# Best Practices for Emulsified Asphalt Chip Seals

**Prepared for the**
**AASHTO TSP-2**
**by the**
**Emulsion Task Force (ETF)**

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- Scott Shuler
- Gary Hicks
- Larry Tomkins
- Rod Birdsall
- Andy Clayton
- Mark Ishee
- Stormy Brewster
- Amy Epps Martin
- Jon A. Epps
- Bobby Betsold

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# Forward

This document titled "Best Practices for Emulsified Asphalt Chip Seals" was developed solely to address Chip Seals using emulsified asphalt. It is recognized that there are other chip seal applications that use hot applied asphalt binders. For simplicity, Chip Seal, as used in this document refers solely to chip seals placed using emulsified asphalt and is used universally to mean Asphalt Emulsion Chip Seals.

A chip seal is the application of emulsified asphalt, followed immediately by a single layer of aggregate to a prepared surface. The primary purpose of the chip seal is to seal fine cracks in the underlying pavement surface and prevent water intrusion into the base and subgrade. Chip seals and similar surface treatments have been used since the 1920's to seal aggregate surfaced roads. Since then, chip seals have evolved into maintenance or preservation treatments that can be used on both low volume and high volume roads.

In recent years, considerable work has been done through the National Cooperative Highway Research Program (NCHRP) on developing best practices and specifications for chip seals. NCHRP Synthesis 342-Best Practices for Chip Seals (2005-Dough Gransberg); NCHRP report 680 Manual for Emulsion Based Chip Seals for Pavement Preservation (2016-Scott Schuler); NCHRP report 14-37 Guide Specifications for the Construction of Chip Seals and Fog Seals (2018- Scott Schuler). Much of the information related to this document is drawn from these publications along with information published by the International Slurry Surfacing Association (ISSA), the Asphalt Emulsions Manufacturers Association (AEMA), AASHTO Transportation System Preservation Technical Service Program (TSP-2) ETF and the (AASHTO COMP). Over the past several years, the ETF has developed AASHTO materials and design standards for chip seals that have been published by the AASHTO COMP. Construction Guide specifications for this treatment have also been developed and approved by the AASHTO COMP and are awaiting publication.

The objective of this document is to provide the user with the knowledge and guidance necessary to construct a chip seal that provides the expected service life or life extension. It is a summary of best practices for chip seals that addresses the following:

- Background and terminology
- Project selection
- Materials used in chip seals
- Mix design and performance tests
- Specifications
- Construction
- Quality Assurance
- Check lists and problem solving

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# 1.0 Introduction

A chip seal is the application of emulsified asphalt, followed immediately by a single layer of aggregate chips to a prepared surface. An emulsified asphalt fog seal is sometimes applied to assist with aggregate retention. The following chip seal practices are not covered by this document:

a) Use of hot applied asphalt binders (> 275°F)
b) Use of rejuvenating emulsified asphalt
c) Use of synthetic aggregates
d) Alternate application techniques such as multiple lifts, scrub seals, Cape seal, inverted seals and the like.

Chip seals have several purposes when applied as a pavement preservation tool including: 1) sealing small cracks 2) reducing further oxidation of the pavement, 3) improving surface texture and skid resistance, 4) preserving and extending pavement life, and 5) providing color contrast and noise differences. If any of these objectives are desired, a chip seal may be a good choice. Chip seals have also been utilized as a pavement construction technique when applied over soil subgrades or aggregate bases to provide an all-weather surface. Many pavements have been constructed using multiple applications of chip seals.

Chip seals are generally recommended when traffic volumes are less than 3000 AADT (average annual daily traffic per lane) and have been documented as a viable pavement preservation tool with traffic volumes greater than 7500 vehicles per lane (Shuler, 1998). High-traffic applications require rigorous attention be paid to material quality, design, placement, traffic control, pavement condition, weather, and all other factors pertinent to construction of high-quality chip seals (Peshkin et. al., 2011).

The performance of a chip seal can vary significantly depending on the preexisting pavement condition, surface preparation prior to the seal, design and construction practices. However, when designed and constructed properly on an appropriately selected pavement the expected life extension provided should range from five to seven years.

## 1.1 Terminology

Much of the terminology shown below associated with chip seals has been documented by ASTM or has been developed by the AASHTO Emulsion Task Forces (ETF). Common terms are included below:

- *Chip Seal* – The application of an emulsified asphalt to a roadway surface followed by a single layer of aggregate. When more than one layer of emulsified asphalt and aggregate is applied, the terms double or triple chip seal are often used.
- *Surface Treatment, Surface Seal, Surface Dressing* – These terms may be used as alternatives to *chip seal* when aggregates are applied to the emulsified asphalt.
- *CRS-2* – a cationic rapid setting emulsified asphalt.

- *RS-2* – an anionic rapid setting emulsified asphalt.
- *CRS-2P polymer modified* – a cationic rapid setting emulsified asphalt typically modified with styrene-butadiene, a styrene-butadiene-styrene block copolymer or latex rubber.
- *RS-2P polymer modified* – anionic rapid setting emulsified asphalt typically modified with styrene-butadiene, styrene-butadiene styrene block copolymer, or latex rubber.
- *HFRS-2P* – an anionic rapid setting high-float emulsified asphalt typically modified with styrene-butadiene, a styrene-butadiene-styrene block copolymer or latex rubber.
- *CSS-1h* – a cationic slow setting emulsified asphalt that normally used for fog seals. This contains a harder base asphalt than CSS-1.
- *CRS-1h* – a cationic rapid setting emulsified asphalt used for fog seals.

## 1.2 Organization of this Document

The organization of the chapters in this document follows a sequence of important steps that are necessary for delivering a high-quality chip seal that performs well in practice.

a. Pavement Selection
b. Materials Requirements
c. Mix Design Process
d. Specifications
e. Equipment and Calibration
f. Construction Operations
g. Quality Assurance and Inspection
h. Check Lists and Problem Solving

## 1.3 Application of Chip Seals

This document covers the design and construction of chip seals as a pavement preservation treatment. The performance of a chip seal is dependent on many factors. These include the existing condition of the pavement to which the chip seal is to be applied, pavement geometry, traffic volume and type, materials and construction practices. The following discussion describes these factors and what affect each has on performance of the chip seal.

### 1.3.1 Pavement Condition

*1.3.1.1 Cracking*

Chip seals are most effective when placed on uncracked pavements as a preventive maintenance application to seal the aging surface from intrusion by moisture and oxygen. The emulsified asphalt residue can seal small cracks and can still be effective when longitudinal and transverse cracks are ¼ inch or less in width. As crack width increases, the emulsified asphalt residue is less effective at bridging the gap and crack sealants should be utilized to seal these cracks prior to chip sealing.

Alligator, or fatigue cracking, is an indication of a weak subgrade or base course or structurally inadequate pavement. When fatigue cracking takes up more than one third the pavement surface, a chip seal may be inappropriate as a maintenance technique. However, a chip seal may reduce moisture infiltration into the subgrade and/or base, thus reducing the potential for future damage.

Block cracking occurs when asphalt becomes brittle due to oxidative aging. This type of cracking originates at the surface and may be relatively uniform across the entire pavement surface. Use of Portland cement stabilized bases can also cause block cracking that does not originate at the surface. Chip seals are an effective treatment over block cracking so long as the damage is not extensive.

The decision to apply a chip seal over existing cracks requires judgment when evaluating the condition of the existing pavement. Pavement distress documents such as the Distress Identification Manual (Publication No. FHWA-HRT-13-092 rev. May 2014) may offer some help in defining the type and extent of cracking. The following photos show some of the types of pavements suitable for chip seals.

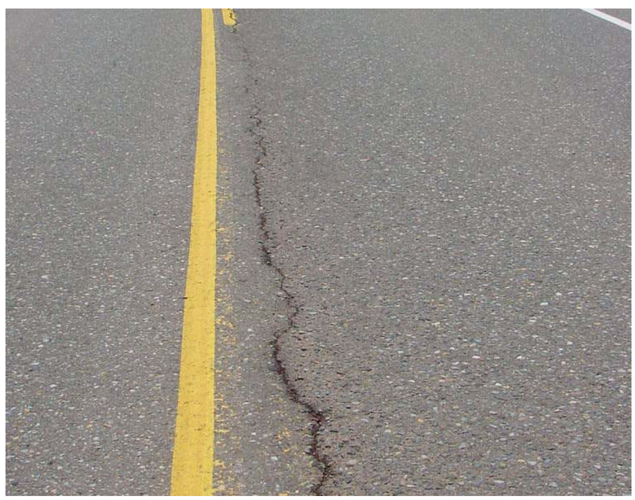

***Figure 1: Minor Cracking***

#### *1.3.1.2 Flushing*

A flushed pavement surface is often soft accompanied by a loss of friction. This condition can allow aggregate to be embedded in the surface after trafficking, resulting in additional flushing. Chip seals may be applied to remedy friction loss, but penetration of the aggregates into flushed pavement surfaces may limit effectiveness unless the aggregates can be retained with lower emulsified asphalt application rates. Flushing and bleeding of the existing surface often occurs in wheel paths. Should this occur, the emulsified asphalt application rate must be reduced in the wheel paths to prevent future flushing and bleeding. This can only be accomplished with variable spray rate asphalt distributors or by varying the size of the nozzles in the asphalt distributor spray bar. This practice has been described in the literature (Shuler 1991) and utilized by Texas DOT (Martin 1989). Further discussion of this topic is presented in more detail in the construction section of this document.  The ball penetration test (New South Wales 2012) is an effective tool for measuring potential embedment. Guidance is included in the design section of this document, regarding when to avoid applying a chip seal based on the ball penetration test.

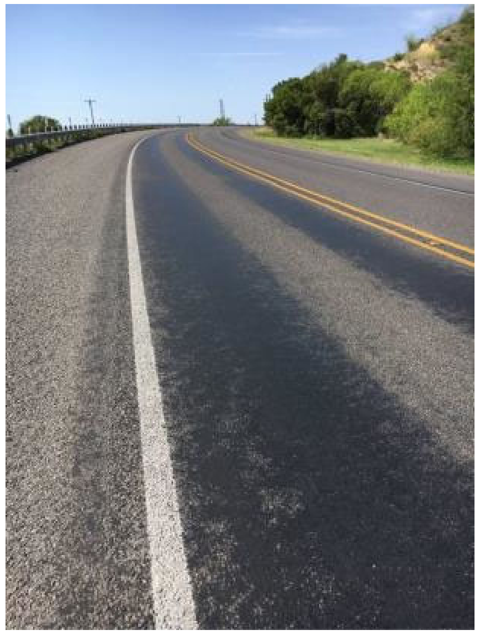

***Figure 2: Flushed Pavement***

### *1.3.1.3 Surface Texture*

Surface texture impacts the amount of emulsified asphalt needed to hold the aggregate in place. Prior to application of the chip seal, the texture of the pavement surface should be evaluated using the sand patch test, or other accepted methods, to determine whether an adjustment to the design emulsified asphalt application rate is appropriate. Adjustment factors for texture based on the sand patch test are provided in the design section of this document.

***Figure 3: Surface Texture***

***Figure 4: Raveling***

The amount of emulsified asphalt applied to the pavement may need to be varied if the surface does not have the same texture along the alignment. This uniformity should be mapped prior to construction to identify locations where emulsified asphalt application rates should vary from design. Uniformity can also vary transversely across the pavement, which is often the case when wheel paths are flushed.

### 1.3.2 Traffic Characteristics

Traffic should be considered for both design and construction purposes as the traffic volume and the type of traffic effects the selection of materials utilized on chip seals. Generally, the higher the traffic volume and higher percentage of heavy trucks on an undivided roadway, the greater the opportunity for vehicle damage (from loose aggregate) if traffic is not adequately controlled during construction. In addition, the volume and nature of the traffic is directly proportional to the potential for aggregate embedment into the underlying pavement. Turning tires and traffic acceleration/deceleration affect the chip seals performance, as the aggregate is more likely to be dislodged under these shear loads than at constant speeds. Areas near traffic lights, stop signs, intersections or uphill/downhill grades are particularly prone to flushing or bleeding and wash boarding of the surface. This section discusses the factors that influence the materials selection process depending on traffic volume, type of traffic and speeds.

#### *1.3.2.1 Selection of Aggregate Size*

Larger aggregates are less likely to become totally embedded by traffic if the underlying pavement is relatively hard. However, the use of large aggregate can lead to more traffic noise and a higher risk of vehicle damage (e.g. broken windshields) when traffic is released. Larger aggregate requires higher emulsified asphalt application rates for proper embedment, resulting in increased sealing ability. The aggregate characteristics are discussed in more detail in the materials section.

#### 1.3.2.2 Emulsified Asphalt Selection

Emulsified asphalts modified with elastomeric polymers provide higher adhesion for the aggregate. This is true both during construction and later in the life of the chip seal. Research on high volume traffic facilities, defined as greater than 7500 vehicles per day per lane (Shuler 1991) indicates that modified emulsified asphalts are required to hold the aggregate in place due to reduced emulsified asphalt application rates. Reduced rates of emulsified asphalt are necessary on these high traffic facilities to reduce the potential for over-embedment and consequent flushing.

#### 1.3.2.3 Emulsified Asphalt Fog Seal

Emulsified asphalt fog seals are sometimes used after the placement of a chip seal. Fog seals provide a high color contrast for pavement markings, especially improving nighttime visibility. There is also anecdotal evidence that the sharp color contrast between the black fog seal and the pavement marking improves public perception. Such benefits may be short-lived, since the color contrast may not remain long after the chip seal is applied. There is also documented evidence that chip seal performance may be improved (Shuler 2007). For example, snowplow induced aggregate loss can be substantially reduced by fog sealing the chip seal soon after construction (King 2008).

### 1.3.3 Pavement Geometry

#### 1.3.3.1 Divided/Undivided

Vehicle damage caused by loose aggregate is directly proportional to the distance between opposing directions and vehicle speed. Divided alignments reduce the probability for broken windshields.

#### 1.3.3.2 Gradient/Curves

Steep inclines and curves may adversely affect performance due to tractive forces and slower moving vehicles. Shear forces due to traffic can dislodge aggregate immediately after construction and sometimes during the life of the chip seal. Therefore, traffic control may need to remain in place longer, or pilot cars that control speed can be used, until the emulsified asphalt has cured sufficiently to retain the aggregate under these conditions.

#### 1.3.3.3 Intersections

Turning, acceleration and deceleration can cause wash boarding, aggregate loss and flushing. Therefore, traffic control may need to remain in place longer, until the emulsified asphalt has cured sufficiently to retain the aggregate under these conditions.

#### 1.3.3.4 Lane Width

Lateral vehicle movement on narrow, secondary roads tends to be more channeled and concentrated than on wider primary facilities. This may result in a greater tendency for flushing and bleeding in the wheel paths.

### 1.3.4 Roadway Type

*1.3.4.1 Highway*

It has been demonstrated that chip seals can be successfully constructed on highways with over 7500 vehicles per day per lane with little or no consequences with respect to vehicle damage (Shuler 1991) if important principles are followed. However, other factors should be considered regarding the use of chip seals on high traffic volume pavements:

1) Noise increases with increasing traffic volume and aggregate size; therefore, smaller aggregates are often desired for high volume traffic roadways.
2) There is less margin for error relative to emulsified asphalt spray rate when using smaller aggregates. This makes the effect of variations in spray rate greater, increasing the potential for aggregate loss or flushing if the rate is less than or more than it should be, respectively.
3) Double or even triple chip seals using larger aggregates for the initial application, and smaller aggregates in secondary applications, are often preferred.

*1.3.4.2 Residential*

Chip seals constructed with larger aggregates are rough textured and can lead to skin abrasions when falls occur during recreational biking and skating etc. These are common complaints received by citizens in anecdotal accounts and should be considered. This effect can be reduced with the application of a fog seal overlaid by a fine aggregate, or with a slurry surfacing making it a Cape Seal.

*1.3.4.3 Rural*

Rural settings are an ideal environment for chip seals. Traffic tends to move more consistently, with less stopping and starting. Traffic volumes are usually lower, creating wider vehicle separation and thus less opportunity for damage. With less traffic, aggregate embedment is more uniform across the road profile, and reduces the potential for wheel path distress.

*1.3.4.4 Urban*

Urban environments are often the least desirable environment for chip seals. This is due to higher traffic volumes coupled with much turning, stopping and starting. Although chip seals have been constructed in such environments with success, traffic control must limit vehicle speeds. The time required for emulsified asphalt residues to gain enough strength to resist the turning, acceleration and deceleration of high volumes of vehicles may be longer than is typical on low volume roads. Therefore, flaggers or pilot cars are recommended. Also tracking of loose aggregate and emulsified asphalt by pedestrians and pets on sidewalks and into homes can be an issue.

### 1.3.5 Construction Preparation

Preparation of the pavement surface prior to chip seal operations can influence performance of the chip seal. This preparation varies depending on the condition of the existing pavement, but at a minimum should include sweeping the surface if loose debris, dust or other contaminants that are present. Micro milling prior to placing the chip seal is used to eliminate the high spots and improve ride quality.

***Figure 5: Micro Milled Surface***

*1.3.5.1 Repairs*

Alligator cracking, potholes, failing patches, and active cracks greater than ¼-inch in width should be repaired prior to chip seal operations. Preferably, these repairs should be accomplished 3 to 6 months in advance of placing the chip seal.

***Figure 6: Crack Sealing***

*Figure 7: Crack Sealing and Patching*

### *1.3.5.2 Pre-Treatment of Patches or Leveling Course*

Hot-mix or cold-mix asphalt patches or leveling courses should be pretreated with a light application of emulsified asphalt prior to applying the chip seal, particularly if patched areas are lower in density and might absorb more emulsified asphalt than older sections of pavement. If not pretreated initially, patched areas or newly placed hot mix surfaces may absorb more of the emulsified asphalt. This effectively reduces the application rate required by the design, potentially resulting in inadequate embedment and aggregate loss.

## 1.3.6 Maintenance

Fog seals may be applied to chip seals if inadequate embedment occurred during initial construction or when in service, to prevent further loss of aggregate due to asphalt embrittlement caused by aging.

*Figure 8: Fog Seal Application*

# 2.0 Material Requirements

Chip seals are a two-step process in which two materials are used. First, an emulsified asphalt is applied using an asphalt distributor followed by an aggregate applied using an aggregate spreader. Materials for Chip Seals are specified in AASHTO MP 27-16. Fog seals are sometimes used after the chip seal has been placed. These are described in this section and in AASHTO MP 33-17.

## 2.1 Emulsified Asphalts

According to the Basic Asphalt Emulsion Manual, 4th edition (Asphalt Institute (AI), AEMA 2008) emulsified asphalts should have the following characteristics when used for chip sealing:

- When applied, the emulsified asphalt should be fluid enough to spray and cover the surface uniformly, yet viscous enough to remain in a uniform layer and not puddle in depressions or run off the pavement.
- After application, it should retain the required consistency to' wet' the applied aggregate.
- It should develop adhesion quickly.
- After rolling and curing, the binder should hold the aggregate tightly to the roadway surface to prevent dislodging by traffic.
- When properly selected and applied in the proper amount, it should not bleed or strip under traffic or with changing weather conditions.

### 2.1.1 Emulsified Asphalt Type

Emulsified asphalts should be either rapid set (RS) or medium set (MS) and should meet the requirements of AASHTO materials specifications M140, M208, and M316. Rapid setting emulsified asphalts are preferred as they allow for faster setting and quicker removal of traffic control. Although rapid setting emulsified asphalts should normally be used for chip seals, dirtier aggregates or certain weather conditions (such as late season construction) can favor medium setting emulsified asphalts. However, use of these materials is discouraged due to the longer setting time required. Therefore, rapid setting emulsified asphalts should always be considered the first choice for the chip seal binder. A note of caution, extremely hot weather (> 110ºF) may cause emulsified asphalts to form a 'skin' on the surface after application, creating a barrier to moisture release thereby delaying the setting time of the chip seal.

### 2.1.2 Emulsified Asphalt Class or Grade

Emulsified asphalts are classified by the particle charge of the emulsifier covering the surface of the asphalt droplets suspended within the water phase of the emulsified asphalt. Anionic emulsified asphalts have a negative particle charge and cationic emulsified asphalts have a positive particle charge. There are also a limited number of emulsified asphalts classified as non-ionic, because the emulsifier has no appreciable electric charge. These emulsified asphalts are often interchangeable, as most classifications should provide equal performance with most available aggregates. They, however, are not compatible with each other. Thorough cleaning of emulsion distributors is required if using the same equipment with two types of emulsions (anionic and cationic). The Basic Asphalt Emulsion Manual,4th edition (AI/AEMA) offers guidance for switching between anionic and cationic products.

Laboratory experiments reported in NCHRP Report 680 were designed to determine whether one class of emulsified asphalt was better suited to one type of aggregate with respect to adhesive ability (Shuler et al, 2011). Results of this research indicate that before the emulsified asphalt has broken, or set, there is a slight effect on adhesion due to particle charge. That is, the anionic favored the limestone and the cationic the granite and basalt as determined by the mass loss when conducted by the sweep test. However, after curing to an 80 percent moisture loss, there was no difference between the emulsified asphalt residues with respect to mass loss. Therefore, efforts to use anionic emulsified asphalts with theoretically positively charged aggregates and cationic emulsified asphalts with supposed negatively charged aggregates appears to be unnecessary. This finding also seems reasonable since there is no evidence that alluvial sources of aggregates, which usually contain many different geologic species, have any greater tendency to fail in adhesion when used in chip seals than quarried aggregates with singular geologic species.

### 2.1.3 Viscosity Grade

Emulsified asphalts are produced in two viscosity categories. Low viscosity is designated with a '-1' and high viscosity with a '-2'. Examples would be RS-1 or RS-2. Because aggregates require approximately 40 percent initial embedment during construction and 50 to 70 percent for final embedment, the high viscosity emulsified asphalts should always be used. The low viscosity emulsified asphalts could flow off the existing pavement before the aggregate is placed

### 2.1.4 Application Rate

The emulsified asphalt application rate must be correct during construction if optimum performance of the chip seal is to occur. Too little emulsified asphalt will allow aggregate loss under traffic, while too much emulsified asphalt will lead to flushing and loss of friction. The optimal application rate is a function of the aggregate size and shape which affects the volume of voids in the compacted aggregate layer: the volume and type of traffic: the pavement gradient and the condition of the pavement surface. The chip seal mix design process discussed in Chapter 3 determines what this rate should be.

### 2.1.5 Viscosity during Construction

The viscosity ranges of the emulsified asphalt should meet the appropriate AASHTO Material Specification, M 140, M 208, or M 316. The viscosity of the emulsified asphalt during construction is important for several reasons as it could affect the fan spray and application rates. If the viscosity is too low, the emulsified asphalt could flow off the pavement before the aggregate are embedded, resulting in a loss of aggregate under traffic and potential environmental issues. If the emulsified asphalt viscosity is too high, adequate wetting (adhesion) of the aggregate might not occur, resulting in a loss of aggregate. Some emulsions (e.g. high float) can be applied in the higher viscosity ranges.

## 2.2 Aggregates

The aggregate in a chip seal serves the following functions:

- It is resistant to the abrasion of moving wheel loads and transfers the wheel load to the under-lying pavement.
- It provides a skid-resistant surface.
- It may provide light-reflecting qualities.
- It may provide a different texture or color to distinguish areas, such as shoulders and travel lanes.

### 2.2.1 Aggregate Considerations

There are many factors to consider when selecting an aggregate for chip seal construction. They are types, gradation, particle shape, cleanliness, toughness/soundness and absorption. There are two broad categories used to describe the types of aggregates used for chip sealing: natural and synthetic. Natural aggregate types are gravels, limestones, sandstones and granites, while synthetic aggregates are lightweight aggregates (expanded shale, clay, or slate produced by a rotary kiln method) and slag (produced as a by-product of steel production). Recycled asphalt aggregates are also being utilized in certain parts of the country (FHWA, 2020).

The next aggregate selection factor is gradation. A single sized aggregate is preferred as opposed to a graded aggregate, for the following reasons:

- The single sized aggregate will provide maximum friction;
- It is less sensitive to variations in binder application rate;
- It provides better drainage due to clear surface channels between the aggregate particles, which allows for rapid removal of water from the roadway.

Graded aggregates cover a wide range of possibilities from dense graded to gap graded. The more well graded (having all size fractions) an aggregate is, the less desirable it will be for chip seal construction. As can be seen in Figure 9, there are less inter-granular voids when using graded aggregates, which means that there is less room to fit the binder in-between the aggregate. As a result, there is a fine line between applying too much binder (which may result in bleeding) or not enough binder (which will result in loss of aggregate).

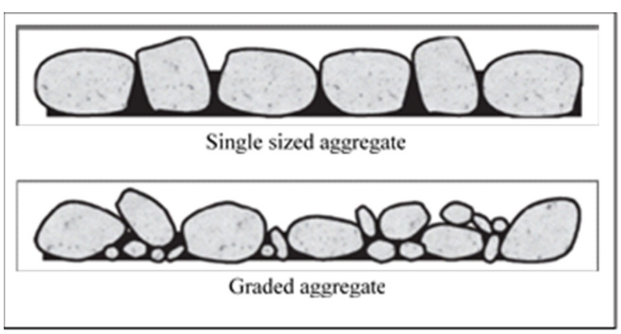


*Figure 9: Effect of Aggregate Gradation*

The next selection factor for aggregates is particle shape. There are four different shapes: flat and elongated, cubical, round, and angular. Flat and elongated shaped aggregate will orientate under traffic to lie on their flattest side and become submerged within the binder (Figure 10). As a result, flatter aggregates are more susceptible to bleeding in the wheel paths. The quantity of flat particles in the aggregate can be determined by the Flakiness Index test. A low Flakiness Index indicates that all the aggregate particles are very nearly cubical in shape. With cubical shaped aggregate, traffic will not affect the orientation of the aggregate and therefore the opportunity for bleeding is reduced, as the chip seal height and aggregate embedment will be uniform.

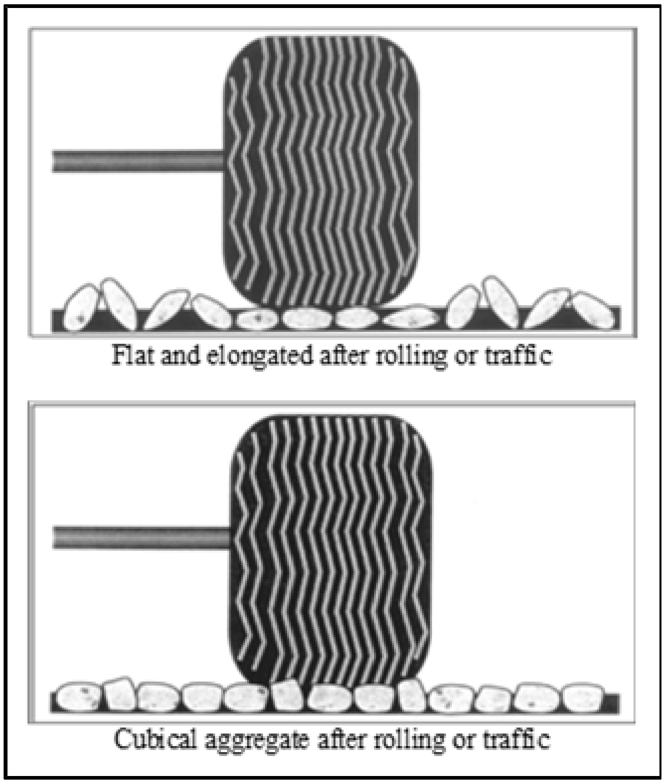


***Figure 10: Effect of Aggregate Shape***

The angularity of the aggregate, a characteristic that can be measured by testing for percent fracture, determines a chip seal's propensity to damage by stopping or turning traffic. A round shaped aggregate is more susceptible to rolling and displacement by traffic than angular shaped aggregate as the angular aggregate interlock is better as shown in Figure 11.

*Figure 11: Round and Angular Aggregates*

Table 1 provides recommended gradations for chip seal aggregates.

*Table 1: Recommended Chip Seal Gradations (Shuler, et al, 2011)*

| Sieve, mm | Sieve, std | Passing, % | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | A | | B | | C | | D[1] | |
| | | Min | Max | Min | Max | Min | Max | Min | Max |
| 19 | 3/4 | 100 | 100 | | | | | | |
| 12.5 | 1/2 | 90 | 100 | 100 | 100 | | | | |
| 9.5 | 3/8 | 5 | 30 | 90 | 100 | 100 | 100 | 100 | 100 |
| 4.75 | 4 | 0 | 10 | 5 | 30 | 90 | 100 | 0 | 65 |
| 2.38 | 8 | | | 0 | 10 | 5 | 30 | 0 | 15 |
| 1.19 | 16 | 0 | 2 | | | 0 | 10 | 0 | 10 |
| 0.60 | 30 | | | 0 | 2 | | | | |
| 0.30 | 50 | | | | | 0 | 2 | 0 | 6 |
| 0.075 | 200 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 3 |

[1]When Gradation D is used where traffic is greater than 500 AADT or in an urban environment the recommended passing 200 is 1%.

### 2.2.2 Cleanliness

Emulsified asphalts can be produced with the ability to coat aggregates containing small quantities of dust (aggregate passing the No. 200 sieve). The maximum amount of this dust is dependent on the emulsified asphalt. For example, medium setting emulsified asphalts can tolerate a higher percentage of dust than most rapid setting emulsified asphalts. This is often related to the demulsibility of the emulsified asphalt. The higher the demulsibility, the less dust can be tolerated before setting occurs without loss of adhesion to the coarse aggregate. Generally, a maximum of 2% dust is a good value to follow. However, the ideal value would be 1 % or less.

### 2.2.3 Moisture Content

Laboratory testing using a sweep test (Shuler, et al 2011) has shown that aggregates in the saturated surface dry condition provide better adhesion than completely dry aggregates. This is preferred since construction aggregates are generally damp. In some parts of the United States, which have low humidity, SSD conditions may not exist.

### 2.2.4 Toughness and Durability

Aggregates must have enough strength to resist crushing during construction and trafficking. Breakdown of the aggregate could lead to bleeding and flushing if the coarse particles are reduced to fine particles. It is important that the aggregate meet all specifications for toughness and durability such as LA abrasion (AASHTO T-96) and soundness (AASHTO T-104). The tests are also included in AASHTO MP 27-16.

### 2.2.5 Porosity

Porous aggregates absorb more asphalt than non-porous aggregates. This does not create performance problems unless the amount absorbed is high, and if not accounted for during the design stage, leaving less binder available to hold the aggregate in place. Porous aggregates, such as limestone, volcanic rocks, and lightweight aggregates, can also have performance issues in locations that experience freeze-thaw or use de-icing chemicals for snow removal operations.

# 3.0 Mix Design Process

The quantity (application rate) of emulsified asphalt and aggregate chips used for chip seal construction plays a large role in determining the success of the treatment. When too much emulsified asphalt is used, the aggregate becomes inundated and flushing occurs. If too little emulsified asphalt is used, the aggregate dislodges under traffic and windshield damage and flushing occurs. When too much aggregate is used, the excess aggregate can break windshields and dislodge already embedded aggregate resulting in flushing. If too little aggregate is used, emulsified asphalt sticks to rollers that dislodge aggregate, and flushing occurs. Too little emulsion can also result in major snowplow damage to the Chip seal. The correct quantity of aggregate and emulsified asphalt should be determined prior to construction using the design procedure described below and by AASHTO PP 82-16.

## 3.1 Aggregate Chip Application Rate Determination

This design procedure used in AASHTO PP 82-16 assumes the completed chip seal will consist of a layer of emulsified asphalt (eventually the residual asphalt) overlaid by a single layer of aggregate with the layer thickness one aggregate thick. The aggregate application rate is determined in the laboratory utilizing the method shown below.

The method to determine application rate consists of fabricating a board measuring three feet square. Three quarter inch thick particle board works well for this. The attach 1-inch by 2-inch wood strips to the edge of the particle board to create a raised edge. Weigh the completed board and record the weight in pounds. Place the aggregate to be used on the project on the board. Try to fit as much aggregate on the board within the confines of the edging as possible and push the chips against the edge of the board until they start piling up. Place as many chips as possible onto the board until every gap is filled. The aggregate should not overlap each other and should be only one stone thick. Reweigh the board containing the aggregate in pounds. Subtract the weight of the empty board from the weight of the board with aggregate. This is the application rate of aggregate to be used on the chip seal in pounds per square yard. Record this application rate as Q. (The application rate will vary depending on the density, gradation, shape, and crushed content of the chips but should be no less than 10 pounds and no greater than 40 pounds).

## 3.2 Emulsified Asphalt Application Rate Determination

The emulsified asphalt application rate is estimated by calculating the amount of asphalt to fill the voids between the aggregate to a specific embedment depth. Several engineered methods have been used in the past such as the McLeod Method and the Modified Kearby Method. The one illustrated below is the AASHTO Design Practice PP 82-16, which is based on the Kearby method (Epps, et al):

$$A = \{5.61\ e\ [1.33Q/W][1-(W/(62.4G))]\ T + V\}/\ R$$

Where the terms are as follows,

A = Emulsified asphalt application rate, gallons per square yard

e = Percent embedment depth of aggregate, expressed as a decimal

Q = Application rate of aggregate from Board Test, in pounds per square yard

W = Dry loose unit weight of aggregate, pounds per cubic foot (see AASHTO T 19)

G = Dry Bulk Specific gravity of aggregate (see AASHTO T 84 and T 85)

T = Traffic Correction Factor, Table 2

V = Pavement Surface Correction Factor, Table 3

R = Emulsified asphalt residue, expressed as a decimal

There are a lot of terms in this equation and it looks complicated. It is not. The only laboratory measurements needed are Q, W and G.

The result of the calculation above is the estimated emulsified asphalt design application rate. This design application rate is the best estimate of how much emulsified asphalt should be applied prior to doing it. However, this may change during construction if the appearance of the application is not acceptable. How this is determined will be described in the chapter on construction.

***Table 2: Traffic Correction Factor, T***

| Chip Seal Class | I | | | II | | III |
|---|---|---|---|---|---|---|
| AADT > | <100 | 100–250 | 251–500 | 501–1000 | 1001–5000 | >5000 |
| Traffic Correction Factor, *T* > | 1.20 | 1.15 | 1.10 | 1.05 | 1.00 | [1] |

[1]Greater than 5000 AADT has not been evaluated sufficiently to develop a recommended traffic correction

***Table 3: Substrate Surface Condition, V***

| Existing Surface Condition | Correction Factor, V, gal/yd$^2$ |
|---|---|
| Flushed-bleeding [a] | -0.06 |
| Smooth, non-porous [a] | -0.03 |
| Slightly porous, slightly oxidized | 0.00 |
| Slightly pocked, porous, oxidized [b] | +0.03 |
| Badly pocked, porous, oxidized [b] | +0.06 |

[a] A quantitative method using the Ball Penetration Test has also been reported in NCHRP Report 680 (see Appendix A).

[b] A quantitative method using the Sand Patch Test has also been reported in NCHRP Report 680.

# 4.0 Preconstruction

## 4.1 Introduction

Before a chip seal can be constructed there are certain factors that must be known about the pavement upon which the new seal will be placed. These include selecting the appropriate: pavement, aggregate and emulsified asphalt.

## 4.2 Selecting the Appropriate Pavement

Chip seals are most effective when applied to pavements with limited distress ideally, those that are rated in good condition. This means cracking is minor with widths no greater than 1/4inch, rutting is no greater than 3/8-inch, and structural distress is isolated with low severity fatigue. However, many times cracking is more severe than this, rutting is more serious and multiple patches are necessary to repair extensive fatigue cracking and chip seals are often used in these environments, as well. The user must be aware that the worse the condition of the existing pavement, the shorter the life cycle of the new chip seal will be. Examples of good candidates were shown earlier (Chapter 2), and examples of poor candidates are shown below:


***Figure 12: Examples of Pavements Not Acceptable for Chip Seals***

### 4.2.1 Evaluating the Existing Pavement Surface

The condition of the existing pavement surface can affect performance of the chip seal if certain issues are not considered. These are texture of the pavement surface, resistance of the pavement surface to penetration of the aggregate under traffic and variability of the pavement surface along the alignment.

### 4.2.2 Substrate Texture

The texture of the existing pavement must be known prior to chip sealing so that an adjustment can be made to the emulsified asphalt design application rate. The texture of the pavement can be measured using the sand patch test (ASTM E965) or other acceptable tests to obtain the texture depth in millimeters as shown in Figure 13. The adjustment to the emulsified asphalt design application rate can then be applied following the procedure described in the design section of this document. Note that this adjustment is for the asphalt residue. Therefore, the amount of emulsified asphalt applied must be back calculated from the asphalt residue content.

***Figure 13: Sand Patch Test Method***

### 4.2.3 Penetration of Aggregate into Substrate

The existing pavement can be tested using the ball penetration test, to determine if the aggregate is likely to penetrate the existing pavement after trafficking and to what level as shown in Figure 14 and described in Appendix A. If penetration is observed, adjustment to the emulsified asphalt application rate is required as described in the design section of this document.


*Figure 14: Ball Penetration Test*

#### 4.2.4 Variability of Pavement Surface

The surface of the existing pavement affects the emulsified asphalt application rate. Therefore, if the surface varies along the alignment, the application rate must change to match these conditions. A thorough map should be made indicating where materials application rates should change in accordance with the changing substrate conditions. These changes are relatively easy to communicate to equipment operators by painting on the pavement surface when application rates vary, prior to spraying.

#### 4.2.5 Laboratory Tests

Certain tests should be performed on the materials before construction begins. These tests are intended to determine: 1) the suitability of the materials and 2) the properties needed for design. Section 2.2 of this document describes these properties. The tests are also included in AASHTO MP 27-16.

#### 4.2.6 Pavement Preparation

The existing pavement should be structurally sound before chip sealing. Areas demonstrating structural failure (alligator cracking), potholes etc. should be patched the full depth of the pavement section using hot mix asphalt before commencing chip seal operations. The surface of these patched areas should be sprayed with a light application of slow setting emulsified asphalt (or other acceptable emulsified asphalt) typically diluted 1:1 with water at the rate of 0.10 gallons per square yard or undiluted at the rate of 0.05 gallons per square yard and allowed to cure thoroughly before chip sealing. Failure to apply a light seal to the surface of the patch may allow the new chip seal binder to be absorbed into the surface of the new patch reducing the amount of binder available to retain the aggregate.

Prior to the commencement of chip seal operations, and after the removal of lane striping (e.g. thermoplastic), the existing pavement should be thoroughly cleaned of vegetation, loose aggregate, soil and debris. Dust and debris on the surface should be removed by power brooms. Vacuum brooms should be used in urban areas, so that surface contaminants are not spread onto adjacent properties. Kick brooms are acceptable for use in rural areas when spreading debris onto shoulders or adjacent properties will not cause conflicts with property owners. Immediately prior to applying the chip seal, the moisture content at the surface of the existing pavement should be damp to dry. A damp surface is acceptable if moisture is present only in surface aggregate voids and not as free moisture between aggregates. The appearance of a damp pavement should not be glossy but should have a dull appearance.

## 4.3 Preconstruction Meeting

Coordinate a preconstruction meeting prior to construction with the engineer to discuss the following topics:

- construction process
- quality control plan, required to be submitted
- mix design, required to be submitted
- materials control
- materials measurement
- equipment calibration, required to be submitted
- traffic control plan
- equipment/process overview
- inspection
- test strip
- unique project conditions
- project documentation
- expectations

These items are discussed in more detail in the construction guide specifications in Appendix B.

## 4.4 Stockpile Management

Selection of the stockpile area is critical to keep the aggregate from being contaminated from debris or unwanted materials. The floor of the stockpile should be smooth, level and free of sod or other contaminants. It is preferred to use previous stockpile areas to reduce aggregate stockpile waste. Place the aggregate in the stockpile to minimize (or prevent) segregation. Segregation is the separation of the different sized aggregate particles. Segregation results in one area of the stockpile containing only the coarser particles and another area containing only finer particles. The best technique to minimize segregation is to dump the subsequent truckloads of aggregate adjacent to the previous pile, thus keeping the larger particles from rolling. Never place stockpiles in a high cone shaped heap, as segregation is very likely to occur.

***Figure 15: Example of High Stockpile***

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.

Use techniques such as one-dump high and benching to build proper stockpiles. When loading material, the loader operator should keep the bucket a minimum of 3 inches from the bottom of the stockpile to minimize contamination.

***Figure 16: Preferred Stockpile Height***



***Figure 17: Loading from Stockpile onto Trucks***

## 4.5 Notification

Public notification about the project can yield positive results for the traveling public, the agency, and the contractor performing the work. It is recommended that the public receive notification and information about the project in both the early and final stage.

The early stage can be implemented by the agency itself and includes the use of local newspapers, radio, television, and agency websites. This process should take place a minimum of a few weeks prior to project start up.

The final stage of notification will more than likely be performed by the contractor and should include a 24-hour notice delivered door to door to those who will be affected by the project. It is important to note that performing a thorough notification will minimize the potential issues that come with an uninformed public.

# 5.0 Equipment

## 5.1 Introduction

There are several types of equipment that are required for chip sealing. They are: 1) asphalt distributor, 2) aggregate spreader, 3) rollers, 4) brooms, 5) haul trucks and 6) front-end loaders. This document assumes the reader has some knowledge about the equipment and how they are used. However, the reader may not be as familiar with the calibration of the asphalt distributor or the aggregate spreader. Calibration is very important to assure the application rate of emulsified asphalt and aggregate applied to the pavement is correct. Although many modern asphalt distributors and aggregate spreaders are computer controlled, calibration is required to verify that the computer controls are delivering the actual flow rates. These calibration checks should be a part of the QA process.

## 5.2 Asphalt Distributor Calibration

The asphalt distributor applies emulsified asphalt to the pavement surface as shown in Figure 18. This must be done uniformly both transverse and longitudinal to the centerline of the pavement. The transverse application is only uniform if all the nozzles in the spray bar are the same size, are flowing at the same rate, are oriented the same direction and are the same distance above the pavement. ASTM D-2995 “Estimating Application Rate of Bituminous Distributors” is considered acceptable to calibrate the distributor in most parts of the United States.

***Figure 18: Typical Asphalt Distributor***

An exception to uniform nozzle size across the spray bar is when lower application rates are desired in the wheel paths. In this case, smaller nozzles are inserted in the spray bar where emulsified asphalt application rate is to be reduced as shown in Figure 19.

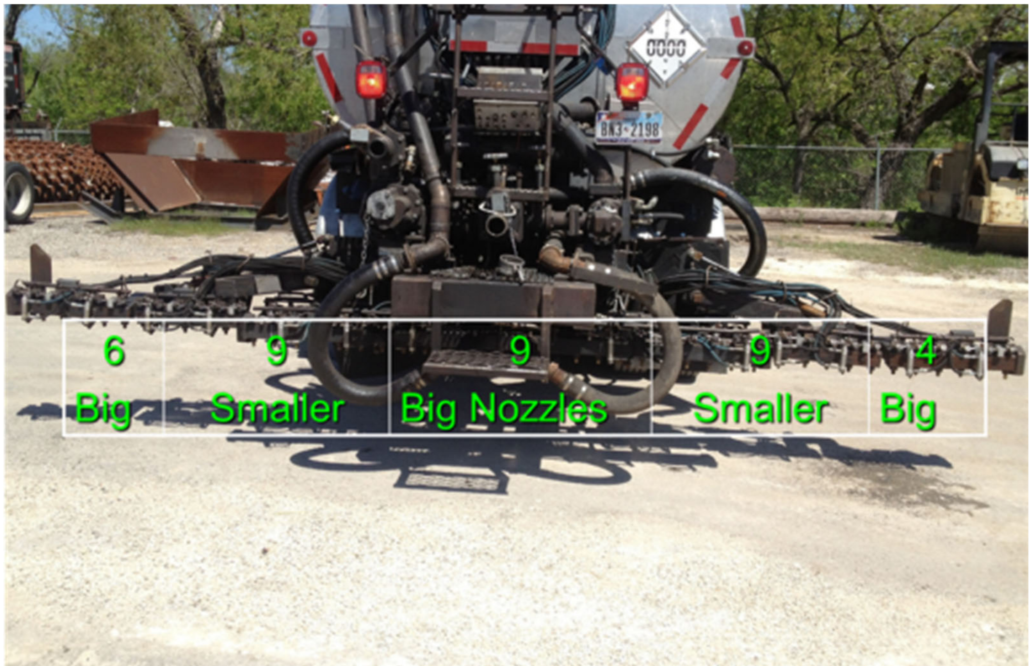


*Figure 19: Variable Spray Set-up, Texas DOT*

### 5.2.1 Nozzle Angle

The next step in calibrating the asphalt distributor is adjustment of the spray bar nozzle angles. Each nozzle has a slot cut across the face of the nozzle. When the nozzle is threaded into the spray bar, the slot should be positioned at an angle of 15 to 30 degrees to the axis of the spray bar as shown in Figure 20 or as recommended by the manufacturer.

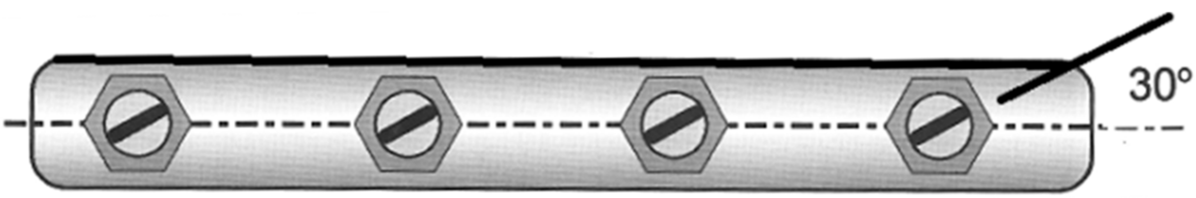


*Figure 20: Spray Bar Nozzle Orientation in Spray Bar*

The angle the nozzles are positioned should be adjusted using the special wrench supplied with the asphalt distributor as shown in Figure 21.

*Figure 21: Adjusting Nozzle Angle with Nozzle Wrench*

However, in cases where this wrench is unavailable, a wrench that fits the hexagonal nozzle will suffice but the angle will have to be judged visually. All nozzles fitted to the spray bar should be full fan nozzles except for the right and left edge nozzles. These nozzles should be half fan nozzles adjusted so the spray from the nozzle remains to the inside of the spray bar.

### 5.2.2 Spray Bar Height

The next step in calibrating the asphalt distributor is adjustment of the spray bar height. If the bar is too high, excess emulsified asphalt will form longitudinal ridges on the pavement, sometimes referred to as 'roping' as shown in Figures 22 and 23.

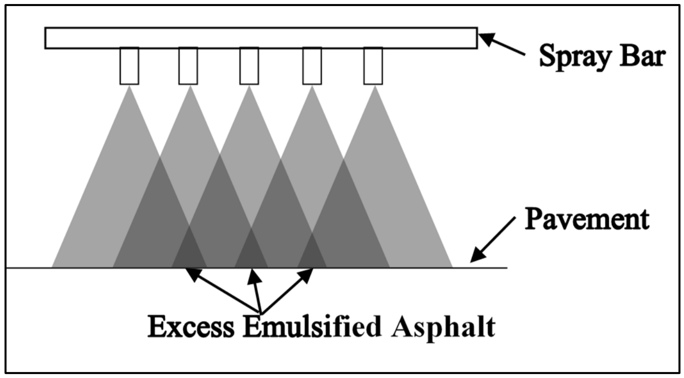


*Figure 22: Streaks Caused by Spray Bar Too High for Double Overlap*

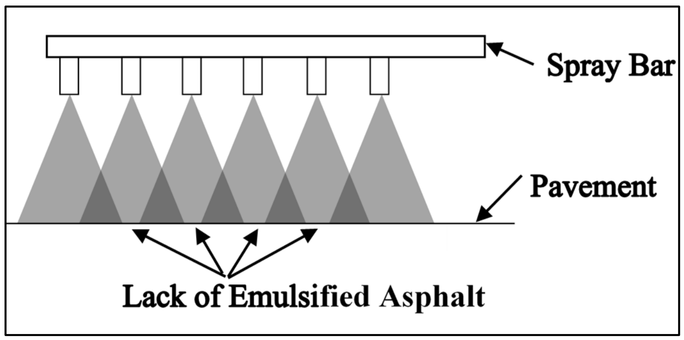


*Figure 23: Streaks Caused by Spray Bar Too Low for Double Overlap*

Therefore, to obtain a uniform, even application of emulsified asphalt, the bar must be adjusted to the correct height. This adjustment process is accomplished by shutting off nozzles to determine where the spray pattern contacts the pavement as shown in Figures 24 and 25. Every other nozzle should be turned off for a double lap application and two nozzles should be turned off for every one that is left on for a triple lap application. The asphalt distributor operator should spray emulsified asphalt onto the pavement surface for as short an interval as possible while an observer watches where the emulsified asphalt hits the pavement from each nozzle left open. If the emulsified asphalt overlaps for a double lap application, the bar is too high, as shown in the photo in Figure 26. If there is a gap between the emulsified asphalt applications, the bar is too low. Note that as the asphalt distributor empties during spraying, the bar height will rise. However, this is not usually enough to cause significant streaking and does not justify adjustment of the spray bar height.

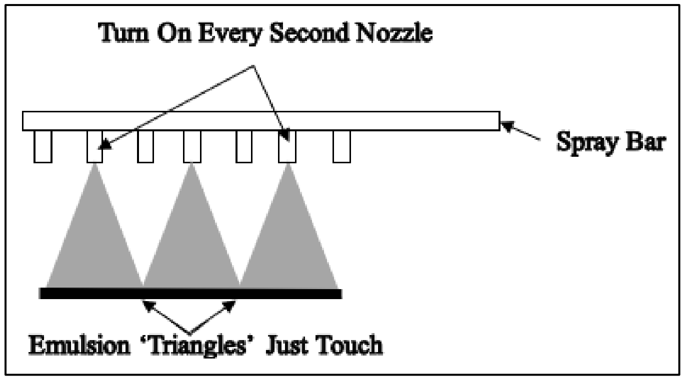


*Figure 24: Obtaining No Streaking for Double Lap Application*

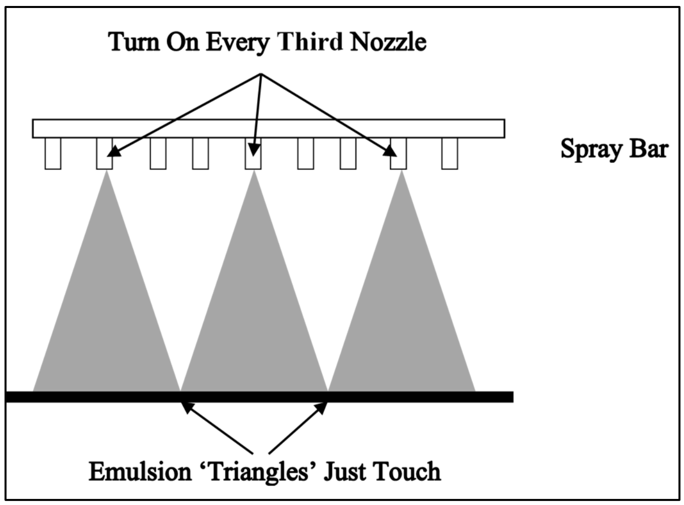


*Figure 25: Obtaining No Streaking for Triple Lap Application*


*Figure 26: Photo of Spray Bar Set Too Low for No Overlap of Nozzles*

### 5.2.3 Transverse Flow Rate

Nozzle size should first be checked. This is done by measuring the width of the slot in the nozzle and by measuring the orifice diameter. Also, some nozzles are labeled by the manufacturer. E. D. Etnyre and other manufacturers supply a list of nozzles describing which nozzles should be used for various application rates. (Figure 27).

**Etnyre Spray Bar Nozzles**
with BearCat and Rosco Equivalents


| Ref. | Part No. | Description | Application Gallons Per Square Yard | Application (Metric) Liters Per Square Meter | US Flow Gallons Per Minute Per Foot | BearCat Equivalent | Rosco Equivalent |
|---|---|---|---|---|---|---|---|
| 1 | 3353788<br>3351013*<br>3354904 | V Slot Tack Nozzle 1/8" Rifle Bored<br>V Slot Tack Nozzle 1/16" Coin Slot<br>V Slot Tack Nozzle 1/8" Counterbored | .05 – .20<br>.05 – .20<br>.05 – .20 | .23 – 0.91<br>.23 – 0.91<br>.23 – 0.91 | 3.0 – 4.5<br>3.0 – 4.5<br>3.0 – 4.5 | 1 | 0 |
| 2 | 3351008 | S36-4 V Slot | .10 – .35 | .45 – 1.58 | 4.0 to 7.5 | | |
| 3 | 3351009 | S36-5 V Slot | .18 – .45 | .81 – 2.04 | 7.0 to 10.0 | | |
| 4 | 3352368 | Multi-Material V Slot | .15 – .40 | .68 – 1.81 | 6.0 to 9.0 | 2 | |
| 5 | 3351015 | 3/32" Coin Slot | .15 – .40 | .68 – 1.81 | 6.0 to 9.0 | | |
| 6 | 3352204 | Multi-Material V Slot | .35 – .95 | 1.58 – 4.30 | 12.0 to 21.0 | 4 | 2 |
| 7 | 3355154 | End Nozzle (use with 3352204 nozzle) | .35 – .95 | 1.58 – 4.30 | 12.0 to 21.0 | | |
| 8 | 3352205 | Multi-Material V Slot | .20 – .55 | .91 – 2.49 | 7.5 to 12.0 | 3 | 1 |
| 9 | 3352210 | End Nozzle (use with 3352205 nozzle) | .20 – .55 | .91 – 2.49 | 7.5 to 12.0 | | |
| 10 | 3351014 | 3/16" Coin Slot | .35 – .95 | 1.58 – 4.30 | 12.0 to 21.0 | | |
| 11 | 3351010 | 1/4" Coin Slot | .40 – 1.10 | 1.81 – 4.98 | 15.0 to 24.0 | | |

* Special Order

*Figure 27: Nozzle Sizes for Etnyre Asphalt Distributors*

The flow rate across the spray bar shall be uniform with each nozzle spraying within ±10 percent of the average flow rate. This is verified by measuring the width of the slot in the nozzle and by measuring the orifice diameter.

However, nozzles of the same apparent size have been measured with different flow rates. Therefore, it is recommended that all nozzles be checked for flow rate before the chip seal operations begin. This is easily accomplished by fabricating a flow apparatus (Martin, 1989). This apparatus consists of a pipe to which each nozzle can be fitted in turn to one end, and a water source fitted to the other end. The flow of water through each nozzle is measured by filling a 1-gal container in a measured period. This is done for each nozzle to be used on the project. If the flow rate of any of the nozzles is greater than plus or minus 10 percent of the average of all the nozzles to be used these nozzles shall be discarded or modified to flow within the 10 percent tolerance.

Determination of uniform lateral flow from the spray bar is determined by collecting a measured volume of emulsified asphalt in containers placed under each nozzle. This process is practical (Shuler 1991) using standard 6-inch by 12-inch concrete cylinder molds lined with one-gallon zip-lock freezer bags. The cylinder molds can be re-used, and the zip lock bags discarded appropriately with the contents as shown in Figure 28. This is in accordance with ASTM D 2995-99 and the TXDOT method.

***Figure 28: Photo of the Bucket Test Used by Texas DOT***

### 5.2.4 Longitudinal Flow Rate

Longitudinal calibration of the asphalt distributors is best accomplished by measuring the volume of the asphalt distributor before and after spraying enough emulsified asphalt to reduce the volume in the asphalt distributor from full to 70 to 90 percent empty.

The longitudinal flow rate must be measured with all nozzles inserted in the asphalt distributor bar. First, the quantity of emulsified asphalt in the truck must be determined. Although there is a volume indicator on the rear of most modern asphalt distributors, these are not calibrated in small enough increments to be of use for calibration and should not be used for this purpose. Instead, the dip stick supplied with the asphalt distributor must be used. This dip stick is usually carried on the top of the tank near the inspection hatch. Prior to spraying emulsified asphalt, take a volume reading with the dip stick as shown in Figure 29.

***Figure 29: Recording Initial Tank Volume with Dipstick***

Record this volume as ‘beginning volume’. Set up the truck and initialize the asphalt distributer’s computer (if equipped). Then spray the emulsified asphalt the required distance to reduce the volume 70 to 90 percent in the tank at the design application rate. Upon completion of the spraying, take a final computer reading and a second dip stick reading. Record this second dip stick reading as ‘ending volume’. Then subtract ‘ending volume’ from ‘beginning volume’ and record this as ‘volume used’. Determine the area of emulsified asphalt sprayed and divide the ‘volume used’ by the area sprayed in square yards, this is the gallons per square yard applied to the pavement. This value should then be compared to the asphalt distributor’s computer final volume reading to evaluate the accuracy of the computer. A correction factor may then be applied to the computer output, if needed, and used for the remainder of the day. Etnyre Manufacturing uses this method, and an example of what the dipstick looks like is shown in Figure 30.


***Figure 30: Close-up of Etnyre Dipstick***

This calibration should be accomplished each day. An example of this calibration is presented below:

Given: 1800-gallon capacity asphalt distributor
12-foot spray width
Trial spray distance = 3630 feet
0.32 gallon/yd$^2$ design spray rate
Dipstick reading beginning of spray = 1765 gallons
Dipstick reading end of spray = 265 gallons

Calculations

1. Check to see if enough volume sprayed. 1765-265=1500 gallons
   1500/1765 = 85 percent >70% and <90%. *OK, enough applied to be valid*
2. Calculate spray rate = 1500 gallons / (12 x 3630/9) = 0.31 gallons/yd$^2$

Therefore, decrease asphalt distributor speed, or recalibrate computer and re-check.

## 5.3 Aggregate Spreader Calibration

Various methods of calibrating this equipment have been used and the ASTM D 5624 procedure can be effective. However, a visual assessment of the lateral distribution of aggregate is a good place to start the process since non-uniform distribution can easily be seen. The veil of aggregate deposited on the pavement from the spreader box can be viewed easily from the front of the box with the spreader approaching the observer as shown in Figure 31. A lack of light coming through the aggregate indicates an excess of aggregate. Excess light means a lack of aggregate. In either case the machine should be stopped, the gates on the spreader contributing to the non-uniformity adjusted and the trial rerun. This procedure provides adjustment to the transverse spread rate. Another procedure to measure the amount of aggregate being deposited is ASTM D 5624, "Determining the Transverse Aggregate Spread Rate for Surface Treatment Applications."

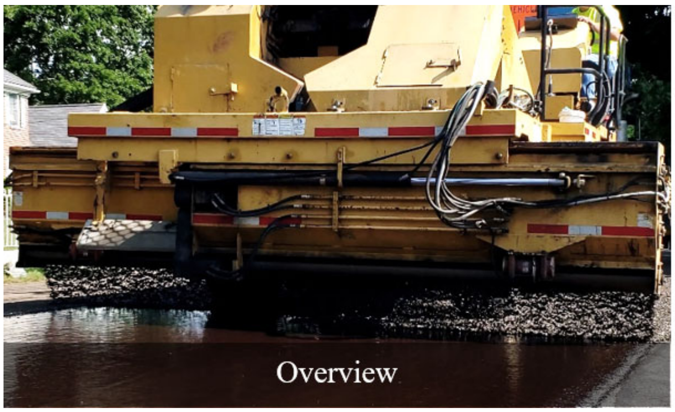



***Figure 31: Uniform Veil of Aggregate Looking from the front of the Spreader***

### 5.3.1 Longitudinal Spread Rate

The aggregate application rate should be very similar to the design application rate. This is a rate where immediately upon dropping the aggregate there should be a significant amount of emulsified asphalt showing through. In fact, the aggregate quantity deposited may seem somewhat inadequate. However, the rate should not be low such that a small decrease in rate would cause pick-up problems on rubber-tire rollers. Emulsified asphalt should be visible upon first dropping the aggregate. If all the emulsified asphalt is covered, there is an excess of aggregate and the rate should be reduced. No more than 10% in excess of the design quantity of aggregate should be applied.

Evaluating the amount of aggregate being placed after the rate is established is important. This provides a quantitative baseline for future work. The best method to accomplish this evaluation is by weighing the aggregate spreader before and after applying the aggregate and calculating the spread rate based on the area covered. This is often not practical. Therefore, a suitable alternative includes estimating the quantity of aggregate spread over a known area by knowing the weight of each transport truck supplying the spreader and dividing the estimated weight of aggregate spread by the area covered for that load. An example follows:

Given:

Trucks loading the aggregate spreader are 12-ton capacity tandem dumps
12-foot wide pavement
28 pounds per square yard design spread rate

Calculations:

1. Check Truck No. 1
   a. Load = 23,803 lbs
   b. Spreader distance = 640 feet
   c. Rate = 23,803/640x12/9 = 27.9 lbs/yd$^2$
2. Check Truck No. 2
   a. Load = 23,921 lbs
   b. Spreader distance = 634 feet
   c. Rate = 23,921/634 x 12/9 = 28.3 lbs/yd$^2$
3. Check Truck No. 3
   a. Load = 23,848 lbs
   b. Spreader distance = 639 feet
   c. Rate = 23,848/639 x 12/9 = 28.0 lbs/yd$^2$
4. Average Rate = (27.9 + 28.3 + 28.0) / 9 = 28.1 lbs/yd$^2$
5. No adjustment needed since measured rate is within 1 percent of design

Compensation for moisture on the aggregate must be considered when calibrating aggregate spreaders. The above example indicates no adjustment is needed since the measured spread rate is within 0.10 lbs/yd$^2$ of the design spread rate. However, if the aggregate had contained as much as 1.02 percent moisture that was unaccounted for, the application rate would have been too low.

# 6.0 Construction Operations

## 6.1 Introduction

Owner agencies wishing to construct emulsified asphalt chip seals are encouraged to utilize the latest edition of the AASHTO construction guide specification. This guide specification was developed so that any owner agency could tailor their specifications to meet their specific conditions. A working copy of the guide specification is included as Appendix B and was the latest version at the time of developing this document.

## 6.2 Environmental Conditions

The ideal ambient air temperature is 70ºF and rising with little or no wind and the pavement surface temperature not less than 60ºF. However, construction of many successful chip seals commenced before the ambient air temperature reached 70ºF with the forecast that the ambient air temperature was expected to be 70ºF and rising within 60 minutes after commencing work. In the northern, cooler climates, nearly all specifications recommend the ambient temperature be 60ºF and rising. Chip seals should only be applied when the high temperature for the following two days is forecast to be above 70ºF.

Wind speeds in excess of 20 mph transverse to the pavement alignment can disrupt the asphalt distributer spray fan patterns leading to an inconsistent application rate. This can also cause the spray fan to be blown onto opposing traffic on two lane facilities, therefore, chip seal operations should be avoided under these conditions.

Chip seal operations should not commence or proceed if there is a threat of rain. There is a possibility that a rainstorm could cause slick unsafe conditions and wash the emulsified asphalt onto concrete gutters or into roadside ditches.

Ambient air temperatures in excess of 110ºF with the sun shining or with moderate winds can cause emulsified asphalts to form a 'skin' on the surface and may prevent the emulsified asphalt beneath the 'skin' to adequately set. This situation may require aggregate to be spread closer to the asphalt distributor, so that the aggregate becomes properly embedded.

## 6.3 Emulsified Asphalt - Transverse Joint Application

Start and stop each emulsified asphalt application by spraying on top of 15 lb./yd$^2$ roofing paper or a similar dimensioned, equally heavy craft paper, placed transverse to the centerline of the pavement. This is shown in Figure 32. The asphalt distributor operator should position the spray bar at the rear of the paper on take-off. A calculation of approximately what distance the asphalt distributor will travel when approximately 10 percent (by volume) is in the tank should be performed, based on the emulsified asphalt application rate. A new strip of roofing paper can then be positioned transverse to the centerline at this location and weighted down with a shovel-full of aggregate at each end. The asphalt distributor operator should be instructed to stop spraying as the spray bar passes over the paper.


***Figure 32: Creating a Perfect Transverse Joint on 15 lb/yd² Roofing Paper***

## 6.4 Aggregate Application

Aggregate should be spread on to the surface immediately after the emulsified asphalt has been applied and before it begins to set. The speed of the asphalt distributor and the aggregate spreader are critical, as the aggregate could roll over in the fresh emulsified asphalt due to excess forward momentum when dropped from the aggregate spreader. The aggregate spreader should always be close behind the asphalt distributor.

The aggregate application rate should be slightly greater than the design application rate and should not exceed 10%. This is a rate where immediately upon dropping the aggregate, the appearance of the surface has some emulsified asphalt showing between the aggregate (salt and pepper look). There should be enough aggregate placed to prevent pickup by the rubber-tire rollers. If all the emulsified asphalt is covered before rolling, there is an excess of aggregate and the rate should be reduced. It is important to avoid spillage between the dump truck and the aggregate spreader; an example of spillage is shown in Figure 33.


***Figure 33: Aggregate Spillage Between the Truck and the Aggregate Spreader***

### 6.4.1 Check the Aggregate Quantity

Although a design is performed in the laboratory to determine the aggregate application rate, adjustments are sometimes needed in the field. This should be done during the first day of construction to make sure the aggregate application rate is just right. This is best done by observing the appearance of the aggregate after it has been dropped into the emulsified asphalt, but before rolling. The appearance should look like that shown in Figure 34. Notice that emulsified asphalt is visible between much of the aggregate which is good. If emulsified asphalt cannot be seen between the aggregate, the aggregate application rate is too high. Conversely, too much emulsified asphalt showing through between the aggregate will cause pickup on rubber tires.

***Figure 34: Appearance of Aggregate in Emulsified Asphalt Before Rolling***

## 6.5 Rolling

Pneumatic rollers tend to pick up aggregate due to the affinity of asphalt residue for rubber tires. However, these rollers also do not tend to crush aggregate in-situ as do steel wheeled rollers. Although lightweight steel rollers may provide a means of leveling the surface of a new chip seal after pneumatic rolling, caution must be taken to avoid breaking aggregate. Also, any rutting in the wheel paths will result in these areas not being adequately rolled due to bridging of the solid steel wheel. Although steel rollers are not recommended, some benefits may be derived from their use; but significant consequences, such as premature aggregate loss, resulting from potential crushing of aggregate and inadequate embedment must be recognized.

The number of rollers used to set and embed the aggregate in place is important. Rollers must be able to keep up with the aggregate spreader and still provide enough passes to embed the chips. The recommended speed of the rollers is 3 mph or less, if the rollers travel too fast, embedment will not be achieved. Therefore, the number of rollers used is a function of the roller speed, roller width, aggregate spreader speed, and the number of passes required to achieve embedment. The faster the aggregate spreader moves, the more rollers will be required to achieve embedment. This is because rollers need to ‘linger’ over an area to obtain the desired aggregate embedment

(Benson and Gallaway 1953, Elmore, et al 1995). Calculation of the number of rollers required has been analyzed based on this ‘linger’ time (Gransberg 2004) and the consensus formed is that the number of rollers should match the production of the asphalt distributor and aggregate spreader as follows:

$$N = 6.67\ P\ x / A$$

Where,

| | | |
|---|---|---|
| $N$ | = | number of rollers |
| $P$ | = | asphalt distributor speed, ft per minute (fpm) |
| $x$ | = | lane width, ft. |
| $A$ | = | area covered in one hour by rollers to get minimum ‘linger’, $yd^2$ |

Example: For an asphalt distributor traveling at 200 fpm and spraying 12 feet wide at a conservative coverage rate of 5000 square yards per hour, N = 3.32 or 4 rollers. Fewer rollers than this will mean rollers will not be able to keep up with the asphalt distributor and the aggregate spreader while maintaining the 5000 $yd^2$ / hr. rolling rate.  If they do keep up, it means the rollers are not spending enough’ linger’ time embedding aggregates because they are traveling too fast. Embedment rates of 50-70% are desirable. As shown in Figure 35, multiple rollers perform the task of embedding the aggregate very effectively.


***Figure 35:  Rolling the Chip Seal***

## 6.6 Sweeping After Rolling

Any loose excess aggregate remaining after rolling should be swept following the time guidelines as shown in Table 4. This can be accomplished using either vacuum brooms or rotary brooms as shown in Figure 36.

*Table 4: Sweeping Sequence*

| Chip Seal Class[a] | | |
|---|---|---|
| **I** | **II** | **III** |
| Within 24 hours after rolling | No later than the following morning | Before traffic is allowed without traffic control |

[a] Class I is less than 500 AADT, Class II is 501 to 5000 AADT, and Class III is greater than 5000 AADT.

Much care should be applied to this operation since significant damage can happen to the chip seal from poor brooming techniques (excessive brooming or too much downward pressure). Rotary brooms should use nylon bristles, not steel, to remove the excess aggregate without damaging the embedded aggregate in place.


*Figure 36: Typical Broom used for Seeping Chip Seals*

## 6.7 Application of a Fog Seal

The application of a fog seal to the surface of a newly constructed chip seal (Figure 37) is beneficial for three reasons. First, the emulsified asphalt fog seal changes the color of the surface creating a much sharper contrast between the pavement markings and the pavement surface which improves visibility. Second, the pavement appearance is that of a new asphalt surface rather than a gravel or crushed stone surface which helps with public relations. Third, the light application of emulsified asphalt binder helps aggregate retention. The application of the fog seal should not be applied prior to 24 hours after placing the chip seal or before the surface has been swept.


***Figure 37: Application of an Emulsified Asphalt Fog Seal***

## 6.8 Traffic Control

Traffic control plans and devices shall meet or exceed the minimum requirements of the Manual on Uniform Traffic Control Devices (MUTCD) and State and local agency requirements. Proper traffic control is essential to the safety and success of the chip seal operation. Traffic control should consider the following:

- Safety of the traveling public
    - Chip seal operations pose a potential hazard to the traveling public, as most of them do not understand the process and do not want to be inconvenienced. It can confuse travelers when the treatment sequence is spread out over a section of the road. Once travelers pass one part of the operation, they often believe it is finished only to run up on another grouping of workers. For this reason, a pilot car with flaggers on each end of the work zone is strongly recommended.
- Safety of the employees performing the work
    - The safety of the work crew and the traveling public is always of top priority. The chip seal process is fast moving and often spread out over a half mile on a road. Ensuring the safety of workers and the traveling public can therefore be challenging. Workers should always wear proper PPE that meet safety and reflective standards.
    - Chip sealing operations involve big pieces of equipment moving up and down the road near each other. The equipment travels in reverse as much as it does forward. Rollers must make multiple passes; this will require backing up over lanes just traveled. Soft or low shoulders can also be a potential problem for rollers if care is not taken when rolling the edge of the roadway. Workers must pay careful attention to their surroundings to avoid collisions. The haul trucks will have to back into the spreaders and be pulled down the road in reverse. The pinch point between the spreader and dump truck is a potential for injury so crew members should use extra caution around the hitch and tailgate of the haul truck.
    - Workers are also required to do hand work around intersection radii and narrow sections of cul-de-sacs where they could be hidden or not seen due to the

equipment. Good practices for worker safety include being aware of the potential accidents at the work site and maintaining awareness of the locations of each part of the equipment train. The crew's understanding of the sequence of the operation is very important to the safety and success of the job.

- Chip seal protection
    - A key component of the ultimate strength of the chip seal is it's curing on the pavement. Time must be allowed for the emulsion to break and for curing to begin before traffic is allowed back onto the completed section. Depending on the weather conditions, amount of traffic and type of seal, this curing time will vary. Traffic control must be maintained to prevent the motoring public from dislodging the aggregate before it has had time to cure. A pilot car should be used to help maintain speed of the motoring public and to keep them off the newly paved section of road while it is curing. (See Figure 38)
- Traffic control devices
    - Signing is required on each end of the work zone. Advanced signing advising "Road Construction Ahead," "Prepare to Stop," and "Flaggers Ahead," are required. Signing along the road being paved advising a temporary reduction in speed to 35 MPH with warnings of unmarked pavement and loose aggregate is also required.


***Figure 38: Dealing with Construction Traffic***

The time required before sweeping or opening to traffic on newly placed chip seal has been found to be related to the moisture content in the chip seal (Shuler et al 2011, Howard et al 2011). When 85 percent of the total moisture in the chip seal has dissipated, it is considered sufficiently cured to support controlled traffic or light sweeping. The remaining moisture can be determined by simply measuring the moisture in the aggregate during construction, adding this moisture content to the moisture content of the emulsified asphalt and measuring the moisture loss after constructing the chip seal over time. The time required for the chip seal to lose 85 percent of the total moisture varies, depending on several variables, including: total moisture of the chip seal, ambient temperature, pavement temperature, wind velocity, humidity, time of year and latitude which affects the solar angle, and shade. Because of these variables, time is not a good criterion for determining when to open a chip seal to traffic. The test procedure presented in NCHRP report 680 has been found to be an adequate indicator of the moisture loss during construction of the chip seal and, hence, a good estimator for when traffic can be returned to the new chip seal.

# 7.0 Quality Assurance

## 7.1 Introduction

Chip seal quality assurance is important to ensure desired performance. The following section describes procedures that should be followed to optimize the probability of success for a chip seal project.

AASHTO R 10 provides standard definitions for terms used in quality assurance procedures. QA is defined as all those planned and systematic actions taken by the Agency and Contractor to provide the necessary confidence that the procured material and workmanship will satisfy the quality requirements of the contract.

QA includes Quality Control (QC), Acceptance and Independent Assurance (IA).
QC is the system used by the Contractor to monitor, assess and adjust production and placement processes to ensure that the material and workmanship will meet the specified quality. QC is the responsibility of the Contractor.

Acceptance is the system used by the Agency/ Engineer to measure the degree of compliance of the quality of the materials and workmanship with the Contract requirements. Acceptance is the responsibility of the Agency/Engineer and will be conducted in accordance with these Specifications.

IA is an unbiased and independent system used to assess all sampling, testing and inspection procedures used for QA. IA is the responsibility of the Agency/Engineer and is conducted in accordance with these Specifications.

## 7.2 Quality Control (QC)

### 7.2.1 General

The chip seal contractor (the Contractor) shall establish, implement and maintain a QC program to control all equipment, materials, workmanship and processes during chip seal construction. The Contractor's QC program shall include preconstruction activities including chip seal design, site preparation, material handling and transportation, and stockpiling. The program shall include procedures required for sampling, testing, inspection, monitoring, documentation, and corrective action procedures during transport, stockpiling, placement and finishing operations. The program shall also include contractor qualifications and a list of contractor personnel for the project with a chain of responsibility.

A written Quality Control Plan shall be developed which details the Contractor's QC program that meets the requirements of these specifications. The QC Plan shall be contract specific and signed by the Contractor's representative. Chip seal construction shall not proceed without Agency acceptance of the QC Plan and QC personnel present on the job. Failure to comply with these provisions will result in shutdown of the operation until such time as the Contractor's operations are in compliance.

The following reference documents are important to ensure that the quality of the product meets expectations:

- **a.** AASHTO R 10 Standard Practice for Definition of Terms Related to Quality and Statistics as Used in Highway Construction
- **b.** AASHTO R 18 Standard Recommended Practice for Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
- **c.** AASHTO R 38 Standard Practice for Quality Assurance of Standard Manufactured Materials
- **d.** AASHTO R66 Standard Practice for Sampling Asphalt Materials
- **e.** AASHTO R77 Standard Practice for Certifying Suppliers of Emulsified Asphalt
- **f.** AASHTO M 140 Standard Specification for Emulsified Asphalt
- **g.** AASHTO M 208 Standard Specification for Cationic Emulsified Asphalt
- **h.** AASHTO M 316 Standard Specification for Polymer-Modified Emulsified Asphalt
- **i.** AASTHO T 11 Standard Method of Test for Materials Finer Than 75-micro m (No. 200) Sieve in Mineral Aggregates by Washing
- **j.** AASHTO T 19 Standard Method of Test for Bulk Density ("Unit Weight") and Voids in Aggregate
- **k.** AASHTO T 27 Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregate
- **l.** AASHTO T 44 Standard Method of Test for Solubility of Bituminous Materials
- **m.** AASHTO T 49 Standard Method of Test for Penetration of Asphalt Materials
- **n.** AASHTO T 51 Standard Method of Test for Ductility of Asphalt Materials
- **o.** AASHTO T 59 Standard Method of Test for Emulsified Asphalts
- **p.** AASHTO T 85 Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregate
- **q.** AASHTO T96 Standard Method of Test for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine (ASTM C 131-01)
- **r.** AASHTO T 104 Standard Method of Test for Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate
- **s.** AASHTO T 111 Standard Method of Test for Mineral Matter or Ash in Asphalt Materials
- **t.** AASHTO T 112 Standard Method of Test for Clay Lumps and Friable Particles in Aggregate
- **u.** AASHTO T 301 Standard Method of Test for Elastic Recovery Test of Asphalt Materials by Means of a Ductilometer
- **v.** AASHTO T 335 Standard Method of Test for Determining Percentage Fracture of Coarse Aggregate
- **w.** 23 CFR 637 Construction Inspection and Approval
- **x.** AASHTO T-350 Standard Method of Test for Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
- **y.** Federal Lands Highway (FLH) T 508 Flakiness Index Value

### 7.2.2 Definitions

The following definitions are important to the production and placement of chip seals.

- **a.** Agency – a state highway agency, other agency or owner responsible for the final acceptance of the project.
- **b.** Calibration – any calibration, standardization, check or verification as required by the test method or standard.
- **c.** Contractor – the prime contractor who has ultimate control of the project.
- **d.** Supplier – one who produces the final product materials (i.e. aggregate and emulsified asphalt) used on the project.
- **e.** Standard – any standard, specification, test method, practice, etc. utilized to achieve compliance with the contract.
- **f.** Testing Lab – the laboratory conducting quality control tests (contractor or supplier) and acceptance tests (agency).

### 7.2.3 Personnel

The following describe the responsibilities and requirements for QC personnel:

- **a.** Responsibilities and Requirement of QC Staff - at a minimum, provide the name of the person responsible for each position listed below, including their telephone number, email, and their qualifications/certifications.
  - I. QC Plan Manager. The person responsible for the execution of the QC Plan and liaison with the Agency. This person shall be on the job and have the authority to stop or suspend construction operations.
  - II. QC Technicians. The person(s) responsible for conducting QC tests and inspection to implement the QC Plan. QC Technicians shall have Level 2 Aggregate Testing certification from the American Concrete Institute (ACI), or other certification program approved by the agency
- **b.** Certified Contractor Staff - at a minimum, one crew member (job foreman or other with decision making authority) possessing a valid chip seal certification shall always be on the job while the chip seal is being constructed. The chip seal certification is administered by the National Center for Pavement Preservation (NCPP) on behalf of AASHTO TSP·2.

### 7.2.4 QC Testing Laboratories and Equipment

The following describes the requirements for testing labs and equipment:

- **a.** The Contractor shall provide the name of the agency approved lab for all tests within the relevant scope of testing.
- **b.** Testing and sampling equipment and measuring devices shall meet the requirements of the specified standards and test methods. The lab shall maintain records of the calibration and maintenance of all sampling, testing, and measuring equipment, and all documents required by the agency.
- **c.** Placement Equipment Calibration – prior to the commencement of work, the asphalt emulsion distributor and aggregate spreader shall be calibrated in the presence of the Agency representative utilizing the materials to be used on the project. Calibration will be performed consistent with procedures in FHWA-HIF-19-029, Chip Seal

Checklist, 2019.
https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19029.pdf

### 7.2.5 QC Activities

QC activities shall include monitoring, inspection, sampling and testing. The Contractor's QC activities shall cover all aspects that affect the quality of the materials and workmanship of the chip seal.

**a)** Component materials
**b)** Transportation material handling
**c)** Mix design by a qualified lab
**d)** Test strip construction and assessment
**e)** Placement and finishing
**f)** Performance
**g)** Review of material certifications supplied by vendors and suppliers.

The suggested QC activities and frequencies required are listed as shown in Tables 5 and 6 or per agency specific requirements. Aggregate samples will be taken at the project stockpile site using AASHTO R 90 Method B. Gradation test results should be provided within 24 hours. A material certification and certificate of compliance from the supplier shall be supplied with each delivery tanker. Emulsified asphalt samples will be taken at the point of delivery from the delivery tanker using AASHTO R 66 and shall be determined by either AASHTO T59 or agency approved method.

***Table 5: Suggested Aggregate QC Requirements***

| Process Control Test | Test Method | Suggested Minimum Frequency |
|---|---|---|
| Gradation | AASHTO T 27<br>AASHTO T 11 | Prior to construction for design, then once per day of placement or every change of source. |
| Unit Weight | AASHTO T 19 | Prior to construction for design, then every change of source. |
| Bulk Specific Gravity | AASHTO T 85 | Once, prior to construction for design, then every change of source. |
| L.A. Abrasion | AASHTO T 96 | Once, prior to construction for design, then every change of source. |
| Soundness Test | AASHTO T-104 | Once, prior to construction for design, then every change of source. |
| Aggregate Absorption | AASHTO T 85 | Once, prior to construction for design, then every change of source. |
| Deleterious Material | AASHTO T 112 | Once, prior to construction, then every change of source. |
| Fractured Faces | AASHTO T335 | Once, prior to construction, then every change of source. |
| Flakiness Index | FLH T 508 | Prior to construction for design, then every other day of placement or change of source. |
| Application Rate | Truckload Yield Check,<br>Tarp on Roadway | Once at startup each production day. |

*Table 6: Suggested Asphalt Emulsion QC Requirements*

| Tests on Emulsion | | |
|---|---|---|
| **Process Control Test** | **Test Method** | **Suggested Minimum Frequency** |
| Viscosity | AASHTO T 59 or T 382 | Once per 200 tons of material placed. |
| Temperature | N/A | Once delivery tanker. |
| Particle Charge | AASHTO T 59 | Prior to loading emulsion distributor |
| Demulsibility | AASHTO T 59 | Once per 200 tons of material placed. |
| Sieve | AASHTO T 59 | Once per 200 tons of material placed. |
| Storage Stability | AASHTO T 59 | Once per 200 tons of material placed. |
| Residue | AASHTO T 59 or R 78-16 | Once per 200 tons of material placed. |
| Application Rate | Computer Printout, Volumetric Measurement, Plate on Roadway | Once at startup each production day, then each 500 tons of aggregate placed. |
| **Tests on Residue** | | |
| **Process Control Test** | **Test Method** | **Suggested Minimum Frequency** |
| Ductility[1] | AASHTO T 51 | Once per 500 tons of material placed. |
| Elastic Recovery[1] | AASHTO T 301 | Once per 500 tons of material placed. |
| Penetration | AASHTO T 49 | Once per 200 tons of material placed. |
| Ash Content or Solubility | AASHTO T 111/T 44 | Once per 200 tons of material placed. |
| MSCR, Jnr, % Recovery[1] | AASHTO T 350 | Once per 500 tons of material placed. |

[1] **Where applicable**

### 7.2.6 Contractor's Quality Control Plan

The Contractor shall submit a written, signed QC Plan to the Agency for acceptance at least 15 days prior to placement. The QC Plan shall detail the Contractor's plans, policies, procedures and organization deemed necessary to measure and control materials, equipment, and the emulsified asphalt chip seal placement process.

The QC Plan shall be maintained to reflect the current status of the operations. Changes must be approved by the agency prior to implementation. At a minimum, the QC Plan shall detail the following:

a. **Scope of the QC Plan.** Reference all applicable specifications.
b. **QC Organization.** Include a QC organizational chart identifying all personnel responsible for implementing the QC Plan and how they integrate and communicate within the Contractor's management structure and the Agency. Include a list of QC

personnel with their names, qualifications, responsibilities, certifications, telephone number and e-mail address.

- **c. QC Testing Facilities and Equipment.** Include the location and qualifications of QC testing facilities, and a listing of all QC testing equipment with the frequency of calibration and verification.
- **d. Materials Control.** Include the sources of all materials used in construction of the chip seal. Describe stockpile management practices, including segregation mitigation, loading, and transport procedures.
- **e. QC Activities.** Describe QC activities deemed necessary to control all aspects of chip seal construction. Include the locations, methods, frequency and personnel responsible for conducting QC sampling, testing, and inspection. Identify lot/sublot sizes, sample identification system and sampling storage/retention procedures.
- **f. Chip Seal Placement and Workmanship.** Describe methods, equipment and materials for construction of the chip seal. Identify methods to ensure proper workmanship:
  - i. Equipment calibration for distributor and aggregate spreader
  - ii. Monitoring application rates
  - iii. Ensure proper spread patterns
    - a) Proper embedment without excessive or inadequate aggregate
    - b) Emulsion drilling or flushing
    - c) Longitudinal joint overlap
    - d) Transverse joints
  - iv. Rolling operations, proper number of passes and coverage
  - v. Sweeping operations and Schedule
  - vi. Method to control traffic
- **g. Documentation.** Describe testing procedures and determine when corrective action is required. The contractor will provide examples of reporting forms, production QC test results, daily production records, non-conformance reports, and document retention details.
- **h. Non-Conformance and Corrective Action.** Establish and maintain an effective and positive system for controlling non-conforming materials as indicated by inspection and test results. Investigate the cause of any non-conformance to prevent recurrence and take prompt corrective action to correct conditions that have resulted, or could result, in the incorporation of non-conforming materials into the work. All non-conforming materials shall be positively identified to prevent use and intermingling with conforming materials. Include procedures and personnel responsible for directing corrective action including suspension of work and disposal or reworking of non-conforming materials. Detail how the results of QC inspections and tests will be used to determine corrective actions, define rules to gauge when a process is out of control and associated corrective action to be taken. At minimum establish corrective action procedures for each control requirement listed above.

### 7.2.7 Records and Documentation

The Contractor shall maintain complete records of all QC tests and inspections.

All QC test results shall be submitted to the Agency within 24 hours or upon request. A material certification shall be submitted from each supplier for each batch of material delivered to the jobsite, including test results. The QC records shall always be available to the Agency and shall be retained for the life of the contract. The Contractor's documentation procedures will be subject to approval by the Agency prior to the start of work, and to compliance checks by the Agency during the progress of the work.

The QC records shall contain all test and inspection reports, forms and checklists, equipment calibrations, supplier material certificates, and non-conformance and corrective action reports.

The QC records shall indicate the nature and number of observations made, the number and type of deficiencies found, the quantities conforming and non-conforming, and the nature of corrective action taken as appropriate for materials as well as workmanship.

### 7.2.8 Compliance with Specifications

At the conclusion of the project, the Contractor shall attest in writing to the Agency that the chip seal has been constructed in accordance with and meets the requirements of the specifications.

## 7.3 Agency Acceptance

### 7.3.1 General

As the owner of the final chip seal, the Agency must ensure the contractor has constructed the project in accordance with the specifications. The Agency will conduct acceptance sampling, testing, and inspections consistent with AASHTO R 10. The agency may conduct verification testing if QC results are used for Acceptance.

### 7.3.2 Acceptance Activities

Typical acceptance activities should include the following:

- **a.** Assure the Contractor has followed the approved QC Plan.
- **b.** Materials – monitor all contractor QC testing.
- **c.** Agency to sample and test:
    - i. Aggregate – Gradation, moisture content, and deleterious materials, once per day or at the discretion of the Agency.
    - ii. Emulsified Asphalt – Once per project or at the discretion of the Agency.

  Note: Actual frequency and lot size will be per each Agency's Frequency Guide Schedules for Verification, Sampling and Testing.
- **d.** Traffic control conforms to plans and specifications and complies with the Manual on Uniform Traffic Control Devices.
- **e.** Surface Preparation – Monitor and approve sweeping methods, verify surface is clean and dry, inlets and manhole covers are protected.
- **f.** Calibration – Witness the calibration of the asphalt distributor and aggregate spreader.

- **g.** Asphalt Distributor – Verify equipment has been calibrated and is in proper operating condition. Monitor for an even application of material.
- **h.** Aggregate Spreader – Verify equipment has been calibrated and is in proper operating condition. Monitor for an even application of material. Ensure spreader is proper distance from asphalt distributor.
- **i.** Pneumatic Rollers – Verify equipment is in proper operation condition and rollers are positioned in echelon so the entire width of the pavement lane is covered. Roll three complete passes over the aggregate, with one pass defined as the roller moving over the aggregate in either direction.
- **j.** Sweepers – Verify equipment is in proper operating condition. Ensure loose material is removed without damaging the fresh chip seal.
- **k.** Application Rates – Monitor and verify correct application rates of emulsified asphalt and cover aggregate.
- **l.** Production Inspection - to be completed after final sweeping to check for unacceptable conditions, such as:
    - i. Bleeding/flushing
    - ii. Raveling/aggregate loss
    - iii. Crushed/broken aggregate
    - iv. Excessive longitudinal joint overlap
    - v. Transverse joint overlap

## 7.4 Independent Assurance Program (IA)

The IA program shall follow Tech Brief: Independent Assurance Programs, FHWA-HIF-12-001 2011 and shall be the responsibility of the Agency or Owner. The IA Program consists of activities that are an unbiased and independent evaluation of all the observations, sampling and testing procedures and equipment used in the acceptance program. The IA Program is staffed by qualified agency personnel or an accredited laboratory not involved with acceptance testing. It ensures the sampling and testing is performed correctly and the testing equipment used in the program is operating correctly and remains calibrated. It involves a separate and distinct schedule of sampling, testing, and observation. The results of the IA testing shall not be used for material acceptance.

# 8.0 Performance

## 8.1 Less Than One Year

The very early life performance of a chip seal is judged based on aggregate loss and bleeding of the chip seal. Aggregate loss can happen as soon as a few hours after removing traffic control. If this loss is greater than 10 percent of the aggregate quantity applied (assuming a one-layer aggregate application) then the performance is not acceptable and an investigation to determine the cause should be conducted. Often, early failures of this type are due to higher than appropriate aggregate application rates or lower than appropriate emulsified asphalt application rates, or both. Early aggregate loss can also be due to excess dust, fine aggregate particles, or a change in aggregate gradation that was not accounted for by an appropriate change in emulsified asphalt application rate. Unexpected low temperatures or wet weather can cause early aggregate loss, as well as removal of traffic control before adequate residue adhesion has developed as shown in Figure 39.

***Figure 39: Aggregate Loss Problems***

Bleeding occurs because of high emulsified asphalt application rate or embedment of aggregate in the substrate, or both. Streaking is caused by the spray bar on the asphalt distributor being either too high or too low. Correction after construction is not possible without the application of another seal. Other typical problems associated with poor construction are shown in Figure 40.


***Figure 40: Typical Early Problems with Chip Seals***

## 8.2 Greater Than One Year

Performance after one year can be measured using texture depth. Some specifications (Austroads 2006) limit design life based on texture of less than 0.035 in. (0.9 mm) on pavements with speeds greater than 43 miles per hour. The relationship shown below has been proposed (Gransberg and James 2005) as a means of predicting approximate texture after one year:

$$Td_1 = 0.07\ ALD \log Yd + 0.9$$

where,

$Td_1$ = texture depth in 1 year (mm);
$Yd$ = design life in years; and
$ALD$ = average least dimension of the aggregate

Texture depth is determined using the sand patch test. If texture is less than the predicted value, the chip seal should be monitored to determine if a loss of texture beyond the limits that can be tolerated is expected. Figure 41 shows what should be expected in a completed project.

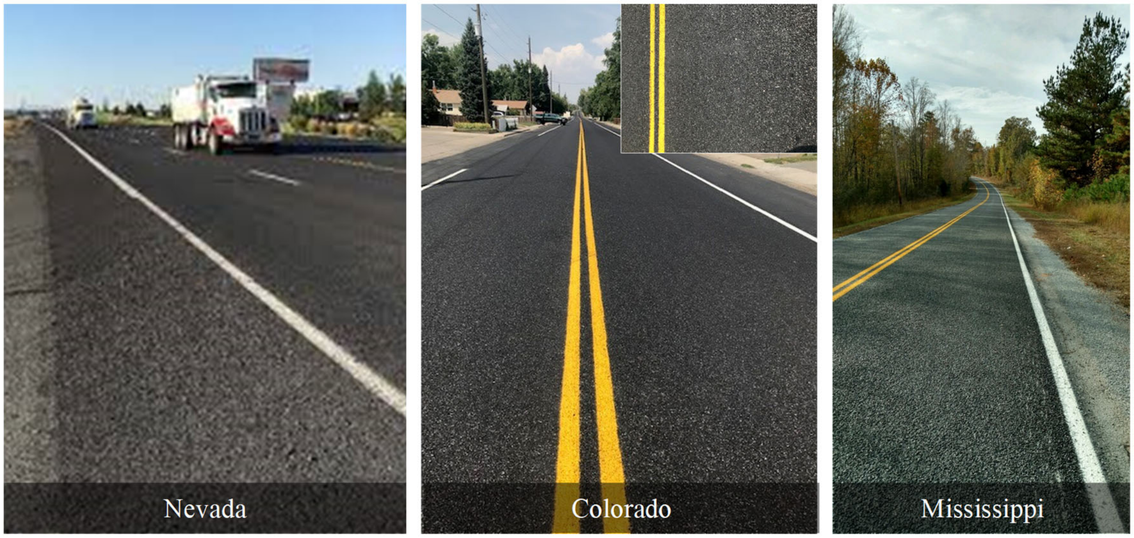


*Figure 41: Good Completed Chip Seals Projects*

# 9.0 Chip Seal Checklists

Because of the complex nature of chip seals, the following checklists have been developed to assist those practicing chip seal technology to make sure all the 'boxes are checked'. The FHWA 2019 checklist for chip seals includes information on items to check prior to and during construction as well as some troubleshooting ideas by identifying common problems and possible solutions. The link to this list is**:**

https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19029.pdf

## 9.1 FHWA Best Practices Check List

This check list was created to guide agency personnel on the use of chip seals during the placement of chip seals. It includes information on the following:

1. Preliminary responsibilities
    a. Document review
    b. Project review
    c. Materials checks
2. Pre-application inspection responsibilities
    a. Pavement surface preparation
    b. Equipment inspections
    c. Weather requirements
    d. Determining application rates
    e. Checking application rates
    f. Traffic control
3. Project inspection responsibilities
    a. Asphalt application
    b. Aggregate application
    c. Truck operation
    d. Rolling
    e. Longitudinal joints
    f. Transverse joints
    g. Rolling
    h. Sweeping
    i. Opening to traffic
    j. Cleanup

Table 7 summarizes the items to check under preliminary responsibilities.

*Table 7: Preliminary responsibilities*

| Item | Documents to check |
|---|---|
| Document review | • Project specifications<br>• Traffic control plan<br>• Construction manual<br>• Agency requirements<br>• Safety data sheets<br>• Applicable OSHA requirements<br>• Certification requirements<br>• Contractor QC plan |
| Project review | • Verify the project is a good candidate for a chip seal<br>o Limit rutting to less than 3/8 inch<br>o Chip seals should not be used on pavements with structural distress<br>o Limit the ADT and % trucks to the agency requirement for chip seals<br>o Determined is crack sealing is necessary<br>o Determine if flushing or bleeding exists |
| Material checks | • The emulsified asphalt is compatible with the aggregate<br>• The emulsified asphalt and aggregate are from approved sources<br>• The emulsified asphalt is sampled and submitted for testing<br>• The aggregate stockpile is sampled and submitted for testing<br>• The aggregate is close to the same size<br>• The aggregate is clean and free of excess fines<br>• The emulsified asphalt application temperature is specified |

Table 8 provides a summary of the pre-application inspection responsibilities while Table 9 provides a summary of the project inspection responsibilities.

*Table 8: Pre-application responsibilities*

| Item | Responsibilities |
|---|---|
| Pavement surface preparation | • Surface has been swept clean and is dry<br>• All distresses have been repaired. Asphalt patches placed within 6 months have been fog sealed<br>• Cracks wider than ¼ have been filled or sealed<br>• Raised pavement markings and thermoplastic markings have been removed<br>• Grass and weeds have been removed or treated with a herbicide<br>• Utility castings have been protected and a marker placed on it to locate it after construction<br>• Review the exiting surface for possible overspray from working irrigation systems during construction |
| Equipment inspections: distributor, aggregate spreader, haul trucks, rollers, and sweepers | • All equipment meets manufacturer's standards<br>• All equipment is free of any fluid leaks<br>• All equipment is clean and calibrated<br>• More details can be found in the FHWA check list |
| Weather requirements | • Follow the range of dates established by the agency for placing chip seals<br>• Construct a chip seal only during daylight hours<br>• Air and surface temperatures have been checked at the coldest location on the project<br>• Suspend construction if the pavement temperature exceeds 140F<br>• Construct chip seals only when the chance for rain is zero or very low |

| | |
|---|---|
| | • High wind speeds can create problems with application of emulsified asphalt<br>• Air and surface temperatures, humidity and wind will affect how long the emulsified asphalt takes to break |
| Determining rates | • Agency specifications and standards are followed<br>• Chip seal design has been performed and initial application rates are set<br>• Emulsified asphalt application rates are generally increased on oxidized and porous pavements and decreased on roads with asphalt rich surfaces<br>• Application rates are generally increased on roads with low traffic volumes and decreased on high volume roads<br>• Aggregate should be applied at a sufficient rate so that equipment tires do not pick up asphalt as the aggregate is placed |
| Checking application rates | • Method A- For calibration using a pan or non-woven geotextile.<br>• Method B-for random checks by measuring of a known area, applying the emulsified asphalt and aggregate, and determining the gallons applied of emulsified asphalt and weight of the aggregate<br>• Details for these methods are included in the FHWA check list |
| Traffic control | • Verify the traffic control plans conform to the requirements of the Manual on Uniform Traffic Control Devices (MUTCD)<br>• Verify the personnel are trained and qualified in accordance with contract documents and agency requirements<br>• Ensure traffic is maintained appropriately to avoid unnecessary delay |

***Table 9: Project inspection responsibilities***

| Item | Responsibility |
|---|---|
| Emulsified asphalt application | • Ample approved distributors are available for continuous operation<br>• Kraft paper or roofing felt is used to start and stop application for straight transverse joints<br>• Emulsified asphalt temperature is within the required application range<br>• Application looks uniform and free of streaking<br>• A check is made of plugged or dripping nozzles<br>• Random checks of application rates are performed<br>• The distributor speed is match to the aggregate spreader speed<br>• The distributor is stopped if any problems are observed |
| Aggregate application | • Enough trucks are available to keep a steady supply of aggregate for the spreader<br>• Aggregate should be applied at a rate to ensure there is no pickup of asphalt on the equipment tires prior to rolling<br>• The aggregate spreader follows closely behind the asphalt distributor<br>• The aggregate spreader travels slowly enough to avoid aggregate from rolling when they hit the surface<br>• The aggregate is in a surface damp condition<br>• The application is stopped if the asphalt covers the top of the aggregate or if aggregate streaks are detected<br>• The application of the aggregate is uniform<br>• The percentage of aggregate embedment is checked, and the emulsified asphalt application rate adjusted as necessary |
| Truck operation | • Trucks travel slowly on the fresh chip seal<br>• Stops and turns are made gradually<br>• Truck operators avoid driving over exposed asphalt |

| | |
|---|---|
| | • Trucks stagger their wheel paths when backing into and leaving the aggregate spreader to eliminate aggregate rollover and to aid in rolling |
| Rolling | • Ensure that rollers follow closely behind the aggregate spreader<br>• Complete the first roller pass as soon as possible after applying the aggregate<br>• Position rollers in echelon so the entire with of the pavement lane is covered in one path<br>• Roll in a longitudinal direction as a speed of less than 3 mph and roll three complete passes over the aggregate<br>• Rollers must avoid driving on exposed asphalt<br>• All stops, starts and turn as made gradually |
| Longitudinal joints | • The distributor lines up so the end nozzle sprays the longitudinal joint and the joint should be overlapped by 2-4 inches for uniform appearance<br>• Longitudinal joints are never made in the wheel path. They are made at the center of the road, center of a lane, or edge of a lane<br>• Longitudinal joints should not be left uncovered overnight<br>• Two methods of longitudinal joint construction are discussed in the check list |
| Transverse joints | • All emulsified asphalt application begins and ends on Kraft paper or roofing felt<br>• All aggregate applications begin or end on Kraft paper or roofing fleet<br>• The Kraft paper or roofing felt is disposed of in a proper way |
| Sweeping | • After rolling is completed, sweeping should be accomplished using approved sweepers<br>• Sweep excess cover aggregate from the pavement as soon as possible. Final sweeping should be completed not later than the morning after placing the chip seal<br>• Do not permit uncontrolled traffic on the chip seal prior to initial sweeping<br>• Sweeping should not dislodge the aggregate that has set in the emulsified asphalt<br>• Re-sweep prior to opening to unrestricted traffic |
| Opening to traffic | • Control traffic speeds with pilot vehicles so traffic does not displace embedded aggregate<br>• Traffic should be controlled at speeds of 35 mph or less until the chip seal is swept again<br>• Reduce speed limit signs are posted when pilot cars are not in use<br>• After sweeping, place temporary pavement markers on the lane lines for delineation before opening to normal traffic<br>• All construction signs are removed when opening pavement to normal traffic |
| Cleanup | • All loose aggregate from sweeping is removed from the roadway and cannot be reused for chip seals<br>• Temporary staging areas for construction equipment and stockpiles are retuned to pre-construction conditions |

## 9.2 FHWA Check List- Troubleshooting Problems

FHWA has updated its check list for emulsified asphalt chip seals. It provides information on identifying common problems and potential solutions. Table 10 summarizes the common problems and possible solutions.

*Table 10: Common Problems and Possible Solutions*

| Problem | Solution |
|---|---|
| Aggregate Embedment > 80% | Lower the asphalt application rate |
| Aggregate Embedment < 50% | Raise the asphalt application rate |
| Excessive emulsified asphalt splattering | Spray pressure too high |
| Streaking or drill marks in the asphalt | • Emulsified asphalt is too cold<br>• Viscosity of emulsified asphalt too high<br>• All nozzles are not at same angle<br>• Spray bar too high<br>• Spray bar too low<br>• Spray bar pressure too high<br>• Nozzles is plugged |
| Exposed asphalt remains after aggregate application | Aggregate spreader gate may be clogged or malfunctioning |
| Excessive aggregate | Spreader gate may be malfunctioning, or the spreader gate may be overloaded |
| Uneven aggregate application | • Recalibrate the aggregate spreader<br>• Hooper gates may not all be set the same |
| Asphalt on top of the aggregate | • Aggregate spreader operating too fast<br>• Trucks, rollers, or pilot car may be operating incorrectly |
| Aggregate being dislodged | • Emulsified asphalt application rate too low<br>• Aggregate is dirty or dusty<br>• Traffic or equipment too fast<br>• Emulsified asphalt break occurred before aggregate placed and rolled<br>• Sweeping begun before emulsion has properly set |
| Asphalt Bleeding or Flushing | • Emulsified asphalt application rate too high<br>• Flat or elongated aggregate being used<br>• Check the calibration of the asphalt distributor and aggregate spreader |
| Loss of Aggregate at Longitudinal joints after sweeping | Check procedures for placing longitudinal joints |

# 10.0 Conclusions and Recommendations

## 10.1 Conclusions

The best practices included in this document have been a compilation of work from industry, agencies and research documents. Documents from NCHRP, Industry, PPRA, and agencies including state and FHWA have provided an abundance of information that should provide successful projects.

It is important that the projects for emulsified asphalt chip seals be selected correctly and be constructed properly using these Best Practices, together with the principles of Quality Assurance. Agency inspection is very important as the agency who is the owner, often gets what they inspect. There are many training modules that agencies can utilize for guidance on site selection, design, material selection, best practices on construction and troubleshooting. It is important that the design engineer, contractor, and inspector be trained on their respective roles and responsibilities. Just in time training is highly recommended as well.

## 10.2 Recommendations

These chip seal best practices incorporate the state of the science as of December 2020. It is to be expected that the technology and practices will continue to improve. Equipment development, changes in material, improved mix design processes and new testing methods and specifications should and will continue to progress through continued research and innovation. It is expected that future editions of these best practices will incorporate these new technological improvements.

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# APPENDIX A – Chip Seal Substrate Penetration Resistance

## Scope

This test method sets out the procedure for determining the depth of penetration by a steel ball dropped onto a road surface under the impact of a standard load.

## General

**a.** The ball penetration measure is used to:

I. Indicate whether the pavement is suitable to apply the prime seal based on the level of compaction and dry-back.

II. Indicate the hardness of a primer seal.

III. In design, help estimate the embedment allowance for sealing aggregate over an existing surface (e.g. over primes, slick or fatty asphalt).

*NOTE: Not reliable for existing seals owing to effect of aggregate.*

**b.** The following document is referred to in this Test Method:

I. AS 2891.5 Methods of sampling and testing asphalt - Determination of stability and flow - Marshall procedure.

## Apparatus

**a.** Ball Penetrometer Unit.

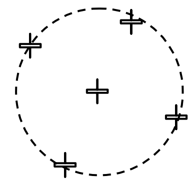
I. Type 1 Ball Penetrometer Unit without a self-standing frame:
- Conform to a Marshall hammer mass and drop height as given in AS 2891.5.
- Hammer fitted with a 19 mm case hardened hemispherical foot (i.e. 'ball').
- A method of measuring the relative penetration of the foot to the nearest 0.5 mm (either the shaft can be scribed or a fitted dial gauge).
- Fitted with a levelling bubble.

OR

II. Type 2 Ball Penetrometer Unit with a self-standing frame (Appendix A.1 and A.2).
- Drop hammer conforming to a Marshall hammer mass and drop height as given in AS 2891.5.
- Supporting frame with adjustable feet to ensure that the hammer is held vertical.
- 19 mm case hardened steel ball, a screw-in 19 mm case hardened hemispherical foot and a screw-in 19 mm case hardened flat (blank) foot.
- A method of measuring the relative penetration of the steel ball to the nearest 0.5 mm.

**b.** Temperature sensor suitable for measuring surface temperature with at least 0° to 100 C range and limit of performance of 1°C.

## Preparation



**a.** Select the sample location to be typical of the road surface. The sample consists of test point at the center and then 4 test points at about a 100 mm radius from the center test point and evenly spaced.
**b.** Clear away loose material from the sample location.
**c.** Where the surface is obviously a soft bitumen surface, carry out the ball penetration test according to Step 5.2, otherwise according to Step 5.1.

## Procedure

## Ball Penetration

**a.** Assemble the Ball Penetrometer ready for use according to the manufacturer's instructions.
*NOTE: Remove any transit pins (e.g. pins B and C for Type 2 as shown in Appendix A.1. To carry the Type 2 Ball Penetrometer, grip the external frame at just below the midway and lift gently.*

**b.** Position the Ball Penetrometer over the test point. Adjust position to ensure that the ball is not resting directly on stone or aggregate.
*NOTE: The gap between aggregates is acceptable.*

**c.** For a bitumen surface, allow the hammer unit to rest on the surface for about 1 min. If the ball sinks into the seal, carry out the test according to Step 5.2.
*NOTE: No impact is applied to the surface.*

**d.** Steady the Ball Penetrometer in an upright in a vertical position so that the levelling bubble is approximately centered. Where provided, adjust the levelling feet.
*NOTE: Type 2: Rest one knee firmly on the unit's base, at the same time grasp the rear of the unit near the top. The free hand is used to raise the hammer weight.*

**e.** Zero the direct measurement scale:
  I. Type 1: Attach the dial gauge (if required). Zero the collar against the scribed shaft and reset the dial gauge (if fitted). Remove the dial gauge (if fitted).
  II. Type 2: Adjust the thumb screw and locking nut on top of the hammer.
*NOTE: Locking of the thumb screw is optional.*

**f.** Apply one blow to the surface by raising the hammer weight to the top of the unit and allowing the hammer to fall freely to directly impact the surface.
**g.** Measure and record the depth of penetration (D) to the nearest 0.5 mm:
  I. Type 1: Reattach the dial gauge (if required) and read the ball penetration depth using the scribed shaft or the dial gauge.
  II. Type 2: Read the ball penetration depth using the scribed shaft.
**h.** Lift the unit and check that no stone or aggregate is showing in the impression.

**i.** Repeat Steps 5.1(b) to (h) a total of 5 times for each sample location.
**j.** Where a bituminous surface is tested, record the temperature of the road surface (T) for each sample location to the nearest 1 C.

## Ball Penetration on Soft Bitumen Surface

**a.** This step is only for testing penetration of a soft bitumen surface using the Type 2 Ball Penetrometer.
**b.** Assemble the Ball Penetrometer according to the manufacturer's instructions except for the following changes:
*NOTE: Separate the frame only when it is evident that the hammer will sink into the seal under self-weight.*

I. Remove the detached upright section and the gauge pin:
- Replace the screw-in ball tip with the blank screw-in tip (refer to Appendix A.2).
- Remove pins A, B and C (refer to Appendix A.1).
- Detach the base of penetrometer frame by removing the two base thumb screws.

II. Assemble depth gauge (from pin of direct measurement scale) by removing graduated pin and reinserting perpendicularly in the slot provided.
III. Remove the 19 mm case hardened steel ball from the base.

**c.** Place the 19 mm case hardened steel ball on the test point.
*NOTE: To prevent the ball from rolling on flushed or graded surfaces, lay a transit pin on the road and place the ball inside the circular end.*
**d.** Center the Ball Penetrometer base over the steel ball.
**e.** Place the assembled depth gauge into the slots of the base sleeve (with the knurled end facing the steel ball). Measure down to the top of the steel ball by releasing the screw and lowering the knurled end onto the steel ball.
**f.** Remove the gauge and record the initial measurement (D1) to the nearest 0.5 mm.
**g.** Place the hammer through the collar in the base so that the blank tip contacts the steel ball.
**h.** Steady the Ball Penetrometer upright in position.
*NOTE: Rest one knee firmly on the unit's base, at the same time grasp the rear of the unit near the top. The free hand is used to raise the hammer weight.*
**i.** Apply one blow by raising the hammer weight to the top of unit and allowing the hammer to fall freely and contact the ball.
**j.** Remove hammer and replace the depth gauge (refer to Step 5.2(e)). Measure to the top of the steel ball (D2).
**k.** Lift the unit and check that no stone or aggregate is showing in the impression.
**l.** Repeat the Steps 5.2(c) to (k) a total of 5 times for each sample location.
**m.** Where a bituminous surface is tested, record the temperature of the road surface (T) for each sample location to the nearest 1°C.

## Calculations

**a.** Where Step 5.1(h) was used, calculate the ball penetration (D) at each test point to the nearest 0.5 mm as follows:

$$\mathbf{D = D_1 - D_2}$$

Where
- D = Penetration depth at test point (mm)
- $D_1$ = Initial measure to top of steel ball (mm)
- $D_2$ = Second measure to top of depressed steel ball (mm)

**b.** Calculate the average ball penetration (Pen) by averaging the 5 penetration depths (D) obtained from each test point.

**c.** Determine the Ball Penetration depth ($Pen_S$) at standard summer road temperature for the sample location as follows:

$$\mathbf{Pen_S = Pen - K (T - T_s)}$$

Where
- $Pen_s$ = Ball Penetration depth (mm) at standard summer road temperature
- Pen = Average penetration depth (mm)
- K = Factor (mm/°C) from Table 1
- T = Temperature of road (°C)
- $T_s$ = Standard summer road temperature for location (°C) from Figure 1 (interpolate to nearest 1°C).

***Table 1: K Factors for Road Surfaces***

| Test Surface | K (mm/ C) |
|---|---|
| Granular base (not primed) | 0.00 |
| Single/single or double/double seal (not fatty) | 0.04 |
| Primer seal (not fatty) | 0.06 |
| Fatty seal, slurry seal, or slick or fatty asphalt | 0.08 |

## Reporting

Include the following results in the report:

**a.** Location and date of test.
**b.** Description of surface being tested.
**c.** Where testing unsealed granular bases, moisture content (if known).
**d.** Where testing a bituminous surface, road surface temperature to nearest 1°C.
**e.** The unadjusted ball penetration values (P) to the nearest 0.5 mm.
**f.** The Ball Penetration (PenS) to the nearest 0.5 mm.
**g.** Reference to this test method.

# APPENDIX B – AASHTO Construction Guide

## Section 406

# Construction Guide Specification for Emulsified Asphalt Chip Seal

## 406.1. DESCRIPTION

This guide specification is intended to provide information needed for owners or contractors to construct emulsified asphalt chip seals. An emulsified asphalt chip seal is the application of emulsified asphalt, followed immediately by a single layer of aggregate chips to a prepared surface.

This guide specification refers to quality requirements for materials and a design method for chip seals available in other AASHTO documents. However, the main purpose is to provide guidance for the construction of emulsified asphalt chip seals applied in one layer. All units of measurement are expressed in English units which are the normal units used in the United States.

Commentaries are included in this Guide specification to 1) emphasize and further explain the section, 2) present options to be considered by the user, or 3) provide sources of additional information. An example of these commentaries is shown below:

Commentary

*This guide specification covers construction of single-application chip seals. If this process is repeated with another application of emulsified asphalt and another layer of cover aggregate, the process is known as a double chip seal. A triple chip seal would require yet another application of emulsified asphalt and cover aggregate. Other terms have been used referring to chip seals such as "seal coat," "surface treatment," "surface seal," "surface dressing," "sprayed seal," and others. Sometimes, a fog seal is applied over the completed chip seal.*

## 406.2. REFERENCED DOCUMENTS

406.2.1. *AASHTO Standards*

- M 140, Emulsified Asphalt
- M 208, Cationic Emulsified Asphalt
- M 316, Polymer-Modified Emulsified Asphalt
- MP 27, Standard Specification for Materials for Emulsified Asphalt Chip Seals
- PP 82, Emulsified Asphalt Chip Seal Design
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 49, Penetration of Bituminous Materials
- T 50, Float Test for Bituminous Materials
- T 59, Emulsified Asphalts
- T 96, Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- T 301, Elastic Recovery Test of Asphalt Materials by Means of a Ductilometer
- T 335, Standard Method of Test for Determining the Percentage of Fracture in Coarse Aggregate
- Guide Specification for Highway Construction, 2020, 10th Edition

406.2.2. *ASTM Standard*

- D5624, Standard Practice for Determining the Transverse-Aggregate Spread Rate for Surface Treatment Applications

406.2.3. *Other Documents*

- The Asphalt Institute. *Manual Series 19, A Basic Asphalt Emulsion Manual*, 4th ed.
- Texas DOT, Determining Flakiness Index, TXDOT Desingnation:Tex-224-F , August 2016
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## 406.3. TERMINOLOGY

406.3.1. *CRS-2, polymer modified*—a cationic rapid-setting emulsified asphalt that includes a polymer modifier typically in the form of a styrene-butadiene latex rubber or a styrene-butadiene or styrene-butadiene styrene block copolymer modified base asphalt binder and meet AASHTO MP 27 for emulsified asphalt chip seals.

406.3.2. *CRS-2*—a cationic emulsified asphalt without a polymer that is rapid setting.

406.3.3. *RS-2, polymer modified*—an anionic rapid-setting emulsified asphalt that includes a polymer modifier typically in the form of a styrene-butadiene latex rubber or a styrene-butadiene or styrene-butadiene styrene block copolymer modified base asphalt binder and meet AASHTO MP 27 for emulsified asphalt chip seals.

406.3.4. *RS-2*—an anionic emulsified asphalt without a polymer that is rapid setting.

406.3.5. *HFRS-2, polymer modified*—an anionic high- float rapid-setting emulsified asphalt that includes a polymer modifier typically in the form of a styrene-butadiene latex rubber or a styrene-butadiene or styrene-butadiene styrene block copolymer modified base asphalt binder.

406.3.6. *HFRS-2*—an anionic high- float emulsified asphalt without a polymer that is rapid setting.

406.3.7. *CHFRS-2, polymer modified*—a cationic high- float rapid-setting emulsified asphalt that includes a polymer modifier typically in the form of a styrene-butadiene latex rubber or a styrene-butadiene or styrene-butadiene styrene block copolymer modified base asphalt binder.

406.3.8. *CSS-1h*—a cationic emulsified asphalt that is slow setting and has a hard penetration residual binder residue.

406.3.9. *SS-1h*—an anionic emulsified asphalt that is slow setting and has a hard penetration residual binder residue.

## 406.4. MATERIALS

406.4.1. *Emulsified Asphalt*—Emulsified asphalt for chip seal shall meet the requirements of M 140, M 208, or M 316.

406.4.2. *Aggregate*—Chip seal aggregate shall conform to the requirements specified in MP 27, Section 6.1, Tables 1 and 2.

406.4.3. *Mix Design*—Design the chip seal to determine aggregate spread rate and emulsified asphalt application rate using a design method such as that described by PP 82.

## 406.5. CONSTRUCTION

406.5.1. *Equipment*:

406.5.1.1. *Asphalt Distributor*—The asphalt distributor shall be self-propelled with a ground speed control device interconnected with the emulsified asphalt pump such that the specified application rate will be supplied at any speed. The asphalt distributor shall be capable of maintaining the emulsified asphalt at the specified temperature. The spray bar nozzles shall produce a uniform double or triple lap application fan spray, and the shutoff shall be instantaneous, with no dripping. All nozzles shall be oriented at the same angle between 15 and 30 degrees using the wrench supplied by the distributor manufacturer. Each asphalt distributor shall be capable of maintaining the specified application rate within ±0.015 gal/yd$^2$ for each load.

Commentary

*Obtaining a triple overlap from the spray bar is the most desirable arrangement because the emulsified asphalt application will generally be more uniform than with double overlap. However, when equipment is calibrated and set up properly very acceptable results have been obtained with double overlap*

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

406.5.1.3. *Pneumatic-Tire Rollers*—A minimum of three self- propelled pneumatic-tire rollers capable of ballast loading, either with water or sand to allow the weight of the machine to be varied from 6 to 8 tons to achieve a minimum contact pressure of 80 lb/in.$^2$ shall be used. The alignment of the axles shall be such the rear- axle tires, when inflated to the proper pressure, can compact the voids untouched by the front-axle tires. All tires shall be as supplied by the roller manufacturer. Width of the rollers shall exceed 60 in.

Commentary

*Steel-wheel rollers have been used as the final roller on some chip seals with success. The advantage is a more even final elevation. This produces fewer prominent chip edges extruding above the surface which can be susceptible to snow plow damage. The disadvantage of steel-wheel rollers is the potential for crushing of aggregate chips that cannot withstand the high stress imparted at the steel roll-chip interface. Therefore, if used, steel rollers should be limited to 5 tons. Vibration shall not be used if the rollers are so equipped.*

406.5.1.4. *Brooms*—Motorized brooms with a positive means of controlling vertical pressure shall be used to clean the road surface prior to spraying emulsified asphalt. Plastic bristle brooms are required to remove loose aggregate after rolling.

Commentary

*Vacuum brooms are preferred in urban or residential areas, but push brooms are acceptable in rural areas where chips being scattered off the roadway do not pose a hazard to pedestrians or vehicles.*

406.5.1.5. *Trucks*—Unless otherwise approved, use trucks of uniform capacity to deliver the aggregate. Provide documentation showing measurements and calculation in cubic yards. Clearly mark the calibrated level. Truck size may be limited when shown on the plans.

406.5.2. *Equipment Calibration*

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

Flow from each nozzle in the asphalt distributor must be within ±10 percent of the average flow of all nozzles as measured by the procedure as described in NCHRP Report 680, Chapter 7 (Shuler, et al 2011).

Uniformity of the aggregate applied transverse to the pavement centerline shall be in accordance with ASTM D5624. Tolerance for each pad tested for transverse spread rate shall be ±10 percent of the average of the total transverse rate.

*Commentary*

*Calibration is very important to assure the quantity of emulsified asphalt and aggregate applied to the pavement is correct. Although many modern asphalt distributors and aggregate spreaders are computer controlled, calibration is required to tell the computer how much emulsified asphalt is being applied. This quantity must be checked prior to spraying emulsified asphalt and spreading aggregates and checked against the quantity the computer (if the distributor is so equipped) indicates is being applied.*

406.5.2.1. *Asphalt Distributor*

All nozzles shall be the same size, provide the same flow rate, be oriented in the same direction, and be the same distance above the pavement.

*Commentary*

*The distributor truck applies emulsified asphalt to the pavement surface. This application must be done uniformly both transverse and longitudinal to the centerline of the pavement to provide the proper adhesive layer necessary for proper aggregate chip adhesion.*

When lower application rates are determined necessary or shown in the plans, smaller nozzles shall be inserted in the spray bar where the emulsified asphalt rate is reduced.

*Commentary*

*Due to minor rutting or heavy truck traffic, it may be desirable to reduce the emulsified asphalt application rate in the wheel paths.*

406.5.2.1.1. *Nozzle Angle*

Nozzles shall be positioned at an angle of 15 to 30 degrees from the horizontal of the spray bar in accordance with the manufacturer's recommendation. All nozzles shall spray a full fan except for the right and left edge nozzles. The right and left edge nozzles shall be adjusted to a half fan such that the spray stays to the inside of the spray bar.

*Commentary*

*The next step in calibrating the distributor is adjustment of the spray bar nozzle angles. Each nozzle has a slot cut across the face of the nozzle. When the nozzle is threaded into the spray bar, the slot should all be positioned at an angle of 15 to 30 degrees to the direction of the spray bar as shown in Figure 1. This angle provides the best position for achieving uniformity in the spray and the triple overlap coverage. The angle should be adjusted using the wrench supplied with the distributor. This wrench is designed when used properly to set the correct angles for each nozzle.*

*Any wrench that fits the hexagonal nozzle can adjust the nozzle angle, but correctness of the angle would have to be visually verified.*

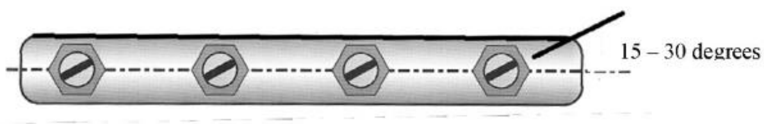


**Figure 1**—Spray Bar Nozzle Orientation in Spray Bar

406.5.2.1.2. *Spray Bar Height*—The spray bar height must be adjusted so that the emulsified asphalt provides exactly two or three overlaps across the entire spray width.

*Commentary*

*Streaking of the emulsified asphalt will occur if the spray bar is set too high or too low as shown in Figures 2 and 3.*

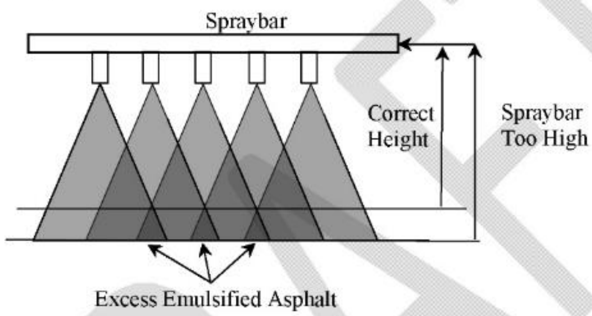


**Figure 2**—Streaks with Spray Bar Too High for Double Overlap

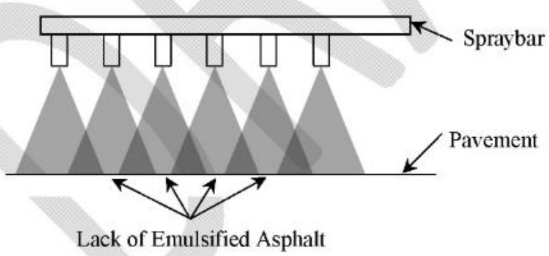


**Figure 3**—Streaks with Spray Bar Too Low for Double Overlap

*To avoid this streaking the bar must be adjusted to the correct height. This adjustment process is accomplished by shutting off nozzles to determine where the spray pattern contacts the pavement as shown in Figures 4 and 5.*

406.5.2.1.3. *Bar Height Adjustment to Achieve Double Lap*

Every other nozzle shall be turned off when a double lap application is desired as shown in Figure 4. The distributor operator shall spray emulsified asphalt onto the pavement surface for as short an interval as possible while an observer watches where the emulsified asphalt hits the pavement from each nozzle left open. If there is overlap of emulsified asphalt from adjacent nozzles, the bar is too high. If there is a lack of emulsified asphalt from adjacent nozzles, the bar is too low.

Once it is confirmed the bar height is correct, the nozzles that were turned off should be turned back on and a double application of emulsified asphalt will result when spraying resumes.

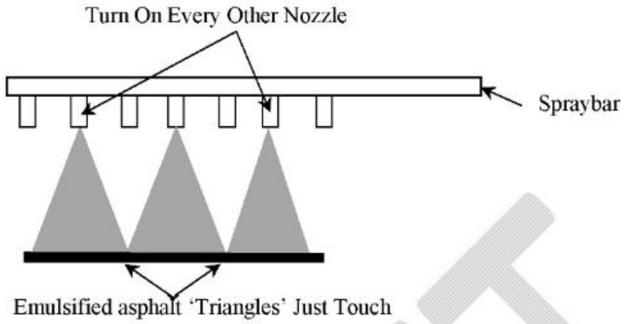


**Figure 4**—Adjustment of Spray Bar Height for Double Overlap

406.5.2.1.4. *Triple Lap Application Bar Height Adjustment*

Every third nozzle shall be turned off when a triple lap application is desired as shown in Figure 5. The distributor operator shall spray emulsified asphalt onto the pavement surface for as short an interval as possible while an observer watches where the emulsified asphalt hits the pavement from each nozzle left open. If there is overlap of emulsified asphalt from adjacent nozzles, the bar is too low. If there is a lack of emulsified asphalt from adjacent nozzles, the bar is too high.

Once it is confirmed the bar height is correct, the nozzles that were turned off should be turned back on and a triple application of emulsified asphalt will result when spraying resumes.

As the distributor empties during spraying, the bar height will rise. However, this is not usually enough to cause significant streaking worth adjustment of the spray bar.

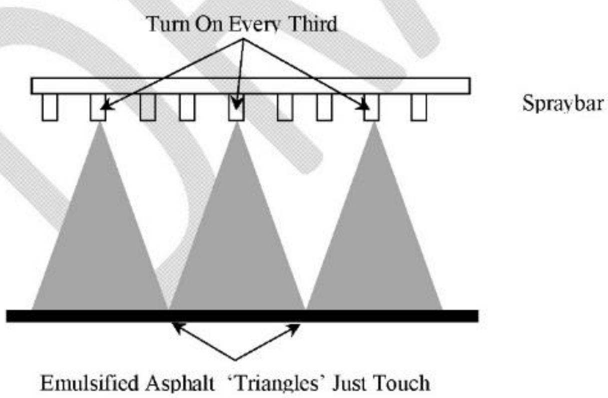


**Figure 5**—Adjustment of Spray Bar Height for Triple Overlap

406.5.2.1.5. *Transverse Flow Rate*—The flow rate across the spray bar shall be uniform with each nozzle spraying within ±10 percent of the average flow rate.

<u>*Commentary*</u>

*This is done by measuring the width of the slot in the nozzle and by measuring the orifice diameter. Also, some nozzles are labeled by the manufacturer. Manufacturers supply a list of nozzles in the owner's document describing which nozzles shall be used for various application rates or on a placard mounted on the equipment.*

*However, nozzles of the same apparent size have been measured with different flow rates. Therefore, it is recommended that all nozzles be checked for flow rate before chip seal operations begin. This is easily accomplished by fabricating a flow apparatus (Martin, 1989). This apparatus consists of a pipe to which each nozzle can be fitted, in turn, on one end and a water source can be fitted to the other end. The flow of water through each nozzle shall be measured by filling a 1-gal container in a measured period. This shall be done for each nozzle to be used on the project. If the flow rate of any of the nozzles is greater than plus or minus 10 percent of the average of all the nozzles to be used these nozzles shall be discarded, or modified to flow within the 10 percent tolerance.*

*Determination of uniform lateral flow from the spray bar is determined by collecting a measured volume of emulsified asphalt in containers placed under each nozzle. This process is practical using standard 6-in. by 12-in. concrete cylinder molds lined with one-gallon zip-lock freezer bags. The cylinder molds can be reused and the zip lock bags discarded appropriately with the contents.*

406.5.2.1.6. *Longitudinal Flow Rate*—The longitudinal spray rate shall be accomplished by measuring the volume of emulsified asphalt in the distributor before and after spraying enough emulsified asphalt to reduce the volume of emulsified asphalt in the distributor by 70 to 90 percent.

*Commentary*

*The longitudinal flow rate must be measured with all nozzles inserted in the distributor bar. First, the quantity of emulsified asphalt in the truck must be determined. Although there is a volume indicator on the rear of most modern distributors, these are not calibrated in small enough increments to be of use for longitudinal flow rate calibration and shall not be used for this purpose. Instead, the dip stick supplied with the distributor must be used. This dip stick is usually carried on the top of the tank near the inspection hatch. Prior to shooting emulsified asphalt, take a volume reading with the dip stick.*

*Pay attention to how the dipstick is used. Many dipsticks are not intended to be submerged in the emulsified asphalt, but instead, are inserted into the top of the tank only until the tip of the dipstick touches the surface of the emulsified asphalt. Then, the volume in the tank is read by indexing the top of the inspection cover to the reading on the dipstick.*

*Record this volume as 'beginning volume'. Set up the truck to shoot emulsified asphalt and shoot a minimum of 3000 feet by 12 feet of emulsified asphalt at the design rate using the gallon per minute pump flow volume and truck speed required by the manufacturer to attain this flow rate. Take a second dip stick reading. Record this reading as 'ending volume'. Subtract 'ending volume' from 'beginning volume' and record this as 'volume used'. Determine the area of emulsified asphalt sprayed. Divide 'volume used' by the area sprayed in square yards. This is the gallons per square yard applied to the pavement. This value shall then be compared to the distributor computer, if equipped, to evaluate the accuracy of the computer. A correction factor may then be applied to the computer output, if needed, and used for the remainder of the day. This calibration shall be accomplished each day.*

*An example of this calibration is presented below:*

*Given:*

*1800-gal capacity asphalt distributor*

*12-ft wide spray width*

*Trial spray distance = 3630 ft*

*0.32 gal/yd$^2$ design spray rate*

*Dipstick reading beginning of shot = 1765 gal*

*Dipstick reading end of shot = 265 gal*

*Calculations:*

1. *Check to see if enough volume shot. 1765 – 265=1500 gal*
2. *1500/1765 = 85 percent >70 percent and <90 percent. OK, enough applied to be valid*
3. *Calculate spray rate = 1500 gal / (12 × 3630/9) = 0.31 gal/yd²*

*Therefore, decrease distributor speed, or recalibrate computer and recheck.*

406.5.2.2. *Aggregate Spreader*

406.5.2.2.1 Transverse Spread Rate

The aggregate spread shall be uniform across the veil and within +/-10 percent of the average spread rate. Various methods of calibrating this equipment have been used and the ASTM D5624 procedure can be effective.

*Commentary*

*A visual assessment of the lateral distribution of chips is a good place to start the process since non-uniform distribution can easily be seen. The veil of chips deposited on the pavement from the spreader box can be viewed from behind with the spreader moving away from the observer or from the front. Either position for the observer is adequate for viewing how uniform the veil of chips is falling out of the spreader box. However, viewing from either front quarter affords the observer a better view of the entire spreader width and is, of course, safer than directly in front of the spreader. Any variation in light passing through the veil of aggregate indicates variation in application rate. More light means a lack of aggregate. Variation in light means the machine shall be stopped, the gates on the spreader contributing to the non-uniformity adjusted and the trial rerun. This procedure provides adjustment to the transverse spread rate. Then, to obtain an objective means of measuring the amount of aggregate being deposited, ASTM D5624 is a good procedure to use.*

406.5.2.2.2 Longitudinal Spread Rate

The longitudinal spread rate shall be uniform and be within +/- 10 percent of the design spread rate.

*Commentary*

*Once the transverse spread rate is adjusted the longitudinal rate can be adjusted. This is also done visually, at first.*

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*Evaluating the quantity of aggregates being placed is important after the rate is established. This provides a quantitative baseline for future work. The best method to accomplish this evaluation is by weighing the aggregate spreader before and after applying the aggregate and calculating the spread rate based on the area covered. This is often not practical. Therefore, a suitable alternative includes estimating the quantity of aggregates spread over a known area by knowing the weight of each transport truck supplying the spreader and dividing the estimated weight of aggregate s spread by the area covered for that load.*

*An example follows:*

*Given:*

*Trucks loading the aggregate spreader are 12-ton capacity tandem dumps*

*12-ft wide pavement*

*28 lb/yd² design spread rate*

*Calculations:*

1. *Check Truck No. 1*
   a. *Load = 23,803 lb*

*b. Spreader distance = 640 ft*

*c. Rate = 23,803/640x12/9 = 27.9 lb/yd²*

*2. Check Truck No. 2*

*a. Load = 23,921 lb*

*b. Spreader distance = 634 ft*

*c. Rate = 23,921/634 × 12/9 = 28.3 lb/yd²*

*3. Check Truck No. 3*

*a. Load = 23,848 lb*

*b. Spreader distance = 639 ft*

*c. Rate = 23,848/639 × 12/9 = 28.0 lb/yd²*

*4. Average Rate = (27.9 + 28.3 + 28.0) / 3 = 28.1 lb/yd²*

*5. No adjustment needed since measured rate is within 1 percent of design.*

*Compensation for moisture on the aggregate s must be considered when calibrating spreaders. The above example indicates no adjustment is needed since the measured spread rate is within 0.10 lb/yd² of the design spread rate. However, if the aggregate above had contained as much as 1.02 percent moisture that was unaccounted for, the application rate would have been too low.*

406.5.3. *Preconstruction Meeting*—Coordinate a preconstruction meeting prior to construction with the engineer to discuss the following topics:

- construction process
- quality control plan, required to be submitted
- mix design, required to be submitted
- materials control
- materials measurement
- equipment calibration, required to be submitted
- traffic control plan
- equipment/process overview
- inspection
- test strip
- unique project conditions
- project documentation
- expectations

406.5.4. *Road Surface Preparations*

406.5.4.1. *Cleaning Pavement*—Clean the roadway surface by sweeping no more than 30 minutes prior to application of the emulsified asphalt and aggregate. However, this 30-minute window may be extended if authorized by the engineer in cases where extending the time does not jeopardize a clean surface prior to chip seal operations. Sweep the pavement with a motorized broom to remove loose material. Clean depressions not reached by the motorized broom with a hand broom. Clean the outer edges of the pavement to be sealed including an adjacent paved shoulder.

406.5.4.2. *Protecting Accessories*—Cover utility castings (manholes, gate valve covers, catch basins, sensors, etc.) to prevent coating with emulsified asphalt. Suitable covering includes plywood disks, Kraft paper, roofing felt or other approved methods. Remove the protective coverings before opening the road to traffic.

406.5.4.3. *Stripe Removal*—Thermoplastic pavement markings shall be removed by grinding or other approved methods prior to chip seal operations. Other pavement markings may be left in place.

*Commentary:*

*If the edge stripes and center lane stripes are worn removal may not be necessary, or, if in doubt, applying a fog seal to the stripes prior to chip sealing has been demonstrated as effective for maintaining good chip seal adhesion. Stop bars and turn arrows should always be removed.*

406.5.5. *Application*

406.5.5.1. *Weather Limitations*—Construct chip seal per the following conditions:

- Ambient and pavement surface temperatures shall be 50°F and rising.
- Application of the chip seal shall be only during daylight hours.
- Suspend chip sealing if the pavement surface temperature exceeds 140°F.
- The road surface shall be dry to damp.

406.5.5.2. *Test Strip*—A test strip shall be constructed on or near the project site. Construct the test strip under similar placement conditions of time of day, temperature, and humidity as expected for the duration of the project. The test strip shall be a minimum of 500 feet in length and shall be constructed with the job mix proportions, materials, and equipment to be used on the project. Adjustments to the mixture formula shall be permitted provided they do not exceed the values stated in the mix design. The Agency shall evaluate the test strip to determine whether project specifications are met. If specifications are not met, additional test strips will be constructed until specifications are met, at no additional cost to the Agency.

406.5.5.3. *Application of Emulsified Asphalt*

Apply the emulsified asphalt at the rate determined by the design. This rate shall be within ±5 percent of the chip seal design rate. After applying the emulsified asphalt, place the cover aggregate at the design application rate. Adjust the rate of application, if necessary, so that some emulsified asphalt can be seen between the aggregate chips, but not so much that aggregate chips adhere to the pneumatic rollers. Inspect the aggregate in the wheel paths for proper embedment. Embedment shall be 50 to 60 percent after rolling. Make additional adjustments to the rate of application during the project, if needed.

The temperature of the emulsified asphalt at the time of application shall be above 120°F.

*Commentary*

*If the temperature is lower than 120°F, there is risk of less material being applied than desired due to high viscosity.*

The longitudinal construction joint for a single course chip seal must coincide with the painted lane line or at the outside edge of shoulder. There shall no overlap of the longitudinal construction joint for a single application chip seal.

406.5.5.4. *Application of Cover Aggregate*—Provide uniformly moistened aggregates, which are damp at the time of placement. Damp aggregates shall be saturated but surface dry with approximate moisture content between 1 and 3 percent depending on the aggregate absorption capacity.

*Commentary*

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

*For non-modified emulsified asphalts like RS-2 or CRS-2 begin spreading chips into the fresh emulsified asphalt when a few chips cast by hand stick to the emulsified asphalt and do not rollover. This shall be done well before the emulsified asphalt begins to 'break' or 'set', but not immediately after spraying unless temperature, wind, or high demulsibility demand it. This practice may not be necessary for emulsified asphalts that are polymer modified. Polymer* *modified emulsified asphalts are highly adhesive immediately after spraying and chips do not tend to roll over after spreading. Therefore, for polymer modified emulsified asphalts chips should be spread immediately after spraying the emulsified asphalt.*

*The application rate of the chips shall be similar to the design rate. This is a rate where immediately upon dropping the chips, the appearance of the surface has some emulsified asphalt showing between the chips. In fact, the chip quantity should seem somewhat inadequate. The chip spread rate should not be low enough to cause pickup problems on rubber-tire rollers. However, the rate should be such that a small decrease in rate would cause pickup. Emulsified asphalt should be visible between the aggregate upon dropping them and before rolling. If all emulsified asphalt is covered before rolling, there is an excess of chips and the rate shall be reduced. It is the responsibility of the construction superintendent to achieve this application rate.*

The speed of the spreader shall be restricted to prevent the aggregates from rolling over. Starting and stopping of the spreader should be minimized. The edges of the aggregate applications shall be sharply defined. Previously used aggregates from sweeping may not be returned to the stockpile or the spreader for reuse.

*Commentary*

*Although a design was done in the laboratory to determine the aggregate application rate, adjustments are almost always needed in the field. This should be done during the first day of construction to make sure the aggregate quantity is correct. This is best done by observing the appearance of the aggregate after they have been dropped into the emulsified asphalt, but before rolling. Some emulsified asphalt should be visible between most of the aggregates. If emulsified asphalt cannot be seen between the aggregates, the rate is too high. Conversely, too much emulsified asphalt showing through between the aggregate will cause pickup on rubber tires.*

406.5.5.5. *Transverse Paper Joints*—When beginning a new application of the chip seal transversely abutting the previously placed chip seal a transverse paper joint shall be used so excess asphalt and chips are not placed at the joint. The transverse paper joint shall be formed by placing 36-in. wide Kraft paper on top of the previously applied chip seal so the edge of the paper aligns with the joint that will be formed when the previously placed chip seal meets the newly applied chip seal. The asphalt distributor shall begin applying emulsified asphalt by starting the application on top of the Kraft paper. After the asphalt distributor moves forward and over the joint, the paper shall be removed.

*Commentary*

*Ideally, the paper should also be placed at the end of the distributor shot, as well. This creates a clean, edge with the correct emulsified asphalt and aggregate quantity at the joint. The placement of the paper is calculated based on the emulsified asphalt shot rate and the quantity of emulsified asphalt in the distributor. The distance the asphalt distributor travels before encountering the paper and turning off the bar should be approximately equivalent to 80 percent of the distributor tank volume. This assures the distributor does not spray until empty which can result in less emulsified asphalt applied than desired at the end of the shot.*

406.5.5.6. *Rolling Operations*—Complete the first roller pass as soon as possible but not longer than two minutes after applying the aggregate. Proceed in a longitudinal direction at a speed less than or equal to 3 mph. Three complete roller passes of the aggregate chips are required as a minimum. One pass is defined as the roller moving over the aggregates in a single direction. Ensure the rolling is completed quickly enough to embed the aggregate, before the emulsified asphalt breaks and no longer than 15 min after the emulsified asphalt is sprayed. Position the rollers in echelon so the entire width of the pavement lane is covered in one pass of the rollers.

*Commentary*

*If desired, final rolling may be accomplished using the steel wheel roller in one pass. The asphalt distributor and aggregate spreader speed may have to be reduced if the rolling operations cannot be accomplished before the emulsified asphalt breaks*

406.5.5.7. *Sweeping*

Excess aggregate shall be swept off the new surface in accordance with Table 1.

**Table 1**—Sweeping Sequence

| Chip Seal Class[a] | | |
|---|---|---|
| I | II | III |
| Within 24 h after rolling | No later than the following morning | Before traffic is allowed without traffic control |

[a] Class I is less than 500 AADT, Class II is 501 to 5000 AADT, and Class III is greater than 5000 AADT.

Do not sweep embedded aggregate until at least 85 percent of the total moisture present in the chip seal has evaporated or aggregates may become dislodged. Moisture present consists of moisture in the aggregate chips and moisture present in the emulsified asphalt. Moisture content shall be determined by the procedure reported in *NCHRP Report 680* (Shuler et al., 2011). Re-sweep areas the day after the initial sweeping. The Contractor shall dispose of the surplus cover aggregate in a manner satisfactory to the Agency. In no case shall the excess aggregates swept from the surface exceed 10 percent of the total amount placed. If this quantity is exceeded, work shall cease until an adjustment is made to reduce the spread rate within tolerances.

406.5.5.8. *Traffic Control*

Traffic may be allowed onto the fresh chip seal after rolling is completed and before sweeping in accordance with Table 2. Before placing on the newly placed chip seal ensure that at least 85 percent of the total moisture present in the chip seal has evaporated or aggregates may become dislodged.

**Table 2**—Timing for Traffic

| Chip Seal Class[a] | | |
|---|---|---|
| I | II | III |
| Traffic controlled with speed limit signs | Traffic controlled with pilot cars | Traffic controlled with pilot cars |

[a] Class I is less than 500 AADT, Class II is 501 to 5000 AADT, and Class III is greater than 5000 AADT.

A pilot car shall be used on two-lane roadways during construction and until the roadway and shoulders have been swept free of loose aggregate.

406.5.5.9. *Protection of Motor Vehicles*—The Contractor is responsible for claims of damage to vehicles until the roadways and shoulders have been swept free of loose aggregate and permanent pavement markings have been applied. If permanent pavement markings are to be applied by Agency forces, the Contractor's responsibility ends after completion of the chip seal and placement of temporary pavement markings.

406.5.5.10. *Fog Seal*

If, in accordance with the plans, a fog seal is applied to the surface of the completed chip seal, spray the fog seal after sweeping and before placement of permanent pavement markings, but not sooner than 24 hours after final rolling. Refer to the AASHTO Construction Guide Specification for Fog Seals (Section 410) in the section for application over chip seals for specific requirements.

Commentary

*Fog seals are applied to the surface of completed chip seals for two reasons: 1) The dark color provides more contrast to pavement markings, and 2) the fog seal provides a slight increase in binder residue to increase chip retention.*

*A fog seal may also be applied to recent hot mix asphalt patches in the pavement to be chip sealed. These fresh hot mix patches can be more absorptive than the surrounding pavement due to* *higher air void content. The fog seal helps prevent the new chip seal emulsified asphalt from being absorbed into the substrate unevenly.*

406.5.5.11. *Sequence of Work*

Construct the chip seal so that adjacent lanes are sealed on the same day when possible. If the adjacent lane(s) has not been sealed sweep all loose aggregate from the unsealed lane(s) before traffic is allowed on the surface without traffic control.

Permanent pavement markings shall not be placed for 24 h after placing the chip seal when no fog seal is applied.

If fog seal is used, the permanent pavement markings shall not be placed before three days have elapsed for water borne pavement marking or ten days for other types of markings.

<u>*Commentary*</u>

The chip seal will usually cure within 24 h under dry conditions and temperatures above 60°F. The fog seal can be applied after the chip seal coat is cured. The fog seal will usually cure within 2 h under dry conditions and temperatures above 60°F. Interim pavement markings can be placed after the fog seal cures. Do not allow traffic on the fog seal until cured.

406.5.6. *Quality Assurance*

**Referred to COMP TS 5c. The "Emulsion Chip Seal Quality Assurance Guide" is being balloted by COMP TS 5c. Action approved by chairs of TS 5b and TS 5c.**

## 406.6. MEASUREMENT

The Engineer will measure work acceptably completed as specified the *AASHTO Guide Specifications for Construction* and as follows:

406.6.1. *Emulsified Asphalt*—Measure the emulsified asphalt for chip seal by volume, at 60°F.

406.6.2. *Aggregate* —Aggregate will be measured based on the area of pavement surfaced.

<u>*Commentary*</u>

*Aggregate can be paid for by the ton, as well. This is easier to verify but results in an incentive to place more aggregate than necessary. Applying too much aggregate is poor practice and results in dislodgement of the embedded aggregate.*

## 406.7. PAYMENT

Payment for chip seals can be done by either paying for the materials in unit costs, or for the completed chip seal by area of pavement sealed.

<u>*Commentary*</u>

*The advantage of payment by the square yard for a completed chip seal is simplicity if the area is easily defined. The disadvantage is that an incentive is created to reduce material quantities. Reduced emulsified asphalt quantities can lead to chip loss and vehicle damage.*

406.7.1. *Payment by Unit Price*—The Agency will pay for accepted quantities at the contract price as follows:

1. Payment for the accepted quantity of emulsified asphalt and aggregate for chip seal (including any required additives) at the contract bid price of measure is compensation in full for all costs of furnishing and applying the material as specified.
2. Payment will be made in accordance with the schedule set forth below at the Contract bid price for the specified unit of measure.

| Item No. | Item | Unit |
|---|---|---|
| State ## | Emulsified asphalt for chip seal | gal |
| State ## | Aggregate for chip seal | tons |
| State ## | Diluted emulsified asphalt for fog seal, if used | gal |

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

406.7.2. *Payment for Completed Chip Seal*

406.7.2.1. Payment for the accepted quantity of the chip seal at the Contract bid unit price of measure is compensation in full for all costs of furnishing and applying the material as specified, including cleaning the existing pavement, stationing, purchase of aggregate, delivery of aggregate, all labor, equipment, and materials necessary for the placement of the chip seal for full lane coverage, sweeping of any loose aggregate after construction and other requirements as specified.

406.7.2.2. Payment will be made in accordance with the schedule set forth below at the Contract bid price for the specified unit of measure.

| Item No. | Item | Unit |
|---|---|---|
| State ## | Chip seal | $yd^2$ |
| State ## | Diluted emulsified asphalt for fog seal, if used | gal |

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