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## CHAPTER 7 CHIP SEALS

### 7.1 OVERVIEW

Chip sealing is the application of a bituminous binder immediately followed by the application of an aggregate. The aggregate is then rolled to embed it into the binder. Multiple layers may be placed, and various binder and aggregate types can be used to address specific distress modes or traffic situations. Chip seals also waterproof the existing surface.

#### 7.1.1 Types of Chip Seals

There are several types of chip seals in use today. They include the following:

- **Single Chip Seal:** A single chip seal is an application of binder followed by an aggregate. This is used as a pavement preservation treatment and provides a new skid resistant wearing surface, arrests raveling, and seals minor cracks. Figure 7-1 illustrates a single chip seal application. Flush coats improve the appearance of chip seals and reduce rock loss.

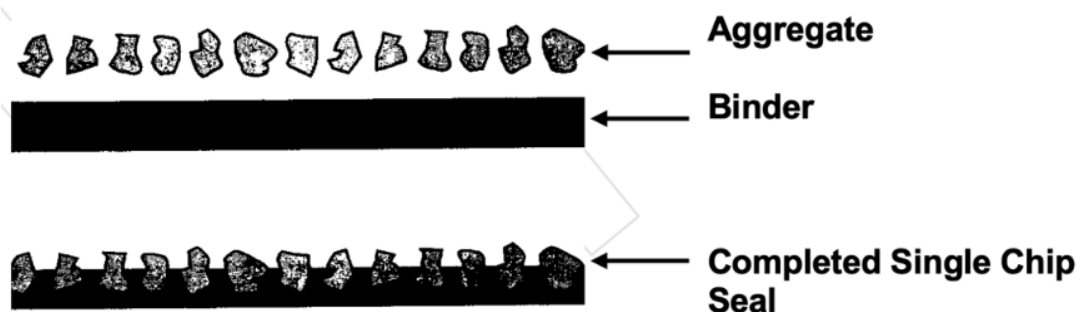


Figure 7-1 Single Chip Seal

- **Multiple Chip Seal:** A multiple chip seal (or armor coat) is a built-up seal coat consisting of multiple applications of binder and aggregate. As an example, a double chip seal consists of a spray application of binder, spreading a layer of aggregate, rolling the aggregate for embedment, applying an additional

application of binder, spreading another layer of aggregate (approximately half the average least dimension of the base coat aggregate), and rolling once more. Sweeping should be done between applications. This process may be repeated, as necessary, to build up pavement edges. Multiple chip seals are used where a harder wearing and longer-lasting surface treatment is needed. Figure 7-2 illustrates a multiple chip seal application.

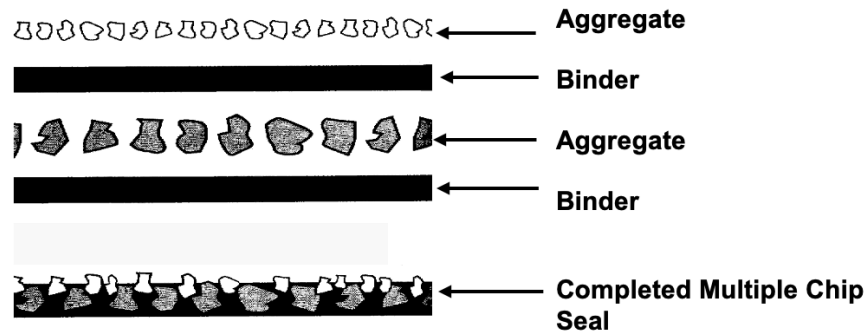


Figure 7-2 Multiple Chip Seal

- **Stress Absorbing Membrane (SAM) Seal:** A SAM is a single chip seal in which a modified binder (normally asphalt rubber) is applied, followed by a layer of aggregate, and rolling. Binder applications are much higher than conventional chip seals. Generally, a SAM has been used with asphalt rubber (AR) binders.
- **Stress Absorbing Membrane Inter-layer (SAMI):** A SAMI is a membrane seal that is used to retard the rate of reflection cracking in new overlays. It consists of an application of an asphalt rubber binder followed by a layer of aggregate, spread, and rolled. An overlay is then placed over the membrane. Caltrans specification (Section 37-2.05) does not allow traffic on a SAMI.
- **Other interlayer applications** - Other interlayers, such as fabrics and glass fibers, followed by a chip seal or double chip seals have also been used in California. These are discussed in more detail in Chapter 13.

### 7.1.2 Binder Types

Binder type varies according to the type of chip seal being used. Binder types include:

- **Polymer Modified Asphalt Emulsion:** Polymer modified asphalt emulsion also contain an elastic polymer. Anionic and cationic polymer-modified emulsions (PMEs), such as PMCRS-2h, are included in the Standard Specifications, Section 94 (Caltrans, 2025).
- **Asphalt Rubber Binder:** Binders modified with high levels of crumbed tire rubber and a high natural rubber content material. These binders are sprayed hot and require hot chips pre-coated with asphalt. Hot applied AR binders (Type II and Type III) can be placed at cooler temperatures than emulsion

binders and can be placed at night. The temperature should meet Caltrans specifications. The best construction practices should be applied.

- **Rejuvenating Emulsion:** These are emulsions modified with rejuvenating oils (and sometimes polymers) that are used to penetrate and soften existing asphalt pavements.

Table 7-1 lists common binder types and their suitable applications.

**Table 7-1 Binder Type and Suitable Applications**

Binder Type	Single	Multiple	Sand	Sam/Sami
Asphalt Emulsions	Yes	Yes	Yes	No
Asphalt Rubber	Yes	Yes	Yes	Yes
Rejuvenating Emulsions*	Yes	Yes	Yes	No

*\*Caltrans use these in scrub seals, but do not use them in chip seals*

## 7.2 PROJECT SELECTION

The general selection of preventive maintenance treatments was covered in Chapter 3. The selection of a pavement for a chip seal project is based on the structural soundness of a pavement and the types of distress that are present. The ability of a treatment to address the current condition of a project is paramount in selecting an appropriate treatment. The main criteria addressed by the varying chip seal types are:

- **Polymer-Modified Emulsion (PME) chip seals** are used to correct raveling and pavement oxidation.
- **Rubberized chip seals** cure quickly, restore skid resistance on worn surfaces and resist reflection cracking.
- **Binders** such as asphalt rubber (including types II and III) may be used to address specific distress modes (Lane et al, 2022).
- **Distresses such as cracking, flushing, and base failures** cannot be addressed with conventional or hot applied chip seals.
- **Deformation, rutting and shoving** cannot be addressed with chip seals of any kind.

Table 7-2 lists appropriate binder/chip seal combinations for addressing various distress mechanisms. Generally, chip seals are not used on roads with AADT > 40,000. A SHRP report discusses some of the applications for chip seals in high volume roads (Peshkin et. al, 2016). Note for asphalt rubber chip seals, it is suggested to use the maximum aggregate size of 3/8-inch for ADT's greater than 5,000 vehicles/lane/day. The desert region of the District 11 of Caltrans can use 1/2 inch because of extra heat in the area. For PME chip seals, the maximum aggregate size of 5/16-inch for ADT's greater than 5,000 vehicle/lane/day.

The main advantages associated with chip seals include:

- **Improved Skid Resistance:** Chip seals provide good skid resistance.
- **Cost Effective Treatments:** Chip seals are typically cost effective when properly placed on the right type of pavement.
- **Good Durability:** Chip seals wear well and can have long service lives.
- **Ease of Construction:** Chip seals are typically constructed rapidly and cause less disruption to the traveling public than other treatments that take longer to place.

**Table 7-2 Binder/Chip Seal Combinations for Addressing Specific Distress Mechanisms**

Binder/ Chip Seal Combination	Raveling	Aged Pavements	Bleeding/Flushing	Load Associated Cracks	Reduce Water Intrusion	Climate Associated Cracks	Heavy Traffic Volumes	Stone Retention	Improve Skid Resistance
PME/Single	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes
PME/Double	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes
PME/Sand	Yes	Yes	No	No	Yes	No	No (light)	Yes	No
AR/SAM	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Rejuvenating Emulsion/single	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes

The main disadvantages associated with chip seals include:

- **Cure Time:** PME seals take several hours (depending on the climatic conditions) to reach a stage where they can tolerate unrestricted traffic.
- **Flying Chips:** Chip seals must be swept to remove excess stone to avoid broken windshields and vehicle damage.
- **Noise Considerations:** Chip seals can be noisy to travel on.
- **Weather Considerations:** Cold applied chip seals must be constructed during warm, dry weather, and during daytime only. Hot applied chip seals may be applied in cooler conditions and at night. This is discussed in more detail later in the chapter.
- **Performance:** Chip Seals create a rougher surface and are generally not used for parking lots. Chip seals do not improve ride quality.

Other limitations of chip seals include:

- **PME Seals:** These are not normally suitable for intersections, tight curves, or high stress areas.
- **Most chip seals** are not suitable for bike paths, unless a slurry or fog seal is placed on top.

## 7.3 DESIGN AND SPECIFICATIONS

### 7.3.1 Material Specifications

#### Binders

Binders are selected based on their performance characteristics. They need to provide good adhesion and/or stickiness. The performance grading (PG) system is used to select binders based on asphalt binder properties and its applied conditions, including climatic and aging conditions. A set of tests measure physical properties of the binder that can be directly related to field performance of the pavement at extreme temperatures. For example, a binder identified as PG 64-10 must meet performance criteria at an average 7-day maximum pavement temperature of 64°C and also at a minimum pavement temperature of -10°C.

Polymer Modified emulsion binders usually contain latex additives, although other elastomeric polymers are often used. The purpose of the polymer is to improve stone retention during the early life of the treatment and to increase the softening point of the binder after cure (i.e., the temperature at which the binder changes phase from being primarily solid to being primarily fluid). The general-purpose base binder is an 85/100-penetration grade asphalt cement. This base binder mostly controls low temperature properties. For cold climates, a softer base asphalt (e.g., an 120/150 penetration grade) may be warranted. For hot climates, a harder base binder (e.g., a 40/50 penetration grade) might be considered. Emulsion specifications are included in Section 94 of the Standard Specifications (Caltrans 2025) and in related SSPs as discussed in Chapter 2 of this guide.

Asphalt rubber binders contain high levels of crumbed tire rubber and high-natural rubber materials, which increases the softening point of the binder, improves stone retention, and produces good resistance to reflection cracking. In general, the base binder largely determines the low temperature properties; softer bases should be used in lower temperature areas. The selection of a particular binder type should also consider climatic conditions, traffic levels, and types of loads associated with the project (e.g., consideration of snowplow use, AADT, and % trucks).

Emulsion specifications are included in Section 94 of the Standard Specifications (Caltrans, 2025) and related SSPs as discussed in Chapter 2 of this guide.

#### Aggregates

For chip seals, the best performance is obtained when the aggregate has the following characteristics:

- Single-sized, if possible.
- Clean.
- Free of clay.
- Cubical (limited flat and elongated particles).
- Crushed faces.
- Compatible with the selected binder type.
- Aggregates must be damp for emulsion use but must be dry for use with hot binders.

The Caltrans specifications for aggregates used in chip seals are included in Section 37-2.01(Caltrans 2025). However, FHWA and local agencies in California have been using recycling asphalt pavements for chip seals and other preservation treatments (Duncan et.al, FHWA report 2020, San Diego County, 2024).

### 7.3.2 Chip Seal Design

Properly designed chip seals have proven to be cost effective in sealing pavements and providing a new riding surface with enhanced frictional characteristics. Many countries have developed rational chip seal design methods and, as a result, have used chip seals on major highways. Caltrans does not currently employ a formal design process for chip seals. The methods currently used are based on experience and do not address adjustments for the factors identified below.

The basics of chip seal design are straightforward, as the binder application and the aggregate application rates are the only major variables to consider. However, to correctly calculate these rates requires an understanding of the materials and the surface they are to be applied. Additional factors to consider include traffic, climate, and existing surface conditions. The proper binder and aggregate application rates are discussed in detail in the following two sections. The design of multiple seal coats is also briefly described. This following section is included for information purposes only and to provide a foundation for an improved design process. The McLeod method has been used by many agencies since the 1960's. It has been updated recently by Ullring et al, (2023). AASHTO has also developed a new design procedure as well, but it is not discussed here (AASHTO, 2016).

#### **McLeod Chip seal method**

In chip seal design, the residual binder application rate is the most important factor affecting seal performance. Enough binder must be present to hold the aggregate in place, but not so much that the binder fills, or is forced by traffic action to cover the aggregate. The proper amount of binder ensures that the desired surface texture is maintained. Chip seal design is not like hot mix asphalt design; film thickness is not as important. Binder application rates are determined on the average least dimension of the aggregate, as well as other aggregate properties such as shape, density, absorption, and grading. The optimum binder content also depends on how much binder flows into existing voids in the pavement, and how much binder is already present at or near the pavement surface.

The McLeod method is the most common design method for chip seals (McLeod, 1969); however, it is not used by Caltrans. This method assumes that 70% of the voids in the aggregate must be filled (i.e., 70% embedment). In some states, this is adequate and has been adopted as the standard; however, modifications can be made for varying project conditions. A more detailed discussion on this design method can be found in "A General Method of Design for Seal Coats and Surface Treatments" by N.W. McLeod (McLeod, 1969). The McLeod method also assumes the use of a cubical, single-sized aggregate. This may not always be the case (e.g., California specifications specify graded aggregates). The main modification for graded aggregates is determining a median aggregate size (50% passing). The aggregate shape must also be examined; this is done by measuring the

flakiness index (Ulring and Wood, 2021). The average least dimension (ALD) can then be determined using the following equation (Ulring and Wood, 2021):

$$H = [M/1.139285 + (0.011506)*FI] \dots \dots \dots (7.1)$$

where: *H* = Average Least Dimension, or (ALD)  
*M* = Median Particle Size  
*FI* = Flakiness Index

ASTM C29 is used to measure the loose unit weight. This approximates the voids in the loose aggregate when it is dropped onto the pavement. The voids in this state are 50% for cubical, single-size aggregate and lower for graded aggregate. It is assumed that once rolled, a cubical aggregate will reduce its unit weight to a voids content of 30% and finally to 20% once trafficked. These assumptions are adjusted when using graded aggregates. Figures 7-3 and 7-4 illustrate the average least dimension (ALD) concept, along with the effects of flakiness and changes in voids based on compaction.

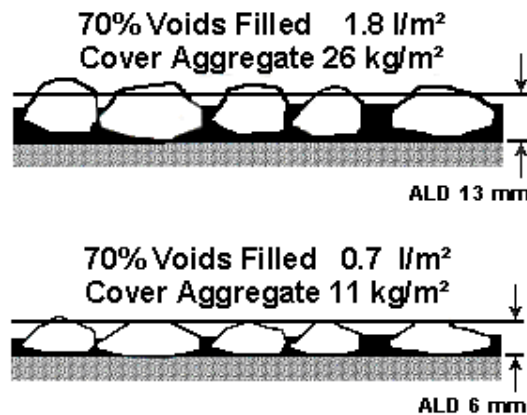


Figure 7-3 Illustration of Flakiness of Aggregates

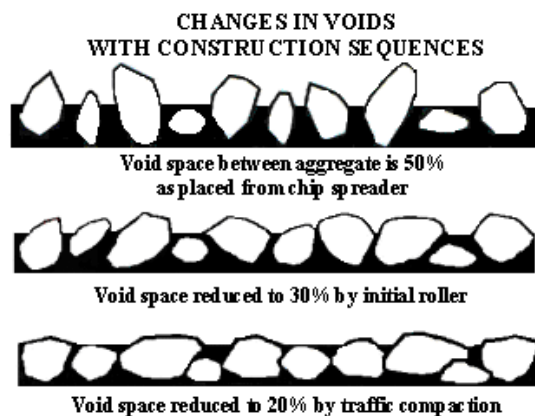


Figure 7-4 Effects of Compaction on Voids in Cubical Aggregate

The voids in loose aggregate may be calculated using the following equation (Ulring and Wood, 2021):

$$V = 1 - W / 62.4 * G \dots\dots\dots (7.2)$$

where: *V = Voids in the Aggregate*  
*W = Loose Unit Weight of the Aggregate (lbs./ft3)*  
*G = Bulk Specific Gravity of the Aggregate (usually determined from local information or measured)*

Most design methods calculate the specific requirements for each job by considering the required corrections in addition to the basic application rate (the rate designed to result in 70% embedment). One method for estimating the binder content is as follows (Ulring and Woods, 2021):

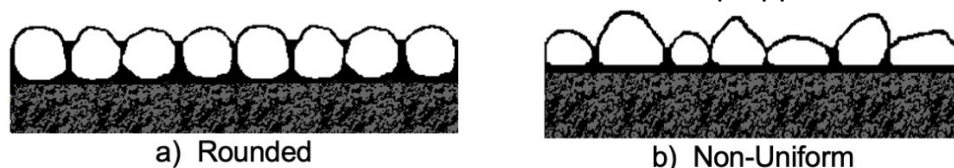
$$B = [2.244(H) \times T \times V + S + A + P] / R \dots\dots\dots(7.3)$$

where: *B = Binder Content (g/yd2)*  
*H = ALD (inches) – (See Figure 6-3)*  
*T = Traffic Factor – (See Table 6-3)*  
*V = Voids in Loose Aggregate (%) – (See Equation 7.2)*  
*S = Surface Condition Factor (g/yd2) – (See Table 7-5)*  
*A = Aggregate Absorption (g/yd2) – (See CTM 303)*  
*P = Surface Hardness Correction for Soft Pavement (g/yd2) – (See Table 7-6)*  
*R = Percent Binder in the Emulsion (%) – (See Manufacturer)*

For areas maintained by snowplows, the binder content is calculated using both the median particle size and the ALD. The average of these two results is used as the starting application rate in these areas.

Corrections to the basic aggregate application rate, address variables of the embedment to the binder. The corrections are applied to the calculation of the binder application rate. These variables include:

- **Aggregate Characteristics:** Important aggregate characteristics include absorption and shape. Corrections for absorption are based on experience and the characteristics of the local aggregates. The shape and size of chips produce different results: rounded chips leave greater voids and do not interlock and are not recommended. This type of chip also requires an additional binder. Non-uniform sized aggregates produce uneven surfaces. Figure 7-5 illustrates both rounded and non-uniform chip applications.



**Figure 7-5 Aggregate Shape Characteristics (South Australian DOT, 1995)**

- **Traffic Volume:** Traffic volumes account for achieving the ultimate embedment of 80% (20% void space). The traffic factor is lower for higher traffic volumes and higher for lower traffic volumes. Table 7-3 lists the application rate correction factors associated with varying traffic levels.

**Table 7-3 Traffic Factors (Urling and Woods, 2021, McLeod, 1969)**

Vehicles/Day	0-100	101-500	501-1000	1001-2000	>2000
Correction Factor	0.85	0.75	0.70	0.65	0.60

- **Loss of Aggregate Due to Traffic (Traffic Whip-Off):** This accounts for traffic operations removing aggregates from newly chip sealed roads. Reasonable values for losses are 5% for low volume roads and residential streets, and 10% for high-speed roads and highways. Table 7-4 lists road types and associated whip-off correction factors.

**Table 7-4 Road Type and Associated Aggregate Loss (Whip-Off) Factor (Urling and Woods, 2021)**

Road Type	Percent Wastage (%)	Whip-Off Factor (E)
Rural & Residential	5	1.05
Higher Volume Roads	10	1.10
State Highways	15	1.15

- **Existing Pavement Condition:** Existing pavement conditions are important to determine the optimum binder content. A smooth surface will require less binder than a rough or porous surface. Table 7-5 details the correction factors associated with various existing pavement conditions.

**Table 7-5 Correction Factors Associated with Existing Road Conditions (Urling and Woods, 2021)**

Existing Pavement	Correction (g/yd <sup>2</sup> )
Black, flushed asphalt	-0.01 to -0.06 (Depending on severity)
Smooth, non-porous or smooth	0.00
Slightly porous and oxidized or matte	+0.03
Slightly pocked, porous, and oxidized	+0.06
Badly pocked, porous, and oxidized	+0.09

- **Embedment:** Aggregates may be punched or embedded into soft pavement surfaces by roller compaction and traffic. Table 7-6 provides corrections based on surface hardness and related traffic volume using a Ball Penetrometer test (Austroads, 1990).

**Table 7-6 Binder Content Correction Based on Surface Hardness and Related Traffic Volume (Austroads, 1990)**

Surface Hardness	AADT per lane 150 to 300	AADT per lane 300 to 625	AADT per lane 625 to 1250	AADT per lane 1250 to 2500	AADT per lane >2500
Hard (Ball Value 1 – 2)	Nil	Nil	Nil	-0.1 l/m <sup>2</sup>	-0.2 l/m <sup>2</sup>
Medium (Ball Value 3 – 4)	Nil	Nil	-0.1 l/m <sup>2</sup>	-0.2 l/m <sup>2</sup>	-0.3 l/m <sup>2*</sup>
Soft (Ball Value 5 – 8)	-0.1 l/m <sup>2</sup>	-0.1 l/m <sup>2</sup>	-0.2 l/m <sup>2</sup>	-0.3 l/m <sup>2</sup>	-0.4 l/m <sup>2*</sup>

*\*Where embedment allowances of 0.3 l/m<sup>2</sup> or more are indicated, consider alternative treatments such as multiple chip seal (armor-coating) with higher quality materials rolled into the surface, or use a primer seal/ prime and seal with a small aggregate to place a larger aggregate seal.*

### Aggregate Application Rates

Calculation of the design aggregate application rate is based on determining the amount of aggregate needed to create an even, single coat of chips on the pavement surface. Though not used by Caltrans, the amount of cover aggregate required can be determined using the following equation (Urling and Woods, 2021):

$$C = 46.8 (1 - 0.4V) \times H \times G \times E \dots\dots\dots(7.4)$$

- where:
- C = Cover Aggregate (lbs/yd<sup>2</sup>)
  - V = Voids in Loose Aggregate (%)
  - H = ALD (mm) – (See Figure 7-3)
  - G = Bulk Specific Gravity – (See CT 206 & CT 208)
  - E = Wastage Factor (%)

Equation 7.1 is used to calculate H (average least dimension) and Equation 7.2 is used to calculate V (voids in loose aggregate). The bulk specific gravity of coarse and fine aggregates, G, can be determined using CT 206 and CT 208, respectively. The wastage factor (E) is to account for whip-off and handling and is normally estimated by the designer based on experience with local conditions. While other design methods are available, Equation 7.4 provides a good starting point and covers most situations. It requires that the user should consider the current attributes of the surface and the conditions to which it will be subjected after the seal coat.

The design of multiple seal coat is based on the same concepts as the single chip seal. First, a design is performed for each layer as if it were the only layer in the system. Next,

three additional rules are applied as follows: 1) the maximum nominal top size of each succeeding layer of cover aggregate should be no more than half the size of the previous layer's aggregate; 2) no allowance is made for wastage; and 3) except for the first application, no correction is made for the underlying surface texture. The amounts of binder determined for each layer of aggregate are added together to calculate the total binder requirement. For two-layer chip seals, 40% of the total binder requirement is applied for the first layer of aggregate and the remaining 60% is applied for the second layer.

**Caltrans Application Rates for PME and Asphalt Rubber Modified Seals**

Caltrans uses both emulsion and hot applied chip seals. They do not use an engineering approach yet but are considering updating their procedure to include corrections for traffic, pavement conditions, and climate in the near future.

**Emulsion Chip Seals.** According to 2025 Caltrans Standard Specifications, emulsions must be applied within the application rate ranges shown in Table 7-7. This applies not only to conventional but also to polymer modified emulsions.

**Table 7-7 Asphaltic Emulsion Application Rates**

<b>Aggregate Gradation</b>	<b>Application Rate Range (gal/sq. yd.)</b>
3/8"	0.30–0.45
5/16"	0.25–0.35
1/4"	0.20–0.30

For double asphaltic emulsion chip seals, the asphaltic emulsions must be applied within the application rates shown in Table 7-8.

**Table 7-8 Asphaltic Emulsion Application Rates**

<b>Double Chip Seals</b>	<b>Application Rate Range (gal/sq. yd.)</b>
1 <sup>st</sup> application	0.30–0.45
2 <sup>nd</sup> application	0.20–0.30

When applied, the temperature of the asphaltic emulsions must be from 130°F to 180°F. Apply asphaltic emulsions when the ambient air temperature is from 65°F to 110°F and the pavement surface temperature is at least 80°F. Do not apply asphaltic emulsions when weather forecasts predict the ambient air temperature will fall below 39°F within 24 hours after application. If high winds blow debris on the roadway or cause spreading issues for the binder, cease operations (section 37-2.02C(2)).

For single chip seals, aggregate must be spread within the spread rate ranges shown in Table 7-9. For double emulsion chip seals, aggregate must be spread within the spread rate ranges shown in Table 7-10.

**Table 7-9 Aggregate Spread Rates**

<b>Aggregate Gradation</b>	<b>Spread Rate Range. (lbs./sq. yd.)</b>
3/8"	20–30
5/16"	16–25
1/4"	12–20

**Table 7-10 Aggregate Spread Rates**

<b>Double Chip Seal</b>	<b>Spread Rate Range. (lbs./sq. yd.)</b>
1 <sup>st</sup> application	23–30
2 <sup>nd</sup> application	12–20

Sweep and remove the excess aggregate on the first application before the second application of asphaltic emulsion.

For Scrub Seals, the NSSP from Caltrans requires that the PMRE must be applied within the application rate ranges shown in Table 7-11 which is the same as for other chip seals (Caltrans Scrub Seal NSSP). These values should be adequate to create a wave in front of the broom. If not, the application rate should be increased until a wave is observed.

**Table 7-11 PMRE Application Rates**

<b>Aggregate Gradation</b>	<b>Application Rate Range. (gal/sq. yd.)</b>
3/8"	0.30–0.45
5/16"	0.25–0.35
1/4"	0.20–0.30

The PMRE should be applied when the ambient air temperature is from 60°F to 105°F and the pavement surface temperature is at least 80°F. Do not apply polymer-modified asphaltic emulsions when weather forecasts predict the ambient air temperature will fall below 39°F within 24 hours after application.

Aggregate gradations are the same as for the other chip seals, and the aggregate must be spread within the spread rate ranges shown in Table 7-12. You may stockpile aggregate for emulsion chip seals if you prevent contamination. Aggregate must have a damp surface at spreading.

**Table 7-12 Aggregate Spread Rates**

Chip Seal Type	Spread Rate Range (lbs./sq. yd.)
3/8"	20–30
5/16"	16–25
1/4"	12–20

Application rates utilized by many agencies come from prior experience. When applying the treatment, 50–70 percent of the aggregate particles should be embedded within the asphalt. If asphalt emulsion is used, the aggregate particles must have 55–60 percent embedment within (Asphalt Institute, 2009). The ideal aggregate particle shape for chip seals is cubical with fractured faces (Asphalt Institute, 2008).

**Hot applied chip seals.** Hot applied chip chips have used asphalt rubber, performance graded binders, and terminal blends or a rubberized asphalt binder. The most widely used hot applied binder is asphalt rubber. The asphalt rubber binder is applied when the ambient temperature is from 60°F to 105°F and the pavement surface temperature is at least 55°F. Do not apply the asphalt rubber binder unless enough aggregate is available at the job site to cover the asphalt rubber binder within two minutes. Intersections turn lanes, gore points, and irregular areas must be covered within 15 minutes (37-2.04C(3)).

Do not apply asphalt rubber binder when pavement is damp or during high wind conditions. If authorized, you may adjust the distributor bar height and distribution speed and use shielding equipment during high wind conditions. When applied, the temperature of the asphalt rubber binder must be from 385°F to 415°F. Apply the asphalt rubber binder at a rate from 0.55 to 0.65 gal/sq. yd. You may reduce the application rate by 0.050 gal/sq. yd. in the wheel paths.

The aggregate is spread at a rate from 28 to 40 lbs./sq. yd. Do not spread the aggregate more than 200 feet ahead of the completed initial rolling.

## 7.4 CONSTRUCTION

### 7.4.1 Construction Process

The sequence of construction events is as follows:

1. Pre-construction meeting

2. Project Preparation
3. Surface Preparation
4. Binder Application
5. Aggregate Spreading
6. Rolling
7. Sweeping (Brooming)

Figure 7-6 illustrates the construction process from binder application through final sweeping. Details of the construction process are provided in the following sections.



a) Binder Application



d) Spreading of Aggregate



c) Rolling



d) Sweeping

**Figure 7-6 Construction Process for Chip Seals**

#### 7.4.2 Preconstruction Meeting

A preconstruction meeting shall be held within 5 days of the start of the seal coat work. The meeting should include discussion of the following topics and should include the Engineer, the project superintendent, project foreman, and traffic control foreman:

- Quality control testing

- Acceptance testing
- Seal coat placement
- Proposed application rates for the emulsion or binder and the aggregate
- JITT training on placement methods
- Check list of items for proper placement
- Unique issues specific to the project
- Safety considerations
- Contingency plan for materials, equipment breakdowns, traffic handling, and possible detours
- Who has the authority to adjust application rates and how adjustments will be documented?
- When is brooming required?

### 7.4.3 Surface Preparation

Preparation of the surface is critical to the performance of the chip seal. This must be addressed in the plans and specs if needed. Areas of the pavement exhibiting structural failures (such as potholes and deteriorated patches) should be addressed by the removal or patching and sealing of the failed area. Avoid the use of cold mix for patching prior to applying the chip seal. Finally, the prepared surface must be clean, dry, and free of any loose material before applying the binder. Preparation for a chip seal project typically includes:

- Milling of the surface (if there is extensive loose material or areas of bleeding that must be removed).
- Crack sealing or filling of cracks that may reflect through the chip seal (see Chapter 4). Crack sealing should be allowed to cure before chip sealing, a minimum of 2 weeks.
- Patching any deteriorated areas or dig outs where required (see Chapter 5).
- Cleaning or brooming any loose material from the pavement surface, such as areas of raveling.
- Removing pavement markers and delineators.
- Covering all manholes, valves and monument covers, grates, or other exposed facilities using a plastic or oil-resistant construction paper, then secure by tape or adhesive to the facility being covered.

If the patched areas are generally more porous than the rest of the pavement, a fog seal or tack coat prior to chip sealing shall be required. Known shaded areas that seldom get sunlight (i.e. under bridge decks) may need a tack coat as well to prevent rock loss. This is particularly important when using emulsion chip seals.

### Materials

A work site needs to contain a facility for storing aggregate and binder. Generally, binders are trucked directly from the manufacturer and off loaded for use. However, situations arise when distance and weather can create the need for off-site storage. The site should be chosen well in advance of project start-up. The aggregate stockpile should ideally be placed on a sloped and paved surface, but at least on a sloped surface to promote drainage of the

stockpile. It should also ideally be protected from contamination with foreign material. Once stockpiled, the aggregate should not be moved until it is to be transported to the road being chip sealed. Following project completion, any remaining aggregate must be removed from the stockpile site and the site restored to its original condition. The methods for storing and handling binders and aggregates, for chip seals, are the same as those for terminal storage as outlined in Chapter 2 of this guide.

## **Weather Conditions**

On the actual day when chip seals are constructed, the weather should be clear and warm. In general, pavement surface temperatures should be 80°F and rising, and the humidity should be 50% or lower. Wind may cause the emulsion spray to be dispersed and compromise uniformity of application rate. It may also blow the emulsion onto passing cars, resulting in claims. A gentle breeze will assist in accelerating cure times. Any rainfall immediately before, during, or after the construction of the PME chip seal will contribute to failure of the treatment. Thus, placement of chip seals should be avoided during such conditions. The actual requirements vary for different binder types and are included in the Caltrans specifications. The pavement should be at least 60 °F for asphalt rubber binders. The temperature requirement could be different depending on different regions of California and season.

## **Traffic Control**

The Resident Engineer (RE) examines and approves the contractor's traffic control plan prepared in accordance with the Caltrans Safety Manual (Caltrans, 2021) and the Caltrans Code of Safe Operating Practices (Caltrans, 2021). The signs and devices used must match the traffic control plan. The work zone must conform to Caltrans practice and requirements set forth in the Caltrans Safety Manual and the Caltrans Code of Safe Operating Practices. All workers must have all the required safety equipment and clothing.

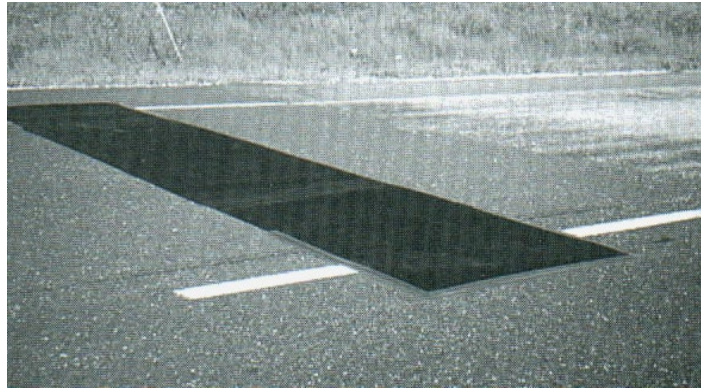
After chipping, pilot cars should be used for 2 and 4 hours to ensure that traffic speed is limited to approximately 20 mph (30 kph). Details can be found in Sections 37-2.01C(4)(d)(ii) and 37-2.01C(4)(d)(iii) of the 2025 Caltrans specs.

### *7.4.4 Joints*

Chip seal passes should begin and end on felt paper or the equivalent. This ensures that the transverse joints are clean and sharp. Longitudinal joints may be made with an overlap. In this process a wet edge (i.e., one without an application of aggregate) of 3 to 4 inches (75 to 100 mm) is left (not in a wheel path) and the next run overlaps this wet edge. The chip distributor then covers the whole run to the pavement's edge. Figure 7-7 illustrates the layout of felt paper at the end of a project lane. The wet edges for longitudinal joints are only for the emulsion chip seal and not for asphalt rubber chip seals.

### 7.4.5 Spraying Equipment

The spray distributor is the most important piece of equipment in the chip seal process. Its function is to uniformly apply the binder over the surface at the designed rate. Typically, spray distributors (boot trucks) are truck mounted as shown in Figure 7-8, but trailer units have also been used. A distributor should have a heating, circulation, and pumping system, along with a spray bar, and all necessary controls to guarantee proper application.



**Figure 7-7 Start and Stop Passes on Roofing Felt (Transverse Joints)**



**Figure 7-8 Spray Distributor**

### Distributor Preparation

The steps associated with preparing the distributor include the following:

- a) Calibrate the distributor by spraying a pre-weighed area of carpet (backed with a waterproof layer) and subtracting the initial weight from that of the sprayed carpet, then dividing the difference by the area of the carpet. Although this is the responsibility of the contractor, the inspector should verify that the distributor is spraying the binder at the correct application rate.
- b) Blow the spray nozzles to ensure there are no blockages and check the nozzle angles (see Figure 7-9) to ensure they spray at an angle 15 to 30 degrees from the

- spray bar axis. Often, the outermost nozzles will be turned in to give a sharp edge with no overspray.
- c) Check the distributor bar's height. The height is usually set so that a double or triple overlap is obtained as illustrated in Figure 7-10. It is typically between 12 inches and 14 inches.
  - d) Check the distributor bar's transverse alignment to ensure it is closely perpendicular to the centerline of the pavement.
  - e) Check the binder temperature to ensure it is in the appropriate range for proper application. Chip seal emulsion should be between 130°F and 180°F) Caltrans 2025. Ensure an adequate supply of binder is available.

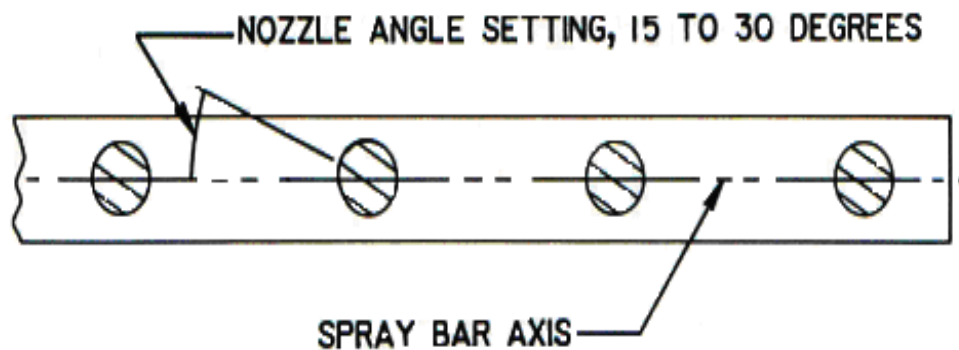


Figure 7-9 Spray Bar with Nozzle Arrangement (McLeod, 1969)

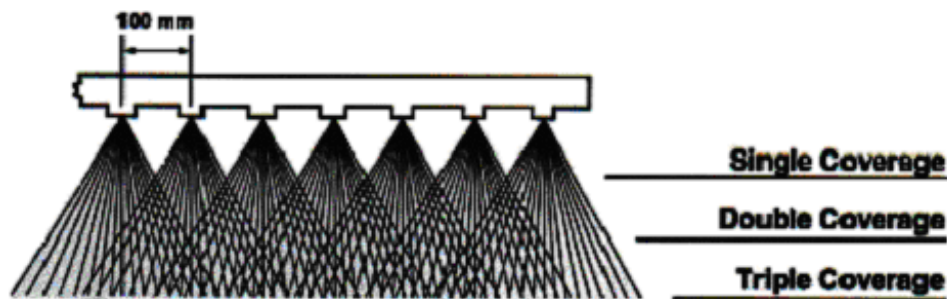


Figure 7-10 Spray Bar Height Arrangements (McLeod, 1969)

Visual checks should be made throughout the spraying process to ensure that the spray bars are clean and are spraying even fans. There should be no streaking of binder visible on the surface. If streaking occurs, the operation should be stopped to recheck proper functioning of the spray bar as well as per binder temperature. The inspector should check application rates frequently. The application rate can be checked using the calibration method mentioned above or using the alternative method outlined in Section 7.6.2 Field Considerations of this chapter. The method above is recommended for equipment calibration while the alternative method is appropriate for quick spot-checking during construction.

For scrub seals, the process is identical to that of a standard chip seal with the exception of the scrub seal broom which is used to force the emulsion into the crack. The wave of emulsion carried by the scrub broom is a function of the amount of cracking in the roadway. In addition, a PMRE can be applied at a rate of 0.25 to 0.40 gals/yd<sup>2</sup>. Unlike PME chip seals, cracks do not need to be sealed prior to applying the scrub seal. Figure 7-11 shows the scrub broom in action.



a) Scrub Box-Side View



b) Rear View

**Figure 7-11 Scrub Broom in Action**

## Chip Spreader

Chip spreaders must be able to spread an even coating of aggregate one layer thick over the entire sprayed surface. Figure 7-12 shows a typical chip spreader.



**Figure 7-12 Chip Spreader**

Prior to applying aggregate on a project, the following steps should be taken:

- a) Calibrate the spreader by spreading chips over a pre-weighed area of carpet and subtracting the initial weight from that of the carpet with chips spread onto it, then dividing the difference by the area of the carpet. Although this is the responsibility of the contractor, the inspector should verify that the spreader is applying the aggregate at the correct application rate.
- b) Ensure all gates in the spreader open correctly.
- c) Ensure the spreader applies the aggregate is an even, single-layer thickness.
- d) Ensure that the spreader is not leaving piles of aggregate and is not spreading too thick. Too thick a layer of aggregate can result in the aggregate being crushed under rollers or by traffic, compromising the seal. Too thick a layer of aggregate can also result in the lever and wedge effect illustrated in Figure 7-13, which also compromises the seal.
- e) Ensure an adequate supply of aggregate is available prior to applying the binder.
- f) Ensure proper moisture content of aggregate for PME chip seals. Ensure the aggregate for the asphalt rubber chip seals is precoated and hot.

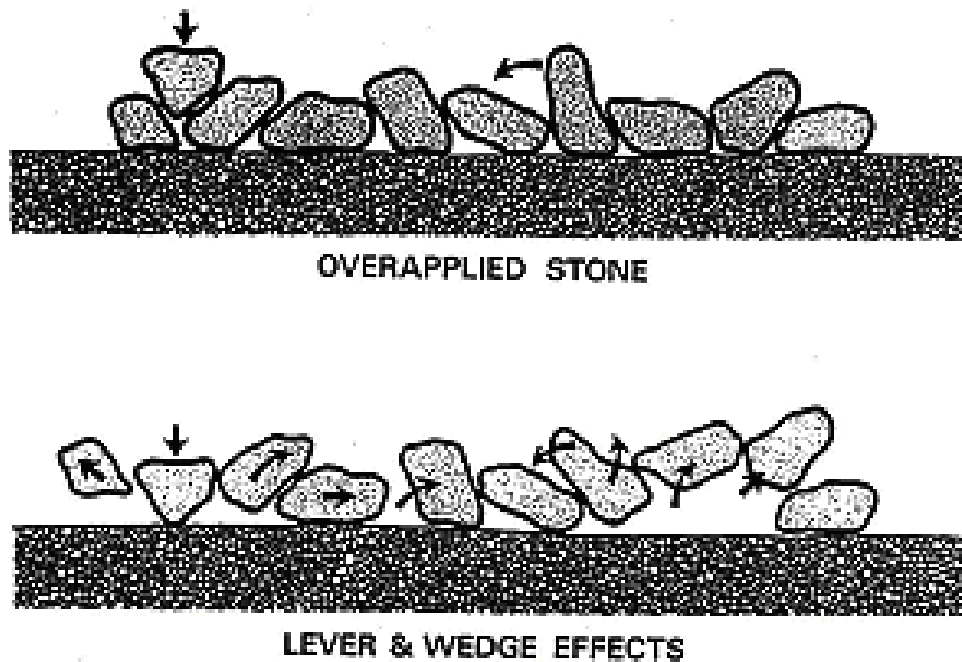


Figure 7-13 Lever and Wedge Effect (South Australian DOT, 1995)

### Chip Spreading Process

The application of aggregate should follow the binder application by no more than 90 seconds in order to obtain the best possible aggregate retention. A good visual check is that the spreader should be no more than 200 ft (60 m) behind the distributor truck. Typically, site conditions dictate this. The first chip spreading pass is usually done against traffic to allow good centerline to match up. The direction for spreading is chosen mostly to minimize truck movements on the fresh emulsion or hot binder. Schedule chip seal activities so that the chip seals are placed on both lanes of the traveled way each work shift.

Visual checks of the spreading operation include checking that the aggregate does not roll or bounce when spreading. The flow of aggregate should also be checked. If a wave of binder forms in front of the blanket of aggregate, the binder application may be too heavy. The scalping screen should also be checked for buildup of clay or other contaminants. If such contamination is heavy, it may be necessary to re-screen the stockpile. The spread pattern should be even without ripples or streaks. If ripples or streams occur, the spreading gates may need to be lowered, and the machine slowed down.

#### 7.4.6 Haul Trucks

Haul trucks are responsible for providing a continuous supply of binder to the site and aggregate to the spreader. Haul trucks should be in good mechanical condition and have back up alarms. Leaking haul trucks can compromise the seal binder. Single axle trucks carry between 5 and 7 tons (4,500 and 6,350 kg) and trucks with tandem axles between 11

and 14 tons (9,000 and 12,700 kg). For this reason, trucks with tandem axles are the preferred. The increased capacity requires fewer hook-ups resulting in less spillage and more efficient operation.

Tires on the trucks should be examined for binder pick up. If pick up occurs, it may severely damage the mat. Tires should be cleaned and sanded. Trucks should not drive on the new surface unnecessarily and should never brake sharply. When driving on the fresh mat, wheel paths should be staggered to assist in embedding the aggregate uniformly. When pulling away from the spreader, trucks should move smoothly and slowly to prevent wheel spin and mat damage. Trucks shall not be allowed to lose or dump chips when pulling away from the chip spreader. No sharp turning movements or high speeds should be allowed on a newly constructed chip seal. Only one haul truck should be allowed between the chip spreader and the rollers at any given time. All other trucks should be behind the rollers to allow them to properly seat the chips.

#### 7.4.7 Rolling

The function of the roller is to embed the aggregate into the binder and orient it into an interlocking mosaic. This is initially accomplished with pneumatic rollers as shown in Figure 7-14; compaction applied by traffic finishes the process. Rolling should be expedited in hotter weather to ensure proper embedment of the aggregate. Steel rollers are not normally recommended for chip seals because they can crush the aggregate. The important variables when rolling chip seals are:

- Contact pressure
- Number of passes and pattern
- Speed
- Smoothness of tires
- Adequate number of rollers

Rollers shall be pneumatic tired type. A minimum of 3 passes conforming to the provisions, Compacting Equipment, in section 37-2.01C(4)(d)(i) shall be furnished (Caltrans, 2025). Initial rolling shall consist of one complete coverage and shall be completed immediately behind the spreader. A coverage is one roller movement over the entire width of the chip seal. Asphalt emulsion and screenings shall not be spread more than 2,500 feet ahead of the completion of the initial rolling. Secondary rolling shall begin immediately after completion of the initial rolling. The amount of secondary rolling shall be sufficient to adequately seat the screenings and, in no case, shall be less than two coverages (Caltrans 2025) When two rollers are used, three passes are sufficient; one forward, one in reverse, and the final pass extending into the next section.



**Figure 7-14 Pneumatic (Rubber Tired) Rollers**

Contact pressure depends on the vehicle weight, the number of tires, tire size and rating, and the tire inflation pressure. Rollers that can be ballasted are very useful in assuring sufficient contact pressure. The ballasted weight should be 3,000 lbs per tire with a corresponding tire pressure of 100 psi. Tires must have a smooth tread, should not vary more than 7 psi in pressure, and should not wobble during operation. (Section 37-2.01C(2)).

Rollers should follow aggregate spreading by no more than 500 ft and should not be operated at more than 6 mph). The rolling pattern will depend on the number of rollers used.

#### **7.4.8 Brooming**

Brooming is required before, after, and sometimes during the chip seal operation. Before applying the chip seal, the pavement must be swept clean of dust and debris. During a multi-coat sealing operation excess aggregate shall need to be broomed off between coats. After the chip seal has been constructed, excess aggregate must be broomed off to minimize whip-off by traffic.

Brooming is done using rotary brooms with nylon or steel bristles or with vacuum mobile pickup brooms. Mechanical pickup brooms are typically specified for AR chip seals with pre-coated aggregate due to storm water contamination concerns. For PME and PMRE chip seals, only nylon brooms should be used. Steel tined brooms should only be used for AR chip seals. The broom should not be worn and should not be operated in such a manner that removes embedded aggregate. Figure 7-15 illustrates a typical brooming operation. Mobile pickup brooms are usually capable of picking up aggregate and storing it. Sometimes so-called “kick brooms” are used. These brooms move the aggregate into a

windrow so that it can be collected, but they often generate dust and may sweep aggregate into watercourses or gutters. Figure 7-16 illustrates a typical kick broom. Vacuum sweepers are preferred by many since they reduce dust and can reuse the collected materials.

Brooming can generally be done within 2 to 4 hours after sealing. Hot applied chip seals can be swept immediately following rolling while conventional chip seals can be swept in 2 to 4 hours. A flush coat shall be applied after brooming to eliminate further rock loss and improve durability prior to opening the pavement to uncontrolled traffic.



**Figure 7-15 Vacuum brooms working in Unison**



**Figure 7-16 Kick Brooms**

### 7.4.9 Summary

An overview of the entire chip seal operations is shown in Figure 7-17. Please note the positions of the various pieces of equipment.



**Figure 7-17 Overall View of a Chip Seal Operation**

## 7.5 FIELD TESTING

Most tests of constructed chip seals are empirical and provide the user an indication of what extra adjustments must be made on the job site. Though not used by Caltrans, the Ball Penetrometer Test (Austroads, 1990) and the Sand Patch Test (ASTM E965) are useful methods for checking the condition of the original pavement and the final seal. In the Ball Penetrometer Test, a ball is hammered on the pavement surface using a Marshall hammer a predetermined number of times. The amount of ball penetration into the existing surface is an indicator of the pavement's hardness with typical values ranging from 0 to 0.02 in (0 to 0.5 mm). The Sand Patch Test provides surface texture information for classifying surface type or examining seals with typical texture depths ranging from 0.04 to 0.1 in (1 mm to 2.5 mm) depending on the aggregate size. Figure 7-18 illustrates a technician performing the Ball Penetrometer Test and the Sand Patch Test.



a) Ball Penetrometer Test



b) Ball Penetrometer Test

**Figure 7-18 Field Test Methods**

The field Vialit test is a possible test for determining chip retention. Figure 7-19 shows a photo of this test. It was required by Caltrans with a percent retention of 95%.

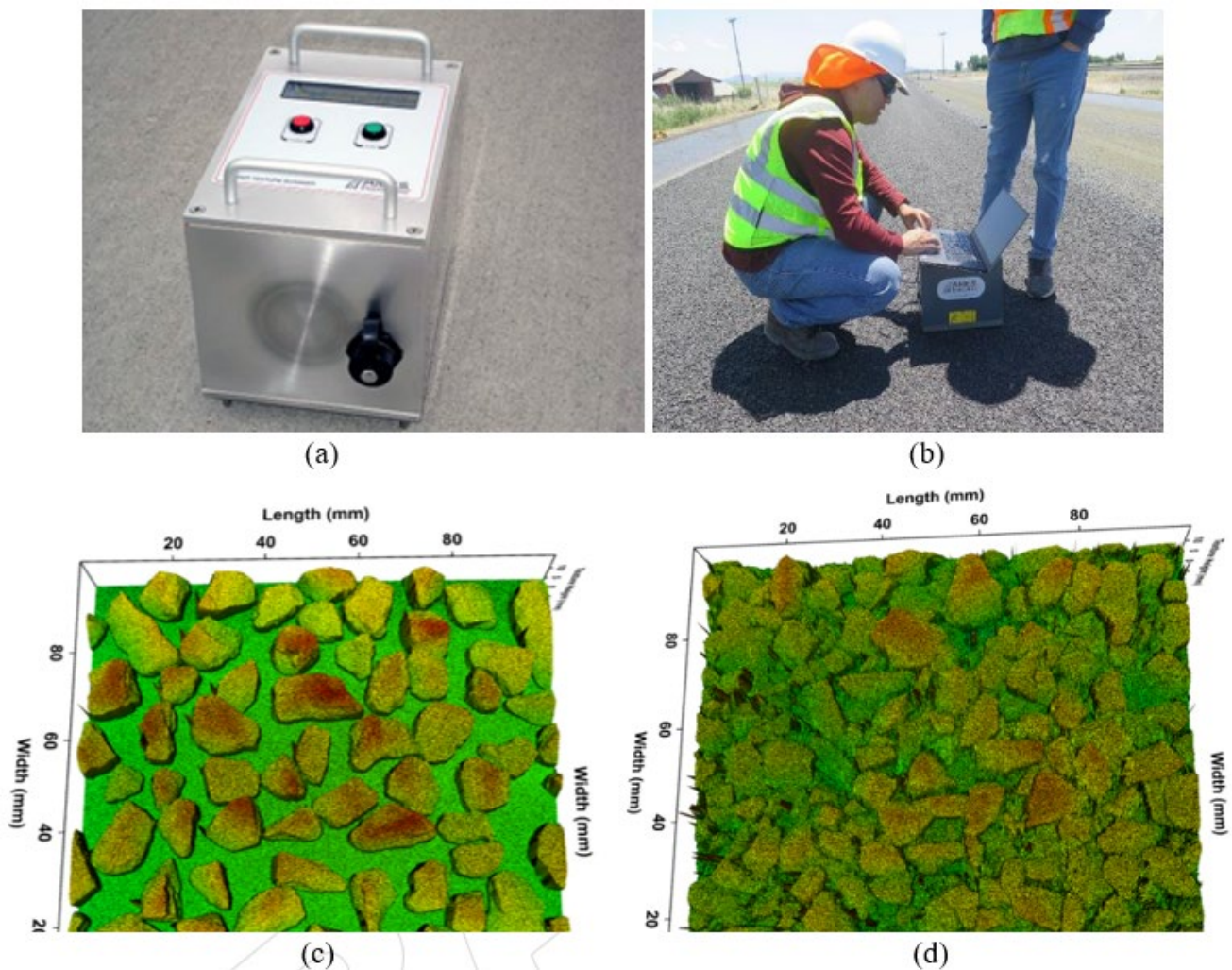


**Figure 7-19 Vialit Test**

The Ames Laser Texture Scanner (LTS 9400/9400HD) scans and measures the texture characteristics of pavement surface. It usually includes the following procedures:

- Scan chip seal sample,
- Download scan data to a PC through the Ethernet interface via the included Ames Texture Scanner software, and
- Calculate the mean profile depth (MPD).

Using an LTS device, the California Pavement Preservation (CP2) Center estimated the embedment of chip seals in an asphalt rubber chip seal pilot project for Caltrans in 2021 (Lane and Cheng 2022). Figure 7-20(a) shows an LTS device, while Figure 7-20(b) shows that staff of CP2 Center using LTS measuring the chip seal surface in a Caltrans project. As shown in Figure 7-20(c), 3/8-inch aggregates were scanned with a LTS 9400HD to generate a 3D surface model. The sampled rocks were laid down with their flat sides. By using the 3D surface model, the average aggregate least common dimension was calculated. Figure 7-20(d) shows the LTS scanned 3D model of newly constructed chip seal surface. By using a software, the 3D point clouds were generated from the 3D scans to calculate the peaks and valleys. Peak (height of aggregate and valley (height of binder) values were used to calculate each aggregate's embedment and then the average aggregate percent embedment (Lane and Cheng, 2022).



**Figure 7-20 LTS 9400/9400HD (a) Front View (b) Working Scene (c) 9400HD Scan of 3/8 inch Aggregates (d) 9400 Scan of a Chip Seal Surface (Ames 2022; Lane and Cheng, 2022)**

## 7.6 TROUBLESHOOTING AND FIELD CONSIDERATIONS

### 7.6.1 Troubleshooting Guide

This section provides information to assist maintenance personnel in troubleshooting problems with chip seals. The guide, along with a related table on problems and solutions, addresses common problems encountered during chip seal projects.

The troubleshooting guide presented in Table 7-13 associates common problems with their potential causes. In California, the most common problem is flushing. In addition to the troubleshooting guide, Table 7-14 lists some common problems and some recommendations.

**Table 7-13 Troubleshooting Chip Seal Problems (Emulsion/Asphalt Rubber)**

Cause	Excessive Loss of Aggregate	Crushing of Aggregates	Pickup of Binder	Adhesion Problems	Raveling of Aggregates	Streaking of Binder	Transverse Patches	Flushing	Failure In Shade	Polishing of Aggregate	Poor Mosaic of Finished Mat
Poor Traffic Control	•		•		•				•		•
Poor Equipment	•		•		•		•	•	•		•
Spray Temperature	•		•		•	•	•		•		•
Vehicle Speeds	•				•	•	•	•	•		•
Distributor Nozzles	•				•	•		•	•		
Cold Surfaces	•			•	•				•		•
Wet	•			•	•				•		•
Windy	•			•	•				•		•
Wrong Binder	•		•	•	•	•		•	•		•
Too Little Binder	•			•	•				•		•
Too Much Binder	•		•					•			•
Too Little Aggregate	•		•					•			•
Too Much Aggregate	•	•		•	•		•		•		•
Wet Aggregate	•			•	•			•	•		•
Dirty Aggregate	•			•	•				•		•
Quality Aggregate	•	•		•	•				•	•	
Wrong Size	•				•			•	•	•	•
Too Little Precoat	•			•	•				•		
Too Heavy Precoat	•				•						

**Table 7-14 Common Problems and Related Solutions**

Problem	Solution
<b>Streaking or drill marks in the emulsion</b>	<ul style="list-style-type: none"> <li>• Ensure the emulsion is at the correct application temperature.</li> <li>• Ensure the viscosity of the emulsion is not too high.</li> <li>• Ensure all the nozzles are at the same angle.</li> <li>• Ensure the spray bar is not too high or too low.</li> <li>• Ensure the spray bar pressure is not too high or too low.</li> <li>• Ensure nozzles are not plugged.</li> </ul>
<b>Exposed emulsion after chip application</b>	<ul style="list-style-type: none"> <li>• Ensure the chip spreader gate is not clogged or malfunctioning.</li> <li>• Ensure the chip spreader is covering all the binder</li> </ul>
<b>Excessive chips/Many chips with small amounts of emulsion</b>	<ul style="list-style-type: none"> <li>• Ensure the chip spreader gate is not malfunctioning or chipper head is not overloaded.</li> <li>• Lower the chip application rate.</li> </ul>
<b>Uneven chip application</b>	<ul style="list-style-type: none"> <li>• Re-calibrate the chip spreader; ensure all spreader gates are set the same.</li> </ul>
<b>Emulsion on the top of chips</b>	<ul style="list-style-type: none"> <li>• Ensure the chip spreader is not operating too fast.</li> <li>• Ensure trucks, rollers, and pilot cars are operating correctly at low speeds.</li> </ul>
<b>Chips being dislodged</b>	<ul style="list-style-type: none"> <li>• Ensure the emulsion application is not too light.</li> <li>• Ensure the chips are not dirty or dusty.</li> <li>• Ensure the traffic or equipment speeds are not too high.</li> <li>• Ensure brooming does not occur before the emulsion is properly set.</li> </ul>
<b>Emulsion bleeding or flushing</b>	<ul style="list-style-type: none"> <li>• Ensure the emulsion application is not too high.</li> <li>• Ensure the aggregate application is not too low.</li> </ul>
<b>After brooming, loss of chip at centerlines</b>	<ul style="list-style-type: none"> <li>• Check the centerline procedure.</li> <li>• Check binder application rate.</li> </ul>
<b>Excessive splattering of the emulsion</b>	<ul style="list-style-type: none"> <li>• Lower the spray pressure.</li> </ul>

### 7.6.2 Field Considerations

The following are field considerations to properly perform a chip seal. The various tables list items that should be considered to promote success. The answers to these questions should be carefully evaluated before, during, and after construction. The appropriate staff to do this will vary by job type and size, and some topics may need attention from several staff. The field supervisor should be acquainted with its contents. Responses to the questions in these tables are not meant to form a report, but rather to call attention to important aspects and components of the chip seal process. Some information is product-specific and contained in the relevant standard specifications, standard special provisions, or special provisions.

**Table 7-15 Field Considerations**

<b>Preliminary Responsibilities</b>	
<b>Project Review</b>	<ul style="list-style-type: none"> <li>• Is the project a good candidate for a chip seal?</li> <li>• How much rutting is present?</li> <li>• How much and what type of cracking exists?</li> <li>• Is crack sealing needed?</li> <li>• How much bleeding or flushing exists?</li> <li>• Review project for bid/plan quantities.</li> </ul>
<b>Document Review</b>	<ul style="list-style-type: none"> <li>• Bid specifications.</li> <li>• Special provisions.</li> <li>• Construction manual.</li> <li>• Traffic control plan (TCP).</li> </ul>
<b>Materials Checks</b>	<ul style="list-style-type: none"> <li>• Is the binder compatible with the chips?</li> <li>• Is the binder from an approved source (if required)?</li> <li>• Have the binder and aggregate been sampled and submitted for testing (if required)?</li> <li>• Are all chips close to the same size?</li> <li>• Are the chips clean and free of excess fines?</li> <li>• Are the chips used with emulsions in a surface-damp condition?</li> <li>• Is the emulsion temperature within application temperature specification?</li> </ul>
<b>Surface Preparation</b>	<ul style="list-style-type: none"> <li>• Is the surface clean and dry?</li> <li>• Have all pavement distresses been repaired and sealed?</li> <li>• Has the existing surface been inspected for drainage problems?</li> <li>• Have pavement markers been removed and temporary markers placed?</li> </ul>

**Table 7-15 Field Considerations (Continued)**

<b>Equipment Inspections</b>	
<b>Broom</b>	<ul style="list-style-type: none"> <li>• Are the bristles the proper length?</li> <li>• Can the broom be adjusted vertically to avoid excess pressure?</li> <li>• Are water misters operable?</li> </ul>
<b>Distributor</b>	<ul style="list-style-type: none"> <li>• Is the spray bar at the proper height?</li> <li>• Are all nozzles uniformly angled 15 to 30 degrees from the spray bar?</li> <li>• Are all nozzles free of clogs?</li> <li>• Is the spray pattern uniform and does it properly overlap (double or triple)?</li> <li>• Is the application pressure correct?</li> <li>• Are the distributor properly calibrated and correct size nozzle tips installed?</li> </ul>
<b>Chip Spreader</b>	<ul style="list-style-type: none"> <li>• Do the spreader gates function properly and are their settings correct?</li> <li>• Is the scalping screen in good condition?</li> <li>• Is the chip spreader’s calibration uniform across the entire chipper head?</li> <li>• Are the truck hook-up hitches in good condition?</li> </ul>
<b>Rollers</b>	<ul style="list-style-type: none"> <li>• What type of roller will be used on the project (pneumatic-tired roller recommended)? Do rollers meet weight requirements?</li> <li>• Does the roller tire size, ratings, and pressures comply with the manufacturer’s recommendations and specifications?</li> <li>• Are the tire pressures the same on all tires? Check weights as well</li> <li>• Do all tires have a smooth surface?</li> </ul>
<b>Haul Trucks</b>	<ul style="list-style-type: none"> <li>• Is the truck box clean and free of debris and other materials?</li> <li>• Is the truck hook-up hitch in working order? What about the back-up alarm?</li> <li>• Is a truck box apron or extension required for loading the chip spreader?</li> </ul>

**Table 7-15 Field Considerations (Continued)**

<b>Equipment Inspections</b>	
<b>Weather Requirements</b>	<ul style="list-style-type: none"> <li>● Do the specifications describe a range of dates when chip sealing can be done?</li> <li>● Have air and surface temperatures have been checked at the coolest location on the project?</li> <li>● Do air and surface temperatures meet agency requirements?</li> <li>● Are high winds expected? High winds can create problems with the emulsion application.</li> <li>● Will the expected weather conditions delay the breaking of the emulsion? High temperatures, humidity, and wind can affect how long the emulsion takes to break.</li> <li>● The application of emulsion should not begin if rain is likely within 24 hours.</li> </ul>
<b>Determining Application Rates</b>	<ul style="list-style-type: none"> <li>● Have agency guidelines and requirements been followed?</li> <li>● Has a chip seal design been done?</li> <li>● Is the surface oxidized or porous? More oil is applied to dried-out and porous surfaces.</li> <li>● Is the traffic volume on the road low? More oil is applied on roads with low traffic volumes.</li> <li>● Is the surface smooth, non-porous, or bleeding? Less oil is applied to smooth, non-porous, and asphalt-rich surfaces.</li> <li>● Is the traffic volume on the road high? Less oil is applied on roads with high traffic volumes.</li> </ul> <p>Is there a salt and pepper appearance after the chips have been applied?</p>

**Table 7-15 Field Considerations (Continued)**

<b>Binder Calibration Considerations</b>	
<b>Checking Application Rates</b>	<p><b>Binder – Method A (Recommended for Calibration)</b></p> <ul style="list-style-type: none"> <li>• The weight of a 1yd<sup>2</sup> (0.84 m<sup>2</sup>) carpet, pan, or non-woven geotextile material is recorded.</li> <li>• The carpet, pan, or non-woven geotextile material is placed on the road surface.</li> <li>• The distributor applies oil over the carpet, pan, or geotextile material.</li> <li>• The weight of the carpet and oil, pan and oil, or geotextile material and oil is recorded.</li> <li>• The weight of the carpet, pan, or geotextile material without oil is subtracted from the weight of the carpet, pan, or geotextile material with emulsion.</li> <li>• The weights applied to the area of carpet (i.e., lb/yd<sup>2</sup> or kg/m<sup>2</sup>) must be converted to the units of the control mechanism, which is gal/yd<sup>2</sup> or l/m<sup>2</sup>, knowing the specific gravity of the emulsion. If the distributor is not spraying the binder at the correct application rate, adjustments must be made to the controls and the process described above repeated until the correct application rate is achieved. Although this is the responsibility of the contractor, the inspector should verify that the distributor is spraying the binder at the correct application rate.</li> </ul>

**Table 7-15 Field Considerations (Continued)**

<b>Binder Calibration Considerations</b>	
<b>Checking Application Rates</b>	<p><b>Binder – Method B (Recommended for Random Checks)</b></p> <ul style="list-style-type: none"> <li>● Park the distributor on level ground and measure the number of liters or gallons of emulsion. Mark the locations of the front and back tires.</li> <li>● Measure off a known distance for a test section.</li> <li>● Have the distributor apply emulsion to the test section.</li> <li>● Return the distributor to the original level ground and re-measure the number of liters or gallons of emulsion.</li> <li>● Subtract the number liters or gallons after application from the original number of liters or gallons to obtain the number of liters or gallons applied.</li> <li>● Divide the number of liters or gallons applied by number of square meters or square yards covered by emulsion to give the application rate in gal/yd<sup>2</sup> or l/m<sup>2</sup>.</li> <li>● If the distributor is not spraying the binder at the correct application rate, adjustments must be made to the controls and the process described above repeated until the correct application rate is achieved. Although this is the responsibility of the contractor, the inspector should verify that the distributor is spraying the binder at the correct application rate.</li> </ul>
<b>Chip Calibration considerations</b>	
<b>Checking Application Rates</b>	<p><b>Chips – Method A (Recommended for Calibration)</b></p> <ul style="list-style-type: none"> <li>● Weigh a 1 yd<sup>2</sup> (0.84 m<sup>2</sup>) tarp or geotextile material.</li> <li>● Place the tarp or geotextile material on the roadway.</li> <li>● Have the chip spreader apply the chips over the tarp or geotextile material.</li> <li>● Weigh the tarp or the geotextile material with the chips.</li> <li>● Subtract the original weight of the tarp or geotextile material from the weight of the tarp or geotextile with the chips. Divide the weight of the chips by the area of the tarp or geotextile to give the application rate in lb/yd<sup>2</sup> or kg/m<sup>2</sup>.</li> </ul>

**Table 7-15 Field Considerations (Continued)**

<b>Chip Calibration considerations</b>	
<b>Checking Application Rates</b>	<p><b>Chips – Method B (Recommended for Random Checks)</b></p> <ul style="list-style-type: none"> <li>● Weigh a haul truck empty.</li> <li>● Load the haul truck with chips and reweigh the truck.</li> <li>● Subtract the weight of the empty truck from that of the loaded truck to obtain the weight of the chips.</li> <li>● Empty all the chips into the chip spreader.</li> <li>● Have the chip spreader apply all of the chips from the weighed truck.</li> <li>● Measure the length and width of the area over which the chips were spread.</li> <li>● Divide the weight of the chips by the area over which they were spread to determine actual rate in lb./yd<sup>2</sup> or kg/m<sup>2</sup>.</li> </ul>
<b>Project Inspection Responsibilities</b>	
<b>Binder Application</b>	<ul style="list-style-type: none"> <li>● Is roofing felt or building paper used to start and stop binder application?</li> <li>● Is the binder within the required application temperature range?</li> <li>● Does the application look uniform?</li> <li>● Are any nozzles plugged?</li> <li>● Is there streaking in the applied binder?</li> <li>● Are application rates randomly checked? Have you sampled the binder?</li> <li>● Is the speed of the distributor adjusted to match the chip spreader to prevent stop-and-start operations?</li> <li>▪ Is the distributor stopped if any problems are observed?</li> </ul>

**Table 7-15 Field Considerations (Continued)**

<b>Project Inspection Responsibilities</b>	
<b>Chip Application</b>	<ul style="list-style-type: none"> <li>• Are enough trucks on hand to maintain a steady supply of chips to the spreader?</li> <li>• The application starts and stops with neat, straight edges?</li> <li>• The binder application starts and stops on building paper or roofing felt.</li> <li>• The chip spreader follows closely (33 yds [30 m] or less) behind the distributor when an emulsion is used?</li> <li>• The chip spreader travels slowly enough to prevent chips from rolling when they hit the surface.</li> <li>• Are the chips in a surface damp condition?</li> <li>• No binder is on top of the chips.</li> <li>• The application is stopped as soon as any problems are detected.</li> <li>• Does the application appear uniform? Have you sampled the chips?</li> <li>• Do the chips have a salt and pepper appearance?</li> <li>• Check the percent chip embedment in the binder and adjust binder or chip application rate if required.</li> </ul>
<b>Traffic Control</b>	<ul style="list-style-type: none"> <li>• The signs and devices used match the traffic control plan.</li> <li>• The work zone complies with Caltrans methods.</li> <li>• Flaggers do not hold the traffic for extended periods of time.</li> <li>• The pilot car leads traffic slowly - 25 mph (40 kph) or less - over fresh chip seals?</li> <li>• Signs are removed when they no longer apply.</li> <li>• Any unsafe conditions are immediately reported to a supervisor?</li> </ul>
<b>Rolling</b>	<ul style="list-style-type: none"> <li>• The rollers follow closely behind the chip spreader.</li> <li>• The entire surface is rolled at least twice.</li> <li>• Roller speeds kept at 5 mph (8-9 kph) maximum?</li> <li>• The roller's first pass is on the meet line.</li> <li>• Rollers do not drive on exposed emulsion.</li> <li>• All stop, starts, and turns are made gradually.</li> </ul>

**Table 7-15 Field Considerations (Continued)**

<b>Project Inspection Responsibilities</b>	
<b>Truck Operation</b>	<ul style="list-style-type: none"> <li>• Trucks travel slowly on the fresh seal.</li> <li>• Stops and turns are made gradually.</li> <li>• Truck operators avoid driving over exposed binder.</li> <li>• Trucks stagger their wheel paths when backing into the chip spreader? This helps to eliminate chip roll over and aids in rolling.</li> </ul>
<b>Longitudinal Joints</b>	<ul style="list-style-type: none"> <li>• The meet line is only as wide as the spray from the end nozzle—about 8 in (20 cm)?</li> <li>• The distributor lines up so that the end nozzle sprays the meet line.</li> <li>• The meet lines are not made in the wheel paths.</li> <li>• The meet lines are made at the center of the road, center of a lane, or edge of a lane.</li> <li>• The meet lines are covered overnight.</li> </ul>
<b>Transverse Joints</b>	<ul style="list-style-type: none"> <li>• All binder and chip applications begin on building paper or roofing felt.</li> <li>• The building paper or roofing felt is disposed of properly?</li> </ul>
<b>Brooming</b>	<ul style="list-style-type: none"> <li>• Brooming does not dislodge the aggregate.</li> <li>• Brooming begins as soon as possible, but not until a sufficient bond has formed between the chip and the binder. Check with the binder manufacturer for their recommendation or refer to agency requirements.</li> <li>• Are misters on mobile pickup brooms operating?</li> </ul>
<b>Opening the Chip Seal to Traffic</b>	<ul style="list-style-type: none"> <li>• Traffic travels slowly –25 mph (40 kph) or less—over the fresh seal coat until the chip seal is broomed and opened for normal traffic?</li> <li>• Reduced speed limit signs are used when pilot cars are not used.</li> <li>• Are pavement markings placed before opening chip seal to normal traffic?</li> <li>• Are all construction-related signs removed when opening chip seal to traffic and traffic control is removed?</li> </ul>
<b>Clean Up</b>	<ul style="list-style-type: none"> <li>• Is all loose aggregate from brooming removed from the roadway and disposed at an approved disposal site?</li> <li>• Are binder spills cleaned up?</li> </ul>

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