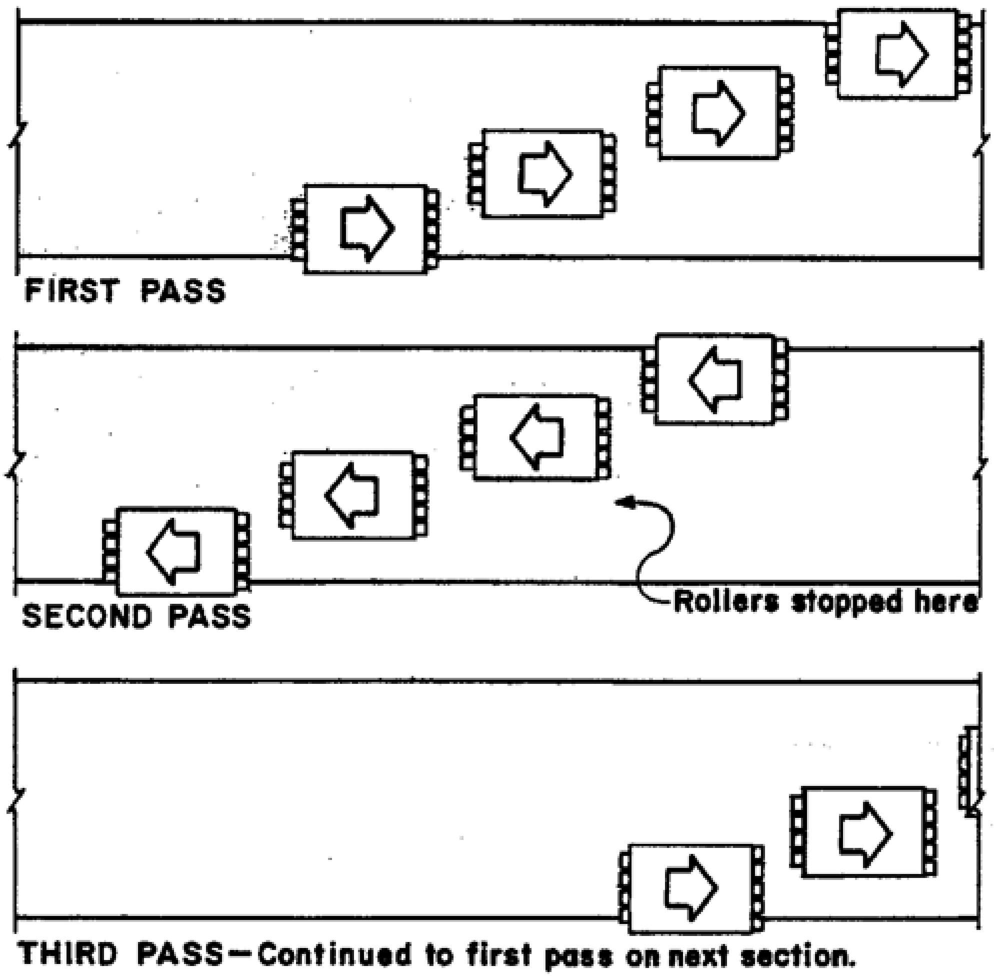


FIGURE 6.7
Echelon Rolling Pattern (Illustration)

(Source: Ron Matteson)

FIGURE 6.8
Echelon Rolling Pattern

6.13.2 Checking the Rolling Pattern

Check the rolling pattern to verify complete coverage and proper embedment is achieved. Rollers should cover the entire width to be rolled. Visually evaluate the results of the completed aggregate orientation. If the aggregate particles are lying in their flattest dimension, the rolling is adequate. If many of the aggregate particles are positioned upright after completing the rolling, additional rolling may be required. Monitor the rolling operation for signs of scuffing. Scuffing can be caused by roller operators stopping and starting too quickly, or turning on the fresh seal.

6.14 Patching or Hand Work

During a chip seal project there are circumstances that occur requiring various amounts of hand patching or hand work. A crew of two or three may be assigned the responsibility for patching. Generally, they are equipped with a truck containing a supply of aggregate, shovels, push brooms, binder material along with swabs or mops to apply the binder material. The most effective location for the patching crew is behind the chain of haul trucks, making repairs before the rollers reach the area to be patched.

6.14.1 Immediate Repairs

The types of repairs made by the patching crew generally are on-the-spot repairs that should not interrupt the seal coat process. These repairs may include the following:

- Removing and/or hand brooming small mounds of excess spilled aggregate on top of the freshly sealed surface. The removal is accomplished either by shoveling the excess aggregate back into the truck, or sweeping the excess material to the side of the shoulder.
- Occasionally a double layer of binder may be sprayed on a joint. This may occur when making a joint where the joint paper was not placed exactly at the edge of the aggregate or if using the newer distributors the binder shots overlap. Binder may then ooze up through the aggregate at this point. The patching crew can cover the binder with additional aggregate to prevent it from sticking to the roller tires. After the spot has been rolled, remove and replace the section. Not removing and replacing the area may result in a noticeable bump.
- If binder splashes outside the coverage of the spreader, cover these streaks of binder with aggregate so the binder will not stick to the roller tires.
- Remove any grass, clay balls or other non-aggregate on the sealed surface, and replace with aggregate.
- If a spot has been missed by the asphalt distributor, due to a clogged nozzle or other reason, apply binder on the bare spot followed by aggregate.

6.14.2 Delayed Repairs

Normally the patching crew works on repairs during the actual sealing operation. There will be some repairs beyond the capability of the patching crew that must be delayed until later. Generally, these are larger areas that fail for a variety of reasons. The repair method for these larger areas should be determined by the Engineer and may range from complete removal and replacement or hand patching. Do not accept work that will be detrimental to the life of the chip seal. The key to success of a seal is uniformity and consistency.

6.15 Intersections and Irregular Shapes

Generally, intersections and irregular shaped areas are chip sealed before the driving lanes. This is done to minimize aggregate loss caused by construction equipment and turning movements and to provide a clean longitudinal joint.

6.15.1 Transitions

Transitions are shot similar to the method for shoulders. Best practices are to start at the narrow end working toward the wider end. As the surface widens, one or two nozzles can be turned on quickly and at the right time. If the sealing operation moves toward the narrow end, there is a potential for overspray. The goal is to construct a straight joint between the transitions and the main lane. Not every situation is the same, thus there will be cases where it is not practical to start at the narrow end.

Transitions often require some touch-up with the hand spraying in order to even up the outside edge. Good results are easier to obtain by touching up the outside edge rather than a ragged joint adjacent to a main lane.

6.15.2 Radii at Intersections

To seal the radii at intersections, apply the binder with the asphalt distributor hand sprayer, and apply the aggregate when possible with the spreader. If use of the aggregate spreader is impractical, apply the aggregate by hand.

6.15.3 Crossovers on Divided Highways

When necessary to chip seal crossovers on divided highways, use a combination of techniques used for transitions and intersection radii.

6.15.4 Driveways and Private Roads

Driveways and private roads, providing access to the highway, are not normally sealed even though they are within KDOT right-of-way. Refer to the KDOT policy on driveways and entrances. In some cases the driveways and entrances may be noted in the Contract Documents.

6.15.5 Problems with Hand Work

Keep hand work to a minimum. It is difficult to achieve uniform application rates of binder and aggregate anytime hand spraying and manual aggregate spreading is used. The lack of uniformity generally results in some type of problem, either immediately or in the future.

6.16 Brooming Excess Aggregate

Some loose aggregate will be present after the aggregate is spread and rolled. It is necessary to remove any excess aggregate, prior to opening the roadway to traffic, rather than letting vehicle traffic whip it off. Loose aggregates tend to dislodge other aggregate under normal traffic.

6.16.1 Timing

Do not begin brooming the excess aggregate off the roadway until the rolling has been completed, and the binder has hardened or cured. If brooming begins before the binder cures, the broom will dislodge the aggregate from the binder. In some situations, such as opening the roadway to restricted traffic, a light brooming may be performed removing excess aggregate that has not been embedded in the asphalt. The down force on the broom’s bristle brush should not be as high as that used when cleaning the pavement. Too high pressure on the broom’s bristle brush can dislodge chips that are not fully embedded, or if the binder has not cured.

Perform the final brooming as soon as the binder is fully cured: in most cases the same day, or the following morning, if the chip seal is placed late in the day. Best results are obtained by waiting until the following morning (as early as possible). Temperatures are lower during the early morning hours, and the aggregate will be held in place more firmly with only the excess aggregate removed. The time for brooming is a judgment call with the requirements to not start brooming until the asphalt material has cured enough to prevent damage by the brooming process or vehicular traffic. When making the judgment to broom consider: traffic volume and type, speed limits, time of year, weather conditions and weather forecast, to name but a few. Ideally brooming is performed prior to opening the roadway to unrestricted traffic. If brooming is performed the next day, install the necessary traffic control for the brooming operation.

6.16.2 Equipment

The equipment required is a rotary broom or a vacuum sweeper for curbed roadways. In some locations hand brooming may be necessary.

6.16.3 Procedures

Begin the sweeping operation at the centerline, sweeping the aggregate toward the outside edge of the roadway. Best practice is to broom excess aggregate away from traffic. There are no set numbers of brooming passes required. The objective is to broom only the excess aggregate off the roadway surface and not dislodging aggregate from the binder.

6.16.4 Inspection

Check for excess aggregate on the main line roadway surface, including any intersections. Continue brooming until all excess aggregate has been removed. Additional brooming may be required at transverse joints where aggregate may have been overlapped. Check the brooming operation for the potential of dislodging aggregate that has been embedded in the binder. Perform the sweeping operation with a minimum interruption or delay of traffic, and as safely as possible.

6.17 Temporary or Permanent Pavement Markings

When the chip seal is applied, the existing center stripe and lane markings will be obliterated. For the safety of motorists, replace markings with either temporary or permanent markings as quickly as possible.

6.17.1 Temporary Markings

If used, place temporary tabs before the chip seal operation begins, and remove the covers from the tabs as soon as possible after the chip sealing operation. When temporary tape stripes are used, place after rolling and before opening to traffic or at the end of the day. When the adjacent lane is to be sealed on a different day, and tabs are used, seal the first side about 8 inches wider, thus the tab is not covered when the adjacent seal is placed. When temporary tape is used, seal the first side short, using the existing stripe until the adjacent pass is made, after which the temporary stripe is placed.

6.17.2 Permanent Markings

Install the permanent striping as soon as possible after completion of the chip seal. If KDOT is to perform the permanent striping, make arrangements with the District paint crew to have the permanent striping performed.

6.18 Opening to Traffic

Keep traffic off the fresh seal coat as long as possible. Review the various factors that can affect when it is appropriate to open the chip seal to traffic. Follow all traffic control plans required by the KDOT Contract Documents.

6.18.1 Traffic Volume

Roadways with a low-traffic volume (approximately 5,000 average daily traffic [ADT]) may be opened to traffic sooner than high-traffic volume roadways.

6.18.2 Truck Traffic

Roadways with a high volume of truck traffic, (greater than 350 trucks per day [TPD]) utilizing hot AC which requires longer to cool (and stiffen), and emulsions need longer to cure in order to reduce damage caused by the trucks.

6.18.3 Traffic Speed

When chip sealing roadways with higher traffic speeds, allow additional time for the binder to bond to the aggregate, prior to opening to traffic. This has a twofold benefit, preventing damage to the freshly placed chip seal and reducing potential damage to vehicles.

6.18.4 Asphalt Type and Weather Conditions

The type of binder used and expected weather conditions affects the amount of time required prior to opening the lane to traffic. For example, in cooler weather, additional curing time is required. If rain is expected, perform additional rolling, and wait as long as possible before opening to traffic. Consider other weather factors as they occur.

As a general rule of thumb, check the amount of embedment of the chips in the binder, and if the chips appear to be loose, additional curing time needs to occur.

6.18.5 Asphalt Cement

Asphalt cements stiffen quicker and binds the aggregate with greater firmness than asphalt emulsions, allowing opening to traffic sooner. Allow the asphalt cement enough time to cool to the requirements of the Contract Documents.

6.18.6 Asphalt Emulsions

Emulsions are typically applied at about 150°F, which may be near the pavement temperature during the summer, thus there is little loss of binder temperature. High humidity conditions require additional time for emulsions to break. When humidity is greater than 50%, keep traffic off the seal as long as possible.

With the use of emulsions, the potential exists for much of the aggregate to be lost were the chip seal to be caught in a rain. When the potential for rain is noticed, it is best to stop the chip seal operation. If caught in a rain, do not allow traffic on the seal coat. After the rain, determine if the chips are being held by the binder before allowing traffic on the chip seal.

6.18.7 Changing Lanes

When a lane is completed and ready to have traffic placed on the fresh chip seal, take both care and caution. One of the first considerations must be the amount of curing that has occurred. Often the goal may seem to be to get the traffic moved in order to continue the chip sealing work, while the correct decision would be keep traffic off of the chip seal allowing more curing time.

When ready to actually move traffic the safety of motorists and construction personnel are of utmost importance. Exercise complete and positive control over the traffic, while resetting traffic control devices and moving equipment onto the opposite side.

6.19 Cleanup

The goal is to return the right-of-way to its condition prior to beginning the chip seal project. Areas that should be taken into consideration:

- Collect and properly dispose of the joint paper used for the construction of transverse joints.
- Sometimes small quantities of binder may have been inadvertently spilled where distributors were loaded and around the heater units. Remove and properly dispose of any spilled binder.
- Remove all excess aggregate at the stockpile area. Remove any trash or debris, and leave the area in a condition acceptable to the Engineer.
- Remove all traffic control devices used on the project after the project has been accepted. Completely remove all construction sign supports from the project.
- Carefully inspect the areas around stockpiles and any other area where equipment has been stored. Inspect fences, mailboxes, and other private property for any debris or damage. Repair as needed.

- Carefully inspect the areas around stockpile locations and any areas where equipment may have been stored. Make sure these areas have been returned to their preexisting condition. Inspect fences, mailboxes, and other private property for any damage or remaining debris and repair as needed.

Chapter 7: Areas of Concern

In this chapter a number of areas of general concern or construction situations encountered will be addressed. These include patching, handling the public complaints and questions, selling the benefits of chip seals, as well as the problems with using chip seals.

7.1 Principal Faults or Defects in Seal Coats

When any chip seal project is being constructed, there will be some areas with defects. Due to the simplicity of chip seals, the type and cause of the defects are limited. With some effort, the defects can be eliminated and avoided during construction if the cause and effect are understood. Some of the most common defects in chip seals are:

- loss of aggregate;
- streaking;
- flushing;
- poor longitudinal joint at centerline;
- joint bumps;
- selecting non structurally sound pavement
- snow plow damage; and
- utilities (cuts and access covers).

7.1.1 Loss of Aggregate

The major causes for loss of aggregate from chip seals are:

- A long delay between applying the binder and applying the aggregate (after applying the binder it begins to cool and harden, reducing the binding properties).
- Performing the chip seal late in the sealing season. By the Contract Documents the seasonal limits and weather conditions for chip seals are specified. Chip seals are intended to be performed during the warmer months.
- Low amount of binder was applied. A fog seal may be applied after the fact which may help hold the chips in place.

- Selecting the wrong type of binder for prevailing conditions. As soon as the problem is discovered change to the preferred binder. An example the electronic charge of the binder and the aggregate are the same.
- Excessive amounts of dust or a film of moisture on the aggregate particles affecting adhesion. If dust is the problem perform extra pre binder brooming. If moisture is the cause delay starting the chip seal until the moisture has evaporated.
- Opening the chip seal to high speed traffic before adhesion is fully developed. Keep the roadway closed until the binder has set.
- A rainstorm occurring after applying the chip seal, but prior to the development of adhesion or curing. This may require resealing the area affected, or applying a fog seal depending on the amount of lost aggregate.
- Applying excessive cover material causing embedded aggregate to be dislodged under traffic. Once discovered decrease the amount of aggregate being applied. See Figure 7.1 for a picture poor adhesion or loss of aggregates.

(Source: Ron Matteson)

FIGURE 7.1
Poor Adhesion or Bond to Road Surface

Rarely will a complete loss of a chip seal occur. When a complete loss of a chip seal does occur, it is due to a poor bond between the existing surface and the chip seal. The cause could be any one of the above or a combination of these at the time the chip seal coat was placed.

It falls upon the contractor's superintendent and the KDOT inspector to anticipate these causes as a potential to produce defects and avoid constructing a chip seal with defects. Generally the causes are unanticipated and when the defects occur they need to be addressed immediately.

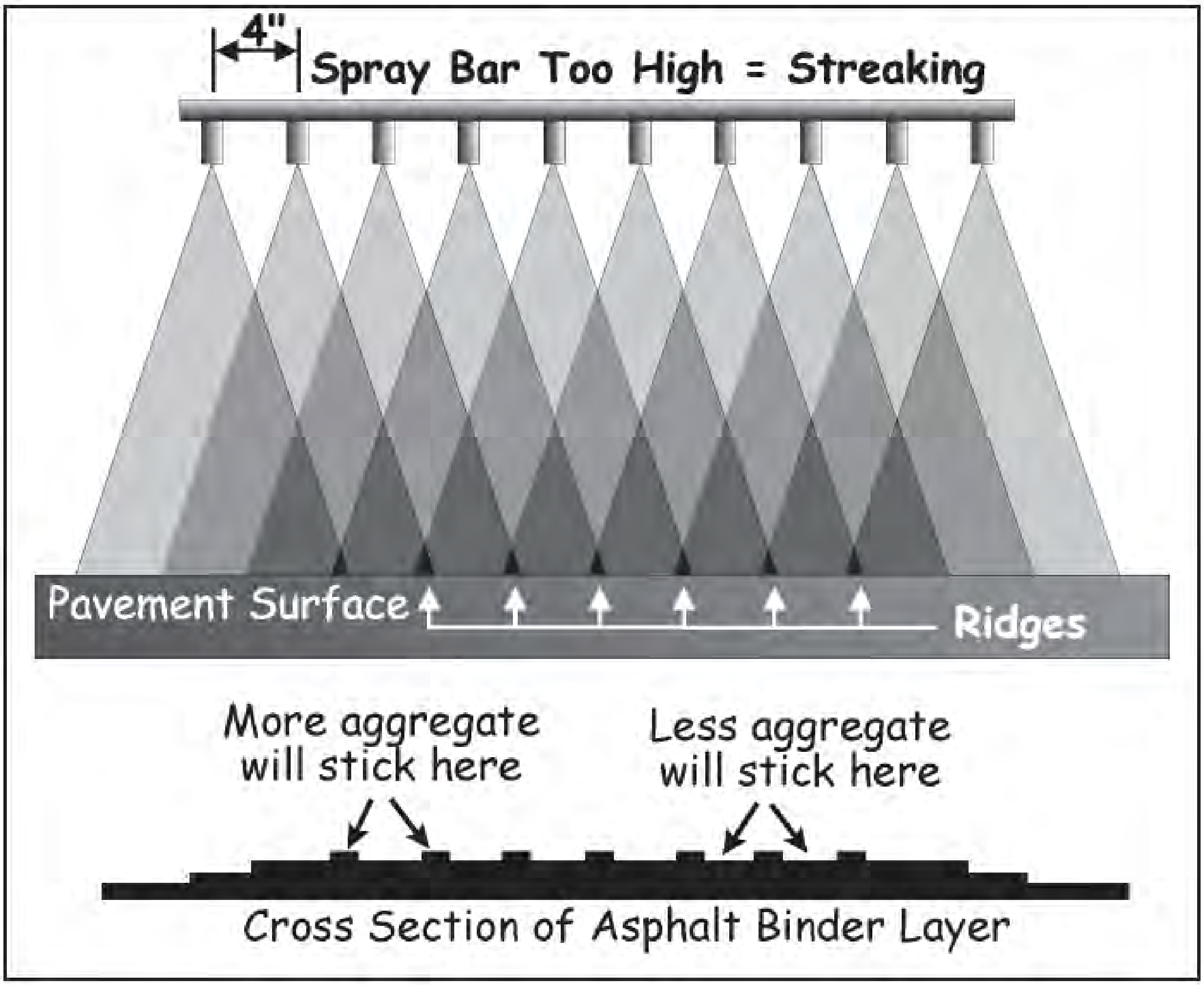
7.1.2 Streaking

Streaking is similar to loss of aggregate, but is generally considered a different defect. Streaking is the result of different quantities of binder or aggregate placed on a part of the pavement when either the binder or aggregate was applied. Streaking results in a lack of uniformity across the lane being sealed. When dark streaks are observed in the pavement, there was either not enough binder applied to hold the cover aggregate in place, or the amount of cover material was inadequate perhaps due to plugged aggregate spreader gates. Occasionally the existing surface on which a chip seal is applied is open or porous allowing a large portion of the binder to soak into the existing surface. When not enough binder is applied to hold the aggregate in place, the aggregate can be easily dislodged by traffic, thus exposing the binder. Streaking may result in reduced friction, and reduces the effective life of the chip seal. Streaking may be observed in any part of the lane dependent on where different application rates occurred.

The most common causes of streaking are mechanical faults such as:

- improper height of the spray bar (See Figure 7.2 for schematic);
- improper or poor operation and adjustment of the distributor nozzles or aggregate spreader gates;
- applying the binder at too low a temperature causing the binder to not fan out properly from the nozzles on the spray bar;
- operating with the spray nozzles partially or completely clogged (faulty strainers or absence of strainers may be partly responsible);

- using spray nozzles of different sizes or makes resulting in different rates of discharge in the spray bar;
- operating when one or more nozzles has not been set vertically;
- operating when one or more nozzles has not been set at the proper angle in the spray bar;
- using damaged or badly worn spray nozzles; and
- using a spray bar in which the center-to-center spacing of the nozzles is not uniform.



(Source: Minnesota Seal Coat Manual, 2006)

FIGURE 7.2
Cause of Streaking

7.1.3 Flushing

Flushing, also referred to as bleeding, occurs when too much binder is applied during the construction of chip seals. Any excess binder migrates upward onto the aggregate causing a black and frequently sticky surface condition. Figure 7.3 shows an example of a flushed chip seal surface.

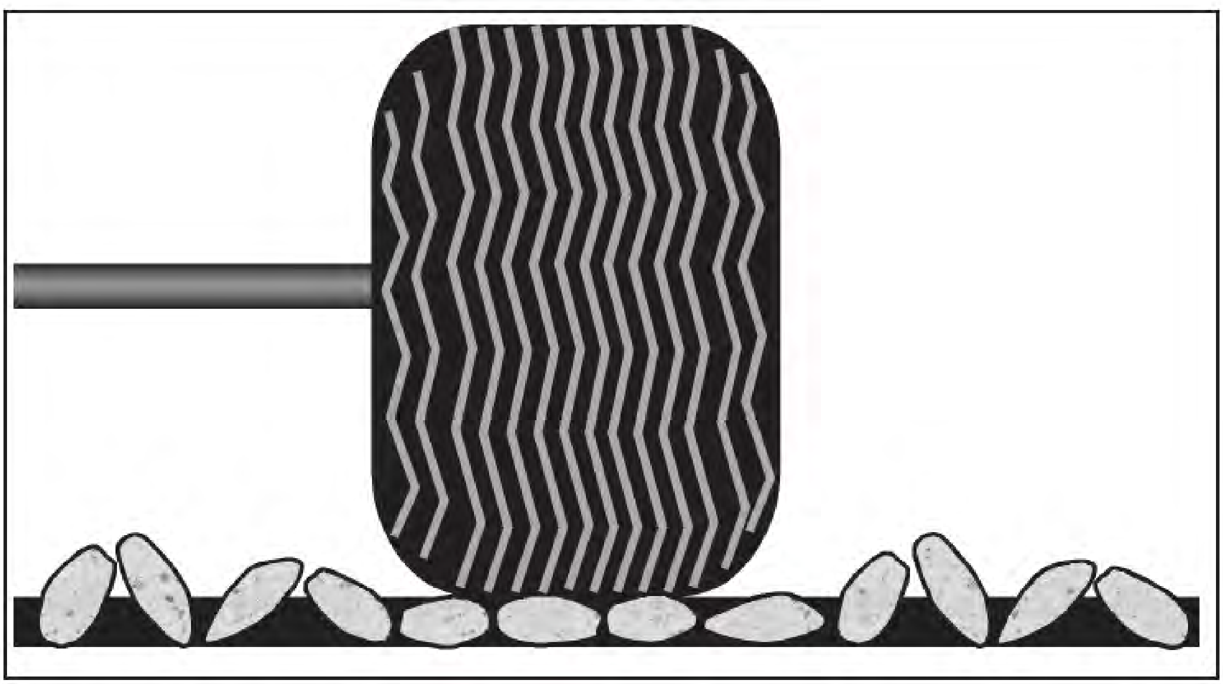
(Source: Ron Matteson)

FIGURE 7.3
Flushing

Visual observation by the traveling public of flushing is quickly seen. A poorly designed (too much binder called for) and constructed seal coat begins with a poor appearance. Often the flushing will not be obvious until traffic has been on the new seal for a short time. A surface that may have flushed badly will also exhibit a loss of friction characteristics. The finished surface fails to satisfy the basic expectations of the traveling public, thus a loss of customer satisfaction.

Flushing and loss of aggregate addressed above have similar appearances. Loss of aggregate is associated with too little binder being applied and the aggregate being dislodged, while flushing is associated with too much binder being applied and the binder migrating to the surface. The use of too little binder occurs less frequently than the application of too much. While the appearance of dark wheel paths may lead one to believe too much binder was shot only on the wheel paths, the reality is the entire lane was shot with too much binder. Either too little or too much binder result in poor quality chip seals and will require corrective actions. One corrective action may be to re-apply the chip seal using a lighter binder shot. The binder that has migrated through the first chip seal application will actually be incorporated into the second chip seal application.

Generally the cause of flushing is simply too much binder has been applied. Another potential contributor to flushing is the shape of the aggregate. If aggregate with numerous longer or flat shapes is used, they may be pushed down flat in the wheel path from traffic. See Figures 7.3 and 7.4 for a photo and a schematic of the problem, respectively. The desired shape of aggregate is more cubical. It is important to look at the design of the chip seal when trying to resolve the situation.



(Source: Minnesota Seal Coat Manual 2006)

FIGURE 7.4
Traffic Causing Flat Chips in Wheel Path (Making It Look Like Flushing)

7.1.4 Poor Longitudinal Joint at Centerline

Often the longitudinal joint at the centerline of the project appears to be raveled or have a loss of aggregate. If the joint is constructed properly, the joint should not be seen. Some causes for poor longitudinal joints are:

- the joint existing on the pavement surface was open or raveled prior to the chip seal. In this condition more binder was soaked into the existing surface thus less binder was available to hold the aggregate;
- the roller operator did not place the roller on the centerline, causing the aggregate to not be embedded into the binder;
- the binder shot may overlap the previously sealed side and when the aggregate is spread, the roller may slightly bridge, thus some aggregate is not toughly embedded.
- the binder shot does not reach the centerline, creating a gap between lanes.
- all of the above causes of poor longitudinal joints will need to be repaired by the patching crew.

As can be seen, there are many causes for joints to be poorly constructed. Care and good workmanship by all parties must be performed to keep these problems to a minimum. Good communications between the inspection forces and the contractor’s crew is absolutely essential.

If a centerline joint does become raveled or open due to any of the above causes, potential solutions may be:

- If a raveled joint is found before the project is accepted, shoot a fog seal on the centerline joint. If found after acceptance, the fog seal may be done by KDOT maintenance forces.
- If a gap is left between lanes, have the patch crew shoot some binder and cover with aggregate prior to rolling.

7.1.5 Joint Bumps

Joint bumps are caused when spraying the binder for the next binder shot overlaps onto previously placed chip seal at a transverse joint. If the aggregate is applied and rolled at the beginning of the "overlapped" binder shot, a bump will occur. The excess aggregate rolled in, even though it may be only one stone thick, is enough to create a noticeable bump. These bumps should be fixed by the patch crew by scraping off the excess aggregate before traffic is allowed on the fresh chip seal.

7.1.6 Selecting Non-Structurally Sound Pavement

If a contract has been let as a chip seal on a structurally unsound pavement as evidenced by mutable longitudinal cracks, alligator cracking or fatigue cracking, a check prior to beginning with the District should be made. Occasionally the distress cracking being observed was not present when the project was selected and a decision to either delay the project and repair the pavement before doing the chip seal or cancelling the project may be made. Generally placing a chip seal on a non-structurally sound pavement is not cost-effective without some pavement preparation actions involved.

7.1.7 Snow Plow Damage

The winter after the application of the chip seal, snow plow damage may occur. This is caused by the down pressure from the plows, and some aggregate not being seated into the binder. It is more noticeable on chip seals done in the later part of the season that have not had the benefit of the traffic during the warmer part of the season. Generally, these are seen as spot areas without cover material. The best way to prevent snow plow damage on projects being placed later in the season is to perform additional rolling when placed. Extra inspection is in order to make sure the proper amount of embedment has been achieved.

7.1.8 Utilities Cuts and Access Covers

On seal coat projects near urban areas, utilities are likely to be encountered.

If there are utility cuts in the surface, and they ride rough or have settled, they should be leveled prior to the chip seal. This activity is generally performed by KDOT Maintenance forces well before the chip seal is applied. Perform any leveling far enough in advance such that any volatiles in the repair materials have time to cure. In some cases, the repair activity may be included in the chip seal contract.

More often, on projects near urban areas, manholes or access covers will be encountered. When encountered, the desire is to not chip seal over them. Some best practices are:

- Cover the access covers with roofing paper or similar material, seal over the covers, remove and dispose of the paper.
- Cover the access cover with sand, remove and dispose the sand binder and aggregate after the seal coat has been performed.

7.2 Handling Complaints

The KDOT field office and the Contractor should expect some complaints on any chip seal project. Document all complaints and handle in a courteous, professional, and timely manner. Some typical complaints coming from the public during or after placement of a chip seal are:

- Vehicle damage from loose aggregate;
- Asphalt on vehicles;
- Noise; and
- Rough ride;

While the chip seal is being performed any complaints of the above nature, except noise and rough ride should be directed to the Contractor. During the preconstruction meeting, obtain a phone number from the contractor to address these types of complaints. After the contract chip seal work is completed, the local KDOT office will handle these complaints. See Section 7.3 for KDOT responses.

When pavement preparation work is being performed by KDOT forces, prior to the contract chip seal, the appropriate local office will investigate each complaint. If action is necessary, handle in a timely manner.

7.3 Public Perception and Education

Chip seals are used extensively throughout Kansas, and the traveling public should be familiar with this type of pavement treatment. It is important for the public to understand why chip seal rather than hot mix asphalt overlays are critical for the preservation of the highway system.

In order to reduce complaints and help educate the general public, it is important to communicate and coordinate information about the chip seal work. The KDOT District's Public Affairs Manager can inform the local media prior construction. Information that should be made available to the public includes:

- when
- where
- why a seal coat is being applied

This information can go a long way to avoiding complaints and generate good public relations.

All complaints that are received require a response that addresses the concerns and serves to educate the public. Complaints may be handled verbally or require a written response. Most public complaints are for:

- loose rock
- noise (tire-pavement noise)
- the perception that chip seals are an inadequate pavement surface
- the perception that an asphalt overlay should be placed

A short explanation of what a chip seal consists of and what it is expected to do such as: A chip seal consists of placing a thin layer of asphalt or binder (glue) on the existing pavement and covering it with a single layer of rock. The asphalt or binder seals most cracks, minimizing moisture infiltration into the existing pavement and works as a glue to hold the rock in place. The new rock increases the friction between the pavement and the vehicle tires thus improving the safety of the roadway. Both of these functions are important to you and KDOT.

A chip seal is cost-effective and is one of the most utilized preventive maintenance treatments on the Kansas State Highway System. Preventive maintenance treatments such as chip seals are used throughout the nation to preserve pavements and extend their useful performance life. KDOT's preventive maintenance treatments, such as chip seals, on the State Highway System are constructed with funds from KDOT's preventive maintenance program. The funding under the preventive maintenance program is limited, and is allocated to provide the most cost-effective treatment for each section of highway. A chip seal typically costs about $35,000 per mile whereas a hot mix asphalt overlay costs about $80,000–125,000 per mile. KDOT continually evaluates and prioritize treatments on all of the highways. Our goal is to be as cost-effective as possible. Note that the funding covers all highways on the State Highway System and we try to pick the best treatments we can afford.

Basically, what KDOT is doing when placing a chip seal is reducing moisture infiltration into the pavement surface and develop friction between the pavement and vehicle tires for safety purposes, pointing out that over time cracks develop and allow water to penetrate the surface and surfaces will become slicker as the pavement wears out. The chip seal is placed to extend the life of the pavement. Often a comparison to why an automobile owner changes the oil in the vehicle can be used as an example. The answer is "to extend the vehicle life." Another example could be to ask, "Why do you paint your house?" Answer: "To preserve the siding from the effects of sun and rain." The same can be said for KDOT using a chip seal: "To extend the pavement life."

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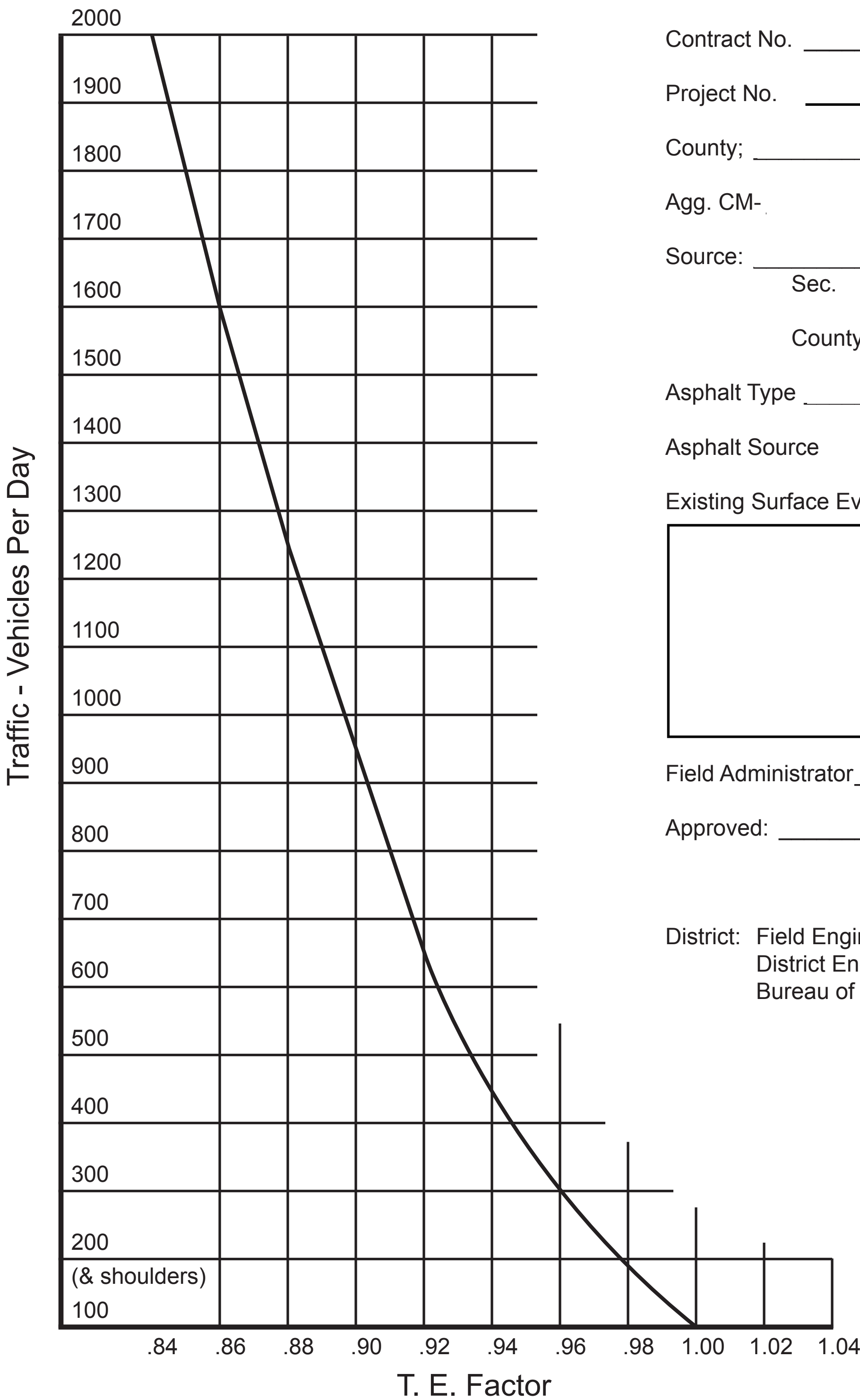
Appendix A: KDOT Asphalt Sealing Design Form

(Form No. 683)

Print | Route | Save | To Catalog | Reset Form | Next Page

KANSAS DEPARTMENT OF TRANSPORTATION
ASPHALT SEALING DESIGN



Contract No. ____________________

Project No. ______ ______ ______

County; ____________________

Agg. CM- Qual. No. ____________

Source: ______ ______ ______
Sec. Twp. Range

County ____________________

Asphalt Type ____________________

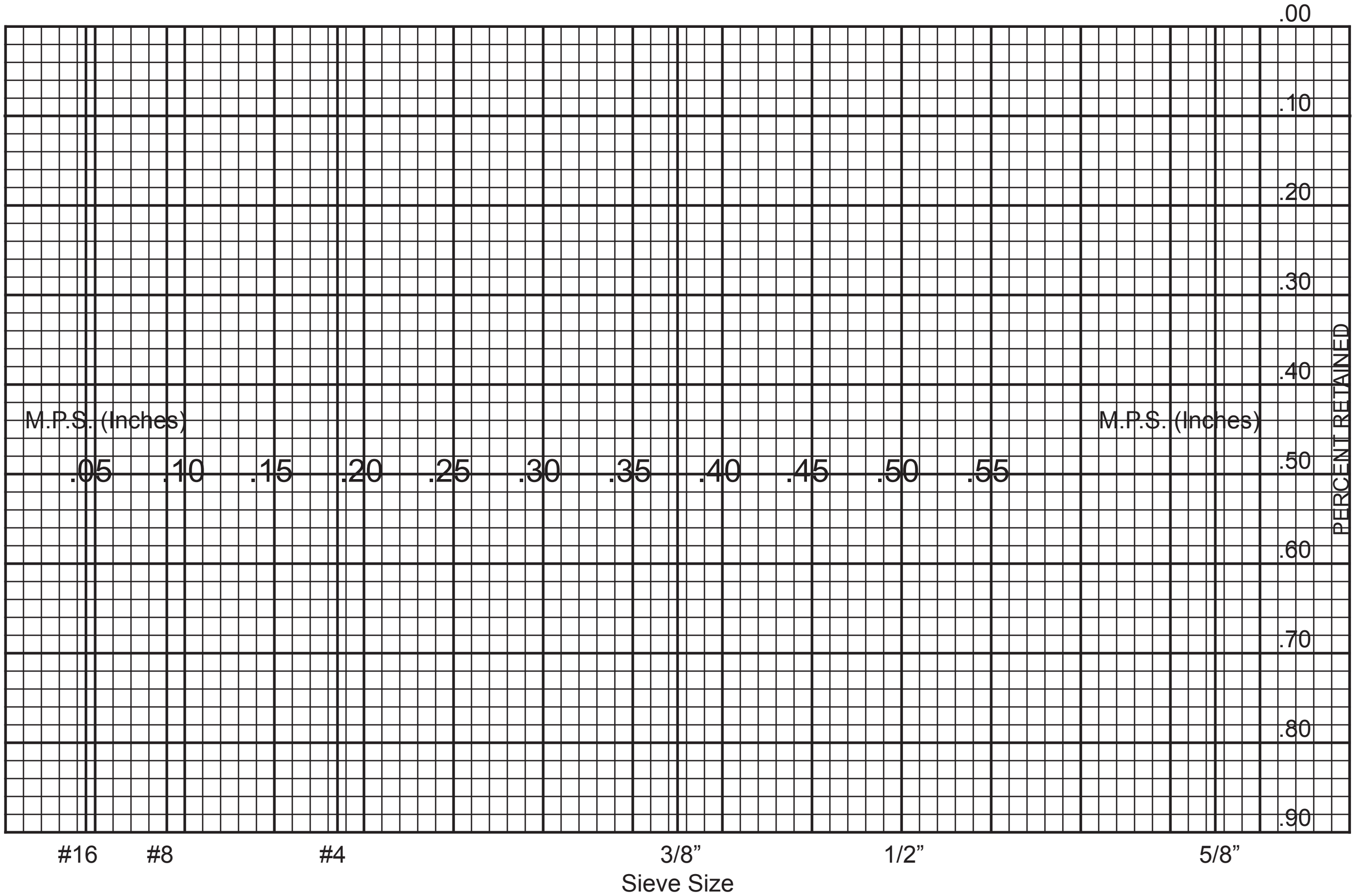
Asphalt Source

Existing Surface Evaluation:

Field Administrator____________________

Approved: ____________________
District Materials Engineer

District: Field Engineer
District Engineer
Bureau of Materials & Research



Median Particle Size (M.P.S.) = ____________ "

Traffic Count ____________________ V.P.D.

T.E. Factor X ____________________ (From Graph)

(For traffic over 2,000 V.P.D., the T.E. Factor = 0.84)

Basic Residue Rate = ____________________ Gals. / Sq. yd.

Pavement Condition Adjust. = ____________ Gals. / Sq. yd. (See Below)

Revised Application Rate, R_a = ____________ Gals. / Sq. yd. (Residue)

Revised Application Rate, $R_e = \frac{R_a}{\text{\% Residue}}$ = ____________ = ____________ Gals. / Sq. yd. Asphalt Binder

---

Aggregate Rate $A_{base} = \frac{36}{\text{M.P.S.}} = \frac{36}{\quad}$ = ____________ Sq. yd. / Cu. yd.

Theo. Max. Aggregate Rate, $A_a = A_{base}$ X (Factor) = ____________ X ____________

A_a = ____________ Sq. yd. / Cu. yd.

CM-	Factor
A	0.70
D	0.90
E	0.94
K	0.90
L	0.90

Pavement Condition	Adjustment	
Flushed Asphalt Surface	– 0.03	Gals. / Sq. yd.
Smooth, Non-porous Surface	0.00	Gals. / Sq. yd.
Slightly Porous, Oxidized Surface	+ 0.02	Gals. / Sq. yd.
Slightly Pocked, Porous Surface	+ 0.04	Gals. / Sq. yd.
Badly Pocked, Porous, Oxidized Surface	+ 0.06	Gals. / Sq. yd.

K-TRAN

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