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Manual for Cape Seals

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MANUAL FOR CAPE SEALS

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16. Abstract

Cape seals are valuable preservation treatments for roads which receive light to medium traffic, and have also performed well on higher-volume roadways. Cape seals are surface treatments which are placed on an existing asphalt pavement.

Cape seals are a multi-layered treatment pavement preservation treatment. First, a chip seal is placed by spraying the pavement with a binder—either an asphalt emulsion or a hot applied asphalt binder—from a distributor truck, and then immediately applying a uniform application of a cover aggregate (a.k.a. chips, or screenings) using a self-propelled chip spreader. The aggregate is quickly rolled to ensure embedment and adhesion of the aggregate to the binder. A slurry surfacing is then applied on top of the chip seal. A slurry surfacing could either be a slurry seal or a microsurfacing. The slurry surfacing provides for a smooth surface, which is desired in most city and residential areas.

This manual presents information on project selection, mix design, and construction to ensure a superior product. It also includes some typical specifications for chip seals and slurry surfacing used for cape seals. It is one of three new reports prepared by the CP2 Center using SB-1 funding. The other two reports provide more detail on chip seals and slurry surfacing. The creation of these reports was a task funded by California Senate Bill 1 (SB-1), passed in April 2017.

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EXECUTIVE SUMMARY

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I. INTRODUCTION

BACKGROUND

California passed Senate Bill 1 (SB-1) in 2017 to raise revenue for transportation infrastructure improvements through increased state gas and other taxes. Part of this money will be distributed back to the local agencies and will be split between all cities and counties throughout the state. The purpose of this manual is to provide information and training for local agency staff so that they will have the ability to recognize their maintenance options and to develop the most cost-effective strategies for preserving their aging hot mix asphalt (HMA) pavements.

Cape seals originated in Cape Province of South Africa near Cape Town, hence the name Cape. They consist of a single chip seal which is covered by a slurry seal or microsurfacing. They were first used as a wearing course in the construction of low-volume roads. In the past several years, they have evolved into maintenance treatments that can be successfully used on both low- and high-volume roads. The popularity of Cape seals is a direct result of their low initial costs in comparison to thin hot mix asphalt (HMA) overlays. Currently, with improved binders and equipment, considerable interest has been shown for using Cape seals in a wide range of applications, such as on public roads, highways, local streets, and a multitude of other surfacing needs throughout the world.

Different binders can be used in the chip seals, being either cold or hot applied. Cold applied binders include modified and unmodified asphalt emulsions, normally with rapid setting additives. Hot applied binders can be polymer-modified asphalt cements, asphalt rubber, and rubberized asphalt such as polymer/crumb rubber blends. The chip seal surface is then covered as soon as possible with a slurry surfacing, either a slurry seal or a microsurfacing. The appropriate binder type for the chip seal layer and the slurry surfacing are selected based on pavement condition, climate, and aggregate properties, desired service life, and cost considerations.

In recent years, multi-layer treatments, which include a layer of a Type III microsurfacing as leveling course, followed by a hot applied chip seal and topped with a slurry seal or microsurfacing, have been used on poor pavements with some success.

Figure 1 shows this concept where the Type III microsurfacing can be used to fill cracks or ruts.

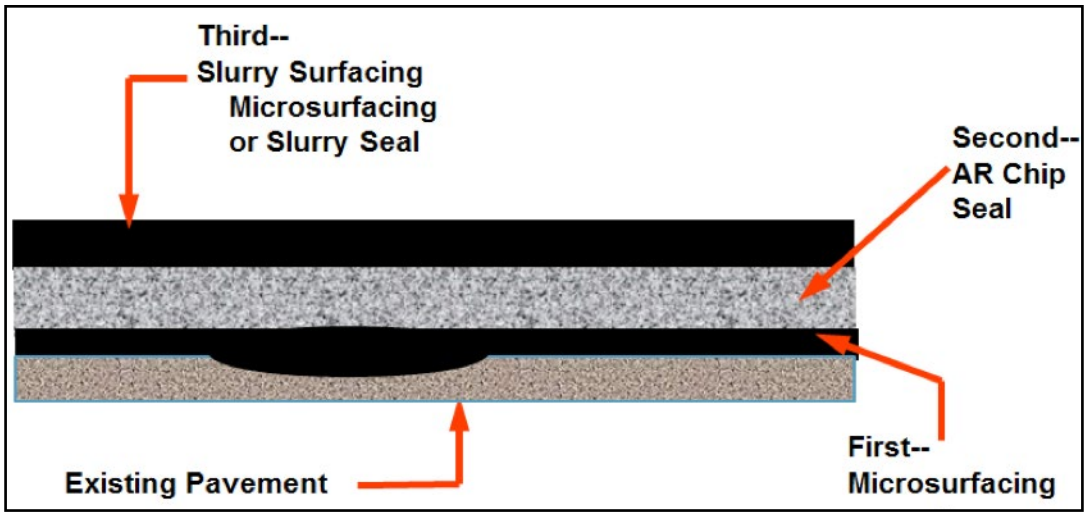

Figure 1. Triple Layer Cape Seal with Rut Filling

PURPOSE

This manual is one of several designed to empower local agency staff, through training, to choose the right treatment at the right time to optimize their maintenance funds. Most local agencies have deferred road maintenance over many years, and there are thousands of miles of public roads that are currently in poor condition. With the new SB-1 funding available for maintenance and construction projects, the importance of proper road maintenance is paramount. Cape seals are just one type of many maintenance treatments that will preserve pavements until a re-construction project can be designed and funded. Cape seals extend the life of a pavement via the prevention of moisture intrusion into the HMA layer, as well as the base and subgrade. When properly designed and constructed, a Cape seal is a cost-effective tool that provides improved life cycle cost benefits.

Although an untreated asphalt pavement may still be adequate after several years of use, pavement deterioration will have already begun, and the application of a Cape seal needs to be applied before significant deterioration has occurred.

ORGANIZATION OF THE MANUAL

This manual is one of three manuals for pavement preservation. The three manuals are 1) Slurry Surfacing, 2) Chip Seals, and 3) Cape Seals.[4 5] This manual discusses Cape seals, including project selection and the design and construction processes. More detail on the design and construction of chip seals and slurry surfacing can be found in the companion manuals.

II. PROJECT SELECTION

WHEN SHOULD A CAPE SEAL BE USED?

The selection of a pavement for a Cape seal project is based on the structural soundness of a pavement and the types of distress that are present. The ability of a specific treatment to address the current condition of a project is paramount in selecting an appropriate treatment.

The main advantages associated with Cape seals include:

- Improved Skid Resistance: Cape seals provide good skid resistance.
- Cost-Effective Treatments: They are cost-effective when properly placed at the right time on the right type of pavement.
- Good Durability: They wear well and can have long service lives.
- Resists Reflective Cracking: Asphalt rubber chip seals used in Cape seals reduce moisture intrusion and slow the deterioration of underlying pavements, as well as resisting the reflection of those cracks to the Cape seal surface.
- Ease of Construction: Cape seals are typically constructed rapidly and cause less disruption to the traveling public than do HMA overlays.
- User Friendly: The finished surface is relatively smooth and is more pleasing to cars, pedestrians, bicyclists, skateboarders than a chip seal.

The main disadvantages associated with Cape seals include:

- Cure Time: Seals involving asphalt emulsions take several hours (depending on the climatic conditions) to cure to a stage where they can tolerate unrestricted traffic.
- Flying Chips: Cape seals involving asphalt emulsions must be repeatedly swept to remove excess stone to avoid broken windshields and vehicle damage.
- Traffic Disruptions. Because separate lane closures are necessary for each operation, traffic disruption and construction time will be greater.
- Weather Considerations: Cape seals involving asphalt emulsions must be constructed during warm, dry weather and during the daytime only. For hot applied Cape seals, the chip seal may be applied in cooler conditions and possibly at night.

WHEN SHOULD A CAPE SEAL NOT BE USED?

Cape seals, particularly those using emulsions, should not be used in the following situations:

- Structurally deficient pavements, such as extensive alligator cracking in the wheel paths
- Numerous cracks greater than 1/4 inch in width, except for asphalt rubber Cape seals on stable pavements with compatible traffic use
- Large number of potholes
- Ride quality needs significant improvement
- Deformation, rutting, and shoving are prevalent
- There could be rain within 24 hours or there is too much wind (for spraying the chip seal) or temperature too low (less than 70°F).

With major localized distresses, repairs must be made prior to Cape sealing, particularly on higher volume roads. Repairs may include the following:

- Digouts
- Patching
- Rut filling

Best practices would be to place a pavement preservation treatment (such as a Cape seal) prior to the pavement reaching a PCI of less than 70. However, with some of the hot applied Cape seals, treatments have been applied to pavements with a PCI value below 50. Multi-layer treatments have been applied to pavements with a PCI as low as 30. Figure 2 shows the PCI values from 0–100 and their corresponding pavement condition rating.

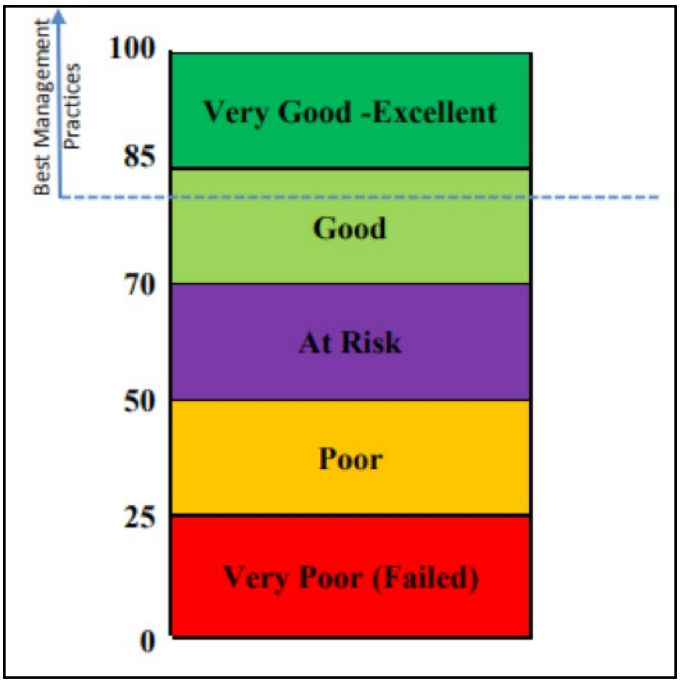

Figure 2. StreetSaver Pavement Condition Index Classifications

(County of Riverside Department of Transportation)[1]

III. TYPES OF CAPE SEALS

Cape seals are combinations of chip seals followed by slurry surfacing. Two broad types of chip seals are currently used: those using asphalt emulsions and those using hot-applied binders to secure the chips. For the slurry surfacing over the chip seal, either a slurry seal or microsurfacing could be used depending on the climate, traffic, and other factors.

ASPHALT EMULSION CAPE SEALS

Types of Emulsions

For the chip seal layer, the emulsion binder type varies according to the type of chip seal being constructed. Binder types include:

- Polymer-Modified Emulsion: Asphalt emulsions are composed of a bituminous material uniformly emulsified with water and an emulsifying or stabilizing agent. Polymer-modified asphalt emulsions also contain polymers to help improve flexibility and chip adhesion. Anionic and cationic emulsions, and polymer-modified emulsions (PME), such as PMCRS-2 and PMCRS-2h, are included in the 2018 Standard Caltrans Specifications, Section 94.[2]

- Rejuvenating Emulsion: These emulsions are modified with rejuvenating oils that are used to penetrate and soften existing aged and oxidized asphalt pavements. This type of emulsion is not only highly polymerized (which adds flexibility, toughness and durability to a chip seal), but it also contains a recycling agent that helps restore the aged pavement surface. With rejuvenation, the aged surface and the walls of the cracks that have occurred through distress are decreased.

For the slurry surfacing, the types of emulsions used in California include the following:

- Conventional QS emulsions
- Polymer-modified QS emulsions (most widely used)
- Rubberized emulsions
- Rubberized Polymer-Modified Emulsions (RPME)
- Microsurfacing emulsions (MSE)

The Greenbook specifies only QS emulsions, as shown below in Table 1 Greenbook Table 203-3.4.5B.[3]

Table 1. Quick-Set Polymer-Modified Emulsion (PMCQS-1h)

Property	Test Method	Value	
		Min.	Max.
Tests on emulsion:			
Saybolt Furol Viscosity@ 25°C, SFS[1]	AASHTO T 59	15	90
Sieve test, %	AASHTO T 59	--	0.30
Storage stability, 1-day, %	AASHTO T 59	--	1
Residue by evaporation, %	AASHTO T 59	60	--
Particle charge	AASHTO T 59	Positive	
Tests or residue by evaporation:			
Penetration, 25°C	AASHTO T 49	40	90
Ductility, 25°C, mm	AASHTO T 51	400	--
Elastic Recovery, %	AASHTO T 301	50	--
Softening Point, °F	AASHTO T 53	135	--

[1] SFS means Saybolt Fural seconds.
[2] PMCQS-1h shall contain a minimum of 2.5 percent polymer content by weight of residual asphalt.

Aggregates

Chip Seal Layer

Aggregates used for emulsion chip seals are usually one-sized and of good quality. 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 and angular shape
- Compatible with the selected binder type
- Damp for emulsion use

Slurry Surfacing Layer

Aggregates for slurry surfacing are well-graded and of good quality. The best performance is obtained when the aggregate has the following characteristics:

- Well-graded
- Clean
- Free of clay
- Crushed faces
- Compatible with the selected binder type
- Aggregates must be damp or surface dry

HOT APPLIED CAPE SEALS

Types of Binders

Chip Seal Layer

The types of binders commonly used in hot applied chip seals in California include the following:

- Performance Graded (PG) Asphalt with Polymers: California is divided into different climate zones based on different climatic conditions. PG asphalt binders are selected to meet expected climatic conditions as well as aging considerations with a certain level of reliability. Polymer modified binders are required in more adverse climate conditions for wider temperature ranges.

- Asphalt Rubber (AR) Binder: These binders are modified with 18–22 percent crumb tire rubber, high natural rubber, and oil extenders, and are generally produced at a field blending plant. These binders are hot applied and require that hot pre-coated chips be placed immediately on the hot AR binder. Hot applied AR binders can be placed at cooler temperatures than emulsion binders and can be placed at night. AR binders are by far the most common type of hot applied chip seal used in California.

- Terminal Blends. These binders are modified with a minimum of 10 percent fine crumb rubber and a minimum of three percent polymer. The blending is done at the refinery or at a field blending plant. These binders are hot applied and require hot pre-coated chips to be placed immediately on the hot binder.

Slurry Surfacing Layer

The binder options for the slurry surfacing are the same as those used in the asphalt emulsion Cape seal. The binders for the slurry are always emulsions and not a hot binder.

Aggregates

Chip Seal Layer

Aggregates used for hot applied chip seals are also single-sized and of good quality. 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 dry for use with hot binders

The aggregates used in these applications also are hot and pre-coated with an asphalt binder of 0.5 to 1.0 percent to ensure better chip retention. The specifics on the aggregates used, including the gradations, are discussed further in a later chapter.

Slurry Surfacing Layer

Aggregates used in the slurry surfacing for the hot applied Cape seal should be of the same quality as used in the emulsion-based Cape seal.

Example of a Completed Cape Seal

In this case, a two-layer Cape seal was placed over approximately 40 percent of the project area, where the streets had few voids and depressions, as opposed to a three-layer seal system used on streets with greater distress. However, some prior PCIs of streets treated with a two-layer Cape seal were as low as 30. The two-layer Cape seal streets had no microsurfacing beneath the chip seal. Figure 3 (right) shows an example of a Cape seal using a two-layer approach of AR chip seal followed by a slurry seal after eight years of performance. This pavement still has additional service life.

Figure 3. City of Lompoc, Pre-project (Lt.), Same Location After 8+ Years (Rt.)

Multi-Layer Seals

In recent years, multi-layer treatments have been used by local agencies on poorer roads and streets. These generally consist of three layers including Microsurfacing + AR Chip Seal + Slurry Seal. This combination for a multilayer Cape seal can perform very well over a relatively long time period (over eight years) and still retain additional service life. Figure 4 shows a highly distressed pavement both before treatment and after over eight years of service within the City of Lompoc, California. The treatment is holding up very well with residential traffic, including trash collection trucks. This pavement still has additional service life.

Figure 4. City of Lompoc Pre-project (Lt.), Same Location After Eight Years (Rt.)

IV. DESIGN PROCESS FOR CAPE SEALS

This section of the report summarizes the design process for Cape seals, including chip seals and slurry surfacing, the two treatments that combine to make up a Cape seal. For more details on the design process, please refer to the companion manuals on chip seals and slurry surfacing.[4] [5]

The design process primarily involves determining the optimum spread rates for the chip seal elements (binder and aggregate) and for the slurry surfacing layer. For slurry surfacing, the mix design process is more complex, as discussed in detail in the Slurry Surfacing Manual. Either a slurry seal or microsurfacing may be placed over the chip seal to create a Cape seal. The choice is dependent on several factors, which include:

- Additional Cost with Microsurfacing
- Daily Construction Time Window
- Available Cure Time Prior to Opening to Traffic
- Weather Conditions During Construction

The cost difference between the slurry seal and microsurfacing is usually small. Microsurfacing may be a better choice with its shorter cure time and its more durable surface. More details on material selection is available in the Chip Seal Manual and the Slurry Surfacing Manual.

As always, proper repair work carried out prior to beginning a Cape seal project improves the longevity of the project. To prevent shoving and rutting in busy intersections, repair distressed pavements with HMA dig-outs and only apply the slurry surfacing, omitting the chip seal.

DETERMINING APPLICATION RATES FOR EMULSION CAPE SEALS

Emulsion Chip Seal Layer

According to the 2018 Caltrans Standard Specifications, emulsions must be applied within the application rate ranges shown in Table 2. These requirements apply not only to conventional but also to polymer-modified emulsions.

Slurry Surfacing

The slurry surfacing used as a part of the Cape seal must have an accepted mix design per local standards.[5] The contractor should submit the mix design to the agency prior to construction. The mix design needs to be completed by a certified laboratory and accepted by the agency prior to construction.

Examples of slurry seal and microsurfacing mix design can be found in the slurry surfacing manual (5).The mix design process includes selecting the following:

- The appropriate application rate for the aggregate (see Table 2 for slurry seal and Table 3 for microsurfacing)
- The amount of emulsion, water, additives, and filler (e.g. cement to be used in the mix to meet all the test requirements for placement and long-term durability, also including the recommended residual asphalt content as well as the recommended changes in water and set control agents for high-temperature weather conditions)
- The mix should be verified with a test strip and the rate approved by the resident engineer, particularly on larger jobs.

Table 2. Application Rates for Slurry Seals (Caltrans, 2018 Standard Specifications)

Pounds of Dry Aggregate per Square Yard				
Types	**Application Rates* (lbs./yd²)**			
Specifications	**Caltrans**	**ISSA**	**Greenbook**	**Note**
Type I	8–12	8–12	8–10	Not recommended for heavy traffic areas.
Type II	10–15	10–18	12–15	As directed by the engineer
Type III	20–25	15–22	20–25	As directed by the engineer

*Use lower rates for smoother existing surfaces and higher rates for rougher surfaces.

A microsurfacing essentially performs the same functions as the slurry seals, but it has binder and aggregate characteristics not found with slurry seals. It may possess a higher-quality aggregate and special additives that are quicker to cure. Table 3 shows the application rates for microsurfacing from the 2018 Caltrans Standard Specifications.

Table 3. Application Rates for Microsurfacing

Pounds of Dry Aggregate per Square Yard				
Types	**Application Rates* (lbs./yd²)**			**Higher rates for rougher more irregular surfaces, i.e., rutting**
Specifications	**Caltrans**	**ISSA**	**Greenbook**	**Full Lane Width**
Type II	10–20	10–20	12–15	As Directed by the Engineer
Type III[a]	20–32	15–30	20–25	As Directed by the Engineer
Type III[b]	30–32	N/A	N/A	As Directed by the Engineer

[a] Caltrans only: Over asphalt concrete pavement.

[b] Caltrans only: Over concrete pavement and concrete bridge decks.

According to the 2018 Caltrans Standard Specifications, the slurry seal mix design, using project source aggregate, project asphalt emulsion, and set-control agents (if any), must comply with the requirements shown in Table 4; the requirements for microsurfacing are reported in Table 5.

Table 4. Slurry Seal Mix Design Requirements

Quality characteristic	Test method[a]	Requirement
Consistency (max., mm)	Technical Bulletin 106	30
Wet stripping	Technical Bulletin 114	Pass
Compatibility	Technical Bulletin 115	Pass[b]
Cohesion test, within 1 hour (min., kg-mm)	Technical Bulletin 139	200
Wet track abrasion (max., g/m^2)	Technical Bulletin 100	810

[a] Test methods are by the International Slurry Surfacing Association.
[b] Mixing test must pass at the maximum expected air temperature at the job site during placement.

Table 5. Microsurfacing Mix Design Requirements

Quality characteristics	Test method[a]	Requirement
Wet cohesion	Technical Bulletin 139	
At 30 minutes (set) (min., kg-cm)		12
At 60 minutes (traffic) (min., kg-cm)		20
Excess asphalt (max., g/m^2)	Technical Bulletin 109	540
Wet stripping (min., %)	Technical Bulletin 114	90
Wet track abrasion loss	Technical Bulletin 100	
6-day soak (max., g/m^2)		810
Displacement	Technical Bulletin 147A	
Lateral (max., %)		5
Specific gravity after 1000 cycles of 57 kg (max.)		2.10
Classification compatibility (min., grade points)	Technical Bulletin 144	(AAA, BAA) 11
Mix time at 25°C (min.)	Technical Bulletin 113	Controllable to 120 seconds

[a] Test methods are by the International Slurry Surfacing Association.

The asphalt emulsion must be added at a rate consistent with the project mix design. The rates are based on the amount of residual asphalt and normally fall within the following ranges based on weight of dry aggregate plus any mineral filler as shown in Table 6.

Table 6. Residual Asphalt in Slurry Seals and Microsurfacing[6]

Gradation	Slurry Seal	Microsurfacing
Type I	10 to 16%	N/A
Type II	7.5 to 13.5%	5.5 to 10.5%
Type III	6.5 to 12.0%	5.5 to 10.5%

DETERMINING APPLICATION RATES FOR HOT APPLIED CAPE SEALS

Hot Applied Chip Seal

When applied, the temperature of the asphalt rubber binder must be from 385 to 415°F. Apply the asphalt rubber binder at a rate from 0.55 to 0.65 gal/sq. yd. The application rate may be reduced to 0.50 gal/sq. yd. in the wheel paths. The rates may have to be adjusted in the field as well.

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

Slurry Surfacing

Slurry surfacing mix design and application rates may vary for both the hot applied and emulsion chip seals. This variation is due to larger chips requiring a heavier application of the slurry surfacing material. Most PMRE chip seals use 1/4 to 5/16 inch chips, and most PME chip seals use 1/4 to 3/8 inch chips. AR chip seals are typically 3/8 inch, but you can use ½ inch chips, so the rougher surface texture will require a heavier application of slurry surfacing to achieve the desired texture. The slurry surfacing may be applied sooner over the hot applied chip seal because the asphalt rubber chip seal binder doesn't require cure time.

The equipment must be calibrated and a test strip applied to verify the application rates. The ISSA Inspectors Manual for High Performance Slurry Systems contains more mix design details as well as example mix design for slurry seals and microsurfacing.[7]

V. CONSTRUCTION

When constructing a Cape seal, the following considerations are important:

- Weather considerations during construction can have a direct impact on performance. The weather should be warm and dry to promote proper binder setting and curing.

- Before beginning the chip seal portion of the Cape seal work, prepare and clean the existing surface. Fill any potholes, level the ruts, and seal large cracks.

- For AR Cape seals, crack seal anything wider than 3/8 inch, and for PME or PMRE Cape seals, crack seal anything wider than 3/16 inch.

- Application rates must be selected to fit site conditions. The procedures identified in the prior chapter should be considered. Proper binder and application rates result in durable, long-lasting chip seals and slurry surfacing.

- A test strip should be constructed to confirm that the spread rates give a good quality product.

- The condition of the aggregate chips is important for the chip seals. Clean aggregate is necessary to ensure the binder will adhere to the aggregate. The chips are crushed and durable and are often one-sized.

- A properly calibrated distributor spray bar is critical to a uniform application of the binder. Most distributor trucks are computerized so that the spread rate is proportionate to the speed of the truck.

- The chip spreader should follow binder application as closely as possible and be applied on the binder almost immediately. With hot ambient temperatures greater than 90°F, more distance between chip spreader and the binder application may be allowed.

- The rolling procedure is critical to embed the chips and promote good bonding. The chips should be rolled immediately after spreading with a pneumatic tire roller.

- Light sweeping with minimum downward pressure is necessary to remove loose aggregate.

- Traffic control is important. The traffic speed should be controlled until the binder has set, the rolling has been completed, and the first sweeping has occurred. A fog seal can be used on the chip seal to hold the rock if the slurry seal is applied at a later time. The slurry surfacing can be applied within a few days for hot applied chip seals and longer for cold applied chip seals. The actual time is based on whether the chip seal has cured.

- Prior to placing the slurry surfacing, the chip seal should be cured. A final sweeping should be done to remove any loose chips.

- The slurry should be placed with a calibrated slurry machine.
- The slurry is rolled with rubber tired rollers to ensure consolidation of the slurry and good bond.
- The slurry is then swept to remove any loose material. This should be done for the first four days and then after two weeks (see examples in Appendix A).

PRE-CONSTRUCTION MEETING

Prior to construction, it is recommended that a preconstruction meeting within 5 days before start of Cape seal coat work at a mutually agreed time and place with the Engineer and a contractor's staff including:

1. Project Superintendent
2. Project Foreman
3. Traffic Control Foreman
4. Resident Engineer
5. Assistant Resident Engineer
6. Quality Control/Quality Assurance (both agency and contractor)
7. Agency's Safety Officer

It may not always be possible for all the contractor's personnel to attend, and detailed meeting notes should be provided by the Resident Engineer. The notes are to be provided to everyone so that they are aware of the project details that were discussed and agreed to.

Make arrangements for the conference facility. Pre-construction meeting participants must sign an attendance sheet provided by the engineer. Be prepared to discuss:

1. Material sources
2. Quality control testing
3. Acceptance testing
4. Seal coat placement
5. Proposed application rates for asphaltic emulsion or asphalt binder and aggregate
6. Training on placement methods

7. Checklist of items for proper placement
8. Unique issues specific to the project, including:
    - Weather
    - Alignment and Geometrics
    - Traffic Control Requirements
    - Haul Distances
    - Presence and Absence of Shaded Areas for PME Chip Seals
    - Any Other Local Conditions
    - Storm Water Pollution Prevention Plan
    - Contractor's Schedule of Work
9. Contingency plan for material deliveries, equipment breakdowns, and traffic handling
10. Who in the field has authority to adjust application rates; and how will adjustments be documented?
11. Schedules for sweeping

EQUIPMENT

Types of Equipment Used

The types of equipment used for chip seals generally consist of the following:

- Calibrated distributor truck
- Calibrated aggregate spreader
- Pneumatic tire rollers
- Self-contained sweeper trucks or brooms
- Trucks supplying the materials

More detail on the equipment used can be found in the chip seal module.

For the slurry surfacing, the equipment used includes:

- Calibrated slurry paver
- Rubber tire rollers
- Self-contained sweeper trucks or brooms
- Trucks supplying the materials

Calibration of Equipment

All equipment needs to be properly calibrated according to acceptable standards. The guides shown in Appendix B provide detailed instructions regarding how to calibrate equipment used for both emulsion and hot applied Cape seals. Calibration procedures for slurry surfacing equipment can be found in the companion Manual for Slurry Surfacing.

CONSTRUCTION PROCESS

Chip seal

The sequence of construction events for chip seals is as follows:

1. Pre-construction meeting
2. Project preparation including water pollution prevention items
3. Weather conditions and traffic control
4. Binder application
5. Aggregate spreading
6. Rolling (pneumatic rollers)
7. Sweeping (brooming)
8. Flush coat application (may or may not be necessary)

Details of the construction process can be found in the companion Chip Seal Manual and in Appendix B of sample specifications.

WORKMANSHIP ISSUES

Emulsion Cape Seals

Regarding workmanship issues, the following need to be monitored for emulsion chip seals:

- Protections of manhole covers and utility boxes
- Protection of concrete curbs and gutters
- Uniform longitudinal application rates (binder and aggregate)
- Uniform transverse application rates (binder and aggregate)
- Transverse joint construction technique for neat appearance
- Monitoring method for application rates
- Rolling operations detailing the roller pattern and number of passes and coverage
- Sweeping operations and schedule

For slurry surfacing, the following workmanship issues need to be monitored:

- Uniform application rates of slurry surfacing
- Uniform slurry consistency
- Transverse joint construction
- Protection of manhole covers and utility boxes
- Protections of concrete curbs and gutters
- Monitoring method for application rates
- Rolling operations detailing the roller pattern and number of passes and coverage (if required)
- Sweeping operations

Hot Applied Cape Seals

The same items need to be monitored for hot applied chip seals:

- Longitudinal and transverse application uniformity
- Transverse joint construction technique
- Longitudinal and transverse joint construction techniques
- Monitoring methods for application rates to minimize bleeding, rock loss and streaking
- Rolling operations detailing rolling pattern and number of passes or coverage
- Require a minimum of three 60-inch wide rollers for hot applied asphalt rubber to provide minimum coverage
- Sweeping operations and schedule
- Method of controlling traffic

Hot applied 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 between 60 and 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 2 minutes. Intersections, turn lanes, gore points, and irregular areas must be covered within 5 minutes.

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.

As mentioned above, for slurry surfacing, the following workmanship issues need to be monitored:

- Uniform application rates of slurry surfacing
- Uniform slurry consistency
- Transverse joint construction
- Protection of manhole covers and utility boxes
- Protection of concrete curbs and gutters

- Monitoring method for application rates
- Rolling operations detailing the roller pattern and number of passes and coverage (if required)
- Sweeping operations

SAFETY

As with all construction projects, safety is the **Number One** concern for pedestrians, motorists, contractors' personnel, and local agency inspectors. A personal injury accident or a fatality cannot be reversed. Cape seal projects have some issues which are unique for this project type. As the design and construction engineer, there are many items regarding safety that you should be aware of.

Traffic Control

One factor is that lane closures are always required for seal coat work, since traffic must be kept off of fresh chip seal and slurry surfacing until at least an initial break and cure has taken place. For treatments involving asphalt emulsions, the time required to cure will depend on climate factors such as air temperature, relative humidity, and wind speed. Hot applied chip seals cure by cooling and hence require a shorter set time before opening to traffic. They can also be done in cooler weather or at night.

If there are shady areas and cooler temperatures, cure time for emulsion materials must be extended since these areas will take longer to cure. Since curing time can vary depending on the weather conditions, it is important that the contractor maintain the detours or traffic control until the slurry surface is cured. Cure time may take several hours after placement. During this time, traffic must be restricted from the new chip seal surface. If an emulsion chip seal surface or slurry surfacing is open to uncontrolled traffic too soon, raveling may occur.

If this is an urban project, the first item that should be considered is detouring traffic. In a downtown situation, it is usually easy to close a street and move traffic over a block. Also, businesses and residences should receive notification of street closures ahead of construction. Business owners will often ask that the construction be done on a weekend or at night so that their normal business is not disrupted. If that is not possible, customers may have to walk by the construction zone. It is important for pedestrian safety to cordon off the work areas from the sidewalks and for flaggers to direct pedestrians who may want to cross the street. Decisions must be made ahead of construction to leave certain intersections open to traffic, and you must determine how access to businesses and residences will be managed during construction. Construction signing for detours must be included in the contract plans.

If this is a rural two-lane road project, only one direction will be constructed at a time, with traffic control enacted using a pilot car with flaggers to alternately allow traffic to be piloted in one direction at a time. After the chip seal or slurry surface is cured, traffic will be switched onto the new surface, and the opposing lane will be constructed. There are traffic control standards that must be adhered to during the construction and curing process.

Safety During Construction

It is important to be familiar with the equipment traffic patterns on the project and to know what the 'NO ZONES' are. Figure 5 shows where these zones are. It is recommended to drive through the project in the traffic queue if there is one-way controlled traffic. For Cape seal operations, observe the flow of equipment (i.e., the distributor truck and aggregate spreading machine for chip seals; the paver for slurry systems) including its direction and speed. Also, observe the haul trucks for the aggregate and the asphalt binder. The haul trucks supplying the aggregate spreader may back up at very high speeds and should have backup alarms. The Resident Engineer is usually in charge of enforcing the safety items on the project. All the equipment must be equipped with backup alarms.

The aggregate and slurry truck drivers have limited vision when backing up. Hence, be sure to make contact with the truck driver before walking behind the truck. The driver will not be able to see who or what is behind their vehicle.

Many observations can be made from the vehicle, so don't stand in the construction zone unless sampling or performing tests. Assign an observer to watch traffic when the tester is unable to**.** Be sure to perform testing or sampling in a lane closure.

Figure 5. Mirrors and the No Zone

All construction personnel must wear safety vests, hard hats, and safety glasses in active construction zones. All construction personnel must also wear long pants, as well as suitable shoes or boots. No sandals or shorts are allowed for construction personnel. If a worker is around a high level of noise, earplugs may be worn by the worker. Gloves should be worn by workers performing hand labor or handling hot materials. Testers handling hot asphalt samples must wear face shields.

VI. QUALITY ASSURANCE, MEASUREMENT AND PAYMENT

Quality assurance establishes the core elements required to achieve quality materials and workmanship for construction projects, as shown in Figure 6 (Franco and Shields, 2018). This goal has been mostly accomplished in hot mix asphalt, but it is just beginning for pavement preservation treatments. This chapter discusses the various aspects of a QA program.

Figure 6. Core Elements of a Quality Assurance Program

CONTRACTOR QUALITY CONTROL PLAN

It is recommended that a written Quality Control Plan (QCP) be developed to detail the contractor's QC program that meets the requirements of these specifications. The QCP shall be contract-specific and signed by the contractors' representative. Where required, Cape seal construction shall not begin or proceed without the engineer's approval of the QCP and QC personnel present on the project. Failure to comply with these provisions will result in shutdown of the operations until such a time as the contractor's operations are in compliance.

Unless the engineer accepts other documentation of the qualifications and/or responsibilities of the contractor's QC staff, the QC staff shall include the following as a minimum:

- QCP Administrator: The person with overall responsibility of the QCP.
- QCP Manager: The person responsible for the execution of the QCP and liaison with the agency. This person shall be on the project and have the authority to stop or suspend construction operations.
- QC Technicians: The person(s) responsible for conducting QC tests and inspection to implement the QCP. QC technicians shall have Level 2 Aggregate Testing Certification from the American Concrete Institute (ACI) or other accrediting body approved by the agency to ensure quality aggregates.
- Certified Crew Members: Three crew members (job foreman, aggregate spreader operator and asphalt distributor operator), at minimum, shall possess a valid chip seal certification and be on the project at all times 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 (Transportation Services Preservation Program).

CONTRACTOR QUALITY CONTROL DOCUMENTATION

The contractor is responsible for quality control (QC) sampling, testing, and documentation, and shall submit a QC plan including materials and procedures for verifying the quality of the chip seal aggregates and binder, measures to ensure placement of materials conforms to the contract documents, and measures and documentation to ensure the in-place end product conforms to the contract documents. The contractor's QC plan shall include but is not limited to sampling, testing, inspection, monitoring, documentation and submittals, and corrective action procedures during transport, stockpiling, placement, and sweeping/ cleanup operations.

The contractor's QC system should address the following:

- Materials production processes
- Materials transportation and handling
- Field placement procedures
- Calibration and maintenance of equipment
- Activities (sampling, testing, and inspection) to maintain each process in control
- Means to make timely adjustments and corrections

SAMPLING AND TESTS TO RUN INCLUDING FREQUENCY

Both contractor and agency need to have a sampling control plan prior to beginning work. An example of such a plan is shown in Table 7.[2]

Table 7. Example of a Sampling Control Plan for Chip Seals

Project Location	
Product	**Producer's Emulsion**
Where	On site/Sampling Port
When	15 minutes after starting application
How much[1,2]	Four 1/2 gallon plastic jugs
Who	Consultant Tester
Testing	Agency and/or Consultant Tester for all emulsion specified characteristics
Product	**Aggregate, Producer**
Where	Stockpile, or from equipment
When	Various times, once daily
How much	1 Bag, 20 pound ±
Who	Operator or Agency Inspector or Agency Tester
Testing	Agency or Consultant Lab for all aggregate specified characteristics

[1] For hot applied binder, use metal buckets for samples.

[2] Emulsion samples must be stored in a shady area and shipped to the certified testing laboratory as soon as possible.

The consultant tester may be employed by either the contractor or the agency. Usually, the person sampling the product will take two samples, giving one to the agency and one to the contractor as a split sample. This is a good strategy in case there is a discrepancy on the test results. Even though there is testing of the product before construction, there needs to be assurance that the product being delivered is verified to be of the same quality as the product that was submitted to the agency prior to construction.

The sampling plan for slurry surfacing prior to beginning work will be similar to the chip seal sampling plan for the emulsion and aggregate. However, prior to beginning work on the slurry surfacing, additional verification testing should be done on the field mix. Section 302-4.4, "Verification Testing," states that the contractor shall provide field samples for extraction tests (ASTM D6304), consistency tests, and modified wet track abrasion tests (ASTM D3910). When the samples comply with the specifications, the contractor's contract work will begin. Table 8 includes an example of a sampling plan for slurry surfacing.

Table 8. Example of a Sampling Control Plan for Slurry Surfacing

Project Location	
Product	**Producer's Emulsion for Slurry**
Where	On site/Sampling port
When	15 minutes after starting application
How much	Four 1/2 gallon plastic jugs
Who	Consultant Tester
Testing	Agency and/or Consultant Tester
Product	**Aggregate for Slurry, Producer**
Where	Stockpile, or from equipment
When	Various times, once daily
How much	1 Bag, 20 pound ±
Who	Operator or Agency Inspector or Agency Tester
Testing	Agency or Consultant Lab for all aggregate specified characteristics
Product	**Slurry Surfacing Mix, Producer**
Road Mixer, Continuous Flow	Field Mix Verification (Agency) Extraction Test (ASTM D6307)
Prior to start of work	Consistency Tests (ISSA TB 106) Modified Wet Track Abrasion Tests (ASTM D3910)

AGENCY INSPECTION AND DOCUMENTATION

The agency has the responsibility to document the quality of the products being used and the construction processes used on their project—referred to as agency acceptance. The Agency Engineer, or Resident Engineer, is responsible for keeping daily diaries to document the construction process, and there is usually an Assistant Resident Engineer on the job. Depending on the size of the project, there may also be an agency tester on the project responsible for the materials sampling. The agency tester may be a consultant tester or an agency employee. The tester should be certified in any and all of the tests that are being run, including sampling the products.

The materials test results are compared to the specified tests to make sure that the materials are within the specified limits of each test specified and performed. Some out-of-specification products may be accepted to be left in place on the project with a deduction, as long as the non-conformance is not excessive. This is at the contractor's discretion. If the materials are too far outside of the specified limits, the engineer should order that the material be removed and replaced at the contractor's expense.

Overall, the primary objectives of agency acceptance are to:

- Measure the quality of all materials provided and placed by the contractor, and
- Determine the corresponding payment the contractor should receive, and any repairs or replacements necessary.

INDEPENDENT ASSURANCE

Independent Assurance (IA) is performed by the agency or designated agency personnel who are not directly responsible for project acceptance. It provides independent evaluation of the QC and acceptance personnel and their equipment, but is not used to make a determination of work quality or acceptability.

When the various ingredients are combined in proper proportions, they produce mixes that ultimately make up the new surface on the pavement. Obviously, high-quality materials, good mixing and construction practices, and good quality control/quality assurance will help maximize the smoothness, uniformity, skid resistance, and appearance of the slurry surfacing. Quality control is critical during the construction process to achieve a uniform surface finish. The contractor is responsible for quality control (QC), and the agency is responsible for project acceptance. If there is a difference in the testing results between the contractor and the agency, it may be necessary to go to dispute resolution. Independent assurance (IA) can mediate in the dispute resolution process, and it monitors both laboratories during their re-testing of the materials.

Samples that have been maintained during the project in case of dispute resolution are run as split samples, similar to a round robin, between the two laboratories whose results are in dispute. The role of independent assurance is to determine why there was a difference in the test results, and to get the laboratories to produce consistent testing results. This is done so the dispute can be settled in a fair and equitable process between the contractor and the agency.

Besides the appearance of the project, the materials need to be tested during construction. If two tests in a row fail, the work should be suspended until the contractor remedies the problem. If no problem can be identified, then re-testing needs to follow. Independent assurance processes may be used when the re-testing is being done between the two laboratories.

MEASUREMENT AND PAYMENT

For the chip seal and the slurry surfacing, if batch weights are printed automatically, the bid item for screenings (chips) will be measured using the printed batch weights, provided the following are applicable:

1. Total aggregate weight for screenings per batch is printed.

2. Total asphalt binder weight per batch is printed.

3. Each truckload’s tare weight is printed before weighing the first batch and after weighing the last batch.

4. Time, date, mix number, load number and truck identification are correlated with a load slip.

5. A copy of the recorded batch weights is certified by a licensed weigh master and submitted to the engineer.

6. Weigh tags are produced at the hot plant where the screenings were stockpiled, heated, and coated.

Submit tags which include the printed batch weights no later than the morning after delivery has been made. The application rates for the binder used in both the chip seal and slurry surfacing determined by the contractor must be reported to the Resident Engineer no later than the following day.

No payment will be made for quantities of screenings or binder which exceed 125% of the calculated quantity required to cover the application area defined in the Special Provisions in compliance with the approved product submittals. This quantity may be exceeded by the Resident Engineer if a contract change order (CCO) is approved.

The contract unit prices paid per ton for Binder and for Screenings shall be considered as full compensation for furnishing all labor, materials, tools, equipment, guarantees, warranties and incidentals and for doing all the work involved in installing chip seal and slurry surfacing, including but not limited to site preparation, cleanup, protecting utility and manhole covers, applying the treatments, corrections to application, street sweeping and all other incidental work required to complete the work as shown and specified.

The contractor must furnish the following warranty after completion of the work and prior to final payment if a warranty is specified:

> “The Contractor hereby warrants that all workmanship and all materials furnished under the contract comply fully with requirements of the Cape Seal specifications. If at any time within two years from the date of filing of the Notice of Completion, any unfaithful or defective work should appear which in the opinion of the agency is due to inferior materials or workmanship, the Contractor warrants doing whatever is necessary to remedy the defects immediately without cost to the agency. The agency will notify the Contractor in writing of the defects and the repairs to be made, and the Contractor will begin repairs within a mutually agreed time frame.”

Some cities and county agencies pay by the square yard or square foot. It is critical for the agency to have good inspection to ensure they are getting what they paid for.

VII. TROUBLESHOOTING GUIDE

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

TROUBLESHOOTING GUIDES FOR CHIP SEALS

The troubleshooting guide presented in Table 9 identifies common problems for both emulsion and hot applied chip seals, and their potential causes. In California, the most common problem is flushing or rock loss after construction, as shown in Figure 7 and Figure 8.

Table 9. Troubleshooting Chip Seal Problems

CAUSE	PROBLEM										
	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[1]	•		•		•	•		•	•		
Climatic Conditions											
Cold Surfaces	•			•	•				•		•
Wet	•			•	•				•		•
Windy	•			•	•				•		•
Binder											
Wrong Binder	•		•	•	•	•		•	•		•
Too Little Binder	•			•	•				•		•
Too Much Binder			•					•			•
Aggregate											
Too Little	•		•					•			•
Too Much	•	•		•	•		•		•		•
Wet	•			•	•			•	•		•
Dirty	•			•	•				•		•
Quality	•	•		•	•				•	•	
Wrong Size	•				•			•	•	•	•
Pre-coat											
Too Little	•			•	•				•		
Too Heavy											

[1] Angle of nozzles, i.e, too much angle may cause too much binder along the edge of the application from the distributor bar.

Figure 7. Rock Loss

Figure 8. Flushing

Figure 9 shows a typical example of debonding, which is also a commonly encountered distress.

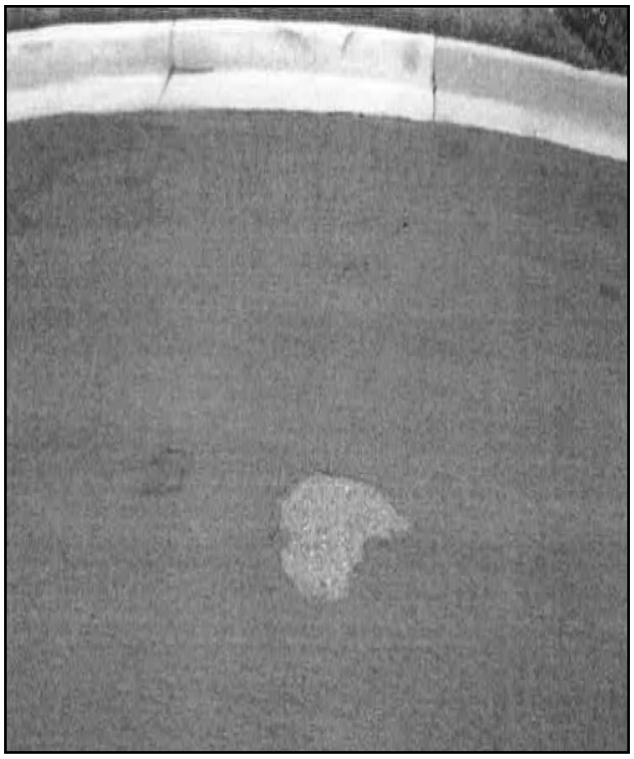

Figure 9. Debonding

Figure 10 shows an example of the slurry breaking too rapidly, causing a buildup of material in the spreader box, and broken mixture that doesn't bond to the pavement and will quickly come off. This can be caused by too high of a temperature or too much cement. Cement is added to the mixture as mineral filler, and as a break rate controller.

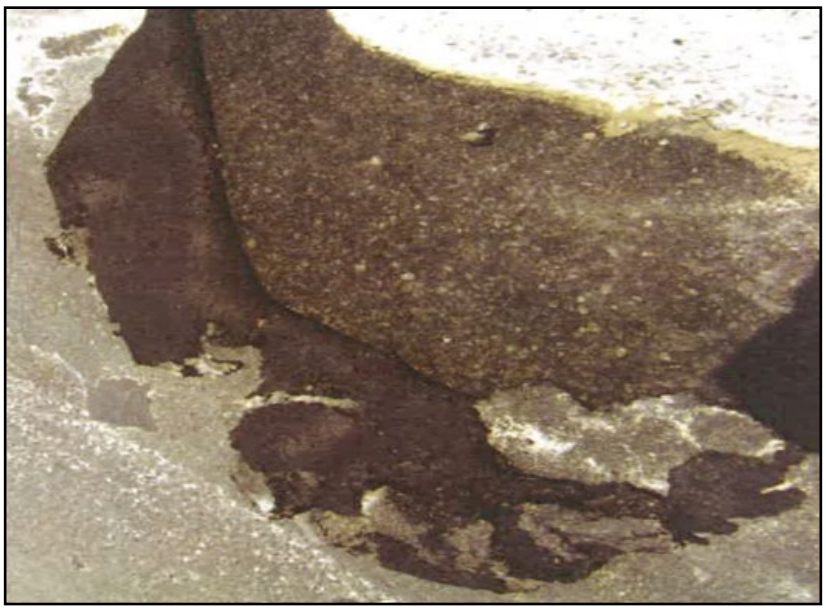

Figure 10. Fast Uncontrolled Break with Debonding

Figure 11 shows an example of surface irregularities with drag marks and scratches. These defects may be caused by the lift being thinner than 1.5 times the maximum aggregate size. Open texture of the pavement surface may also cause irregularities in the finished slurry surface. The open texture requires more slurry to fill the voids, and the application rate or the consistency of the slurry may need to be adjusted to achieve a smooth slurry surface.

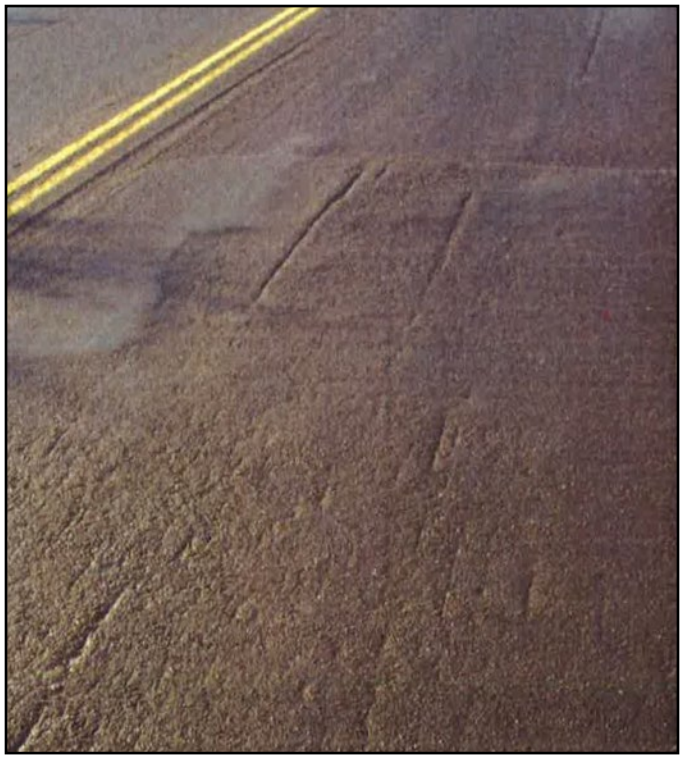

Figure 11. Excessive Drag Marks and Scratches

In addition to the troubleshooting guide, Table 10 lists some commonly encountered problems and lists some recommended solutions.

Table 10. Typical Problems and Recommended Solutions for Chip Seals

Problem	Solution
Streaking or Drill Marks in the Binder	• Ensure emulsion or asphalt binder is at correct application temperature. • Ensure the viscosity of the emulsion or asphalt binder is not too high. • Ensure all the nozzles are at the same angle. • Ensure the spray bar is not too high or too low. • Ensure the spray bar pressure is not too high or too low. • Ensure nozzles are not plugged.
Exposed Emulsion After Chip Application	• Ensure the chip spreader gate is not clogged or malfunctioning. • Ensure the chip spreader is covering all the binder.
Excessive Chips/Many Chips with Small Amounts of Binder	• Ensure the chip spreader gate is not malfunctioning or chipper head is not overloaded. • Lower the chip application rate.
Uneven Chip Application	• Re-calibrate the chip spreader; ensure all spreader gates are set the same.
Binder on the Top of Chips	• Ensure the chip spreader is not operating too fast. • Ensure trucks, rollers, and pilot cars are operating correctly at low speeds.
Chips Being Dislodged	• Ensure the binder application is not too light. • Ensure the chips are not dirty or dusty. • Ensure the traffic or equipment speeds are not too high. • Ensure sweeping does not occur before the emulsion is properly set.
Bleeding or Flushing	• Ensure the binder application is not too high. • Ensure the aggregate application is not too low.
After Sweeping, Loss of Chip at Centerlines	• Check centerline procedure. • Check binder application rate.
Excessive Splattering of the Binder	• Lower the spray pressure by lowering the speed of the distributor truck.

TROUBLESHOOTING GUIDES FOR SLURRY SURFACING

The troubleshooting guide presented in Table 11, which is modified from Caltrans MTAG, identifies common problems for slurry surfacing and their potential causes, and Table 12 lists some solutions.[8] This is a very useful guide for determining what may be wrong during field construction. ISSA also provides some excellent suggestions for problem solving in Chapter VII of the ISSA Inspector's Manual for Slurry Surfacing (2010).

Table 11. Trouble Shooting Slurry Surfacing Problems

CAUSE	PROBLEM										
	BROWN	WHITISH	WILL NOT SET	POOR COATING	DELAYED OPENING TO TRAFFIC	BREAKS IN BOX	RAVELS	FLUSHES	DELAMINATION	SEGREGATION	SCUFFING
Emulsion											
Emulsion Unstable				●		●			●		
Emulsion too Stable	●		●		●		●				
Emulsion too Hot						●					
Too Little Emulsion	●			●			●				
Too Much Emulsion								●			
Mix											
Too Many Fines				●		●	●				
Too Much Cement		●				●					
Too Little Cement			●		●		●			●	●
Too Little Additive				●		●	●				●
Too Much Additive		●	●		●		●				
Too Much Water	●		●		●		●	●		●	●
Too Little Water		●			●	●	●		●		
Aggregate/Emulsion not Compatible			●	●	●		●		●	●	●
Weather Conditions											
Too Hot	●			●		●	●	●			
Too Cold			●		●		●		●		
Rain	●		●	●	●		●	●	●		
High Humidity		●	●								
Surface After Treatment											
Fatty (Oily)			●					●			
Dusty or Dirty Aggregate							●		●		
Aggregate not Pre-Wetted							●		●		

Table 12. Common Problems and Related Solutions

Problem	Solution
Uneven Surface--Wash Boarding	• Ensure the spreader box is correctly set up. • Ensure the viscosity of the mix is not too high. • Made adjustments so that the mix does not break too fast. • Wait until the ambient temperature is lower. • Use water sprays on the front of the spreader.
Poor Joints	• Reduce the amount of water at start up. • Use water spray if runner of spreader box is running on fresh material.
Excessive Raveling	• Add cement and reduce additive so that the mix breaks and cures faster. • Check aggregate to ensure the clay fines are not too high. • Control traffic longer at low speeds. • Wait until fully cured before allowing traffic. • Wait until mix is properly set before sweeping or opening to traffic.

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APPENDIX A: SAMPLE SPECIFICATIONS

The sample specifications in this appendix were developed as part of NCHRP project 14-37. The specifications include specs for emulsion chip seals, hot applied chip seals, and fog seals, the latter of which are often used with chip seals (Shuler et al., 2018).

A-1 EMULSION CHIP SEAL SAMPLE SPECIFICATION

The emulsion chip seal sample specification can be accessed through the following link:

https://www.csuchico.edu/cp2c/_assets/documents/specs/emulsion-chip-seal-sample-specification-1.pdf.

A-2 HOT APPLIED CHIP SEAL SAMPLE SPECIFICATION

The hot applied chip seal sample specification can be accessed through the following link:

https://www.csuchico.edu/cp2c/_assets/documents/specs/hot-applied-chip-seal-sample-spec-1.pdf.

A-3 MICROSURFACING SAMPLE SPECIFICATION

A sample specification for Microsurfacing can be found from the following website:

https://www.csuchico.edu/cp2c/_assets/documents/specs/appendix-a-2-microsurfacing-sample-spec-1-20-2019.pdf.

A-4 EMULSION FOG SEAL SAMPLE SPECIFICATION

The emulsion fog seal sample specification can be accessed through the following link:

https://www.csuchico.edu/cp2c/_assets/documents/specs/fog-seal-sample-spec-1.pdf.

APPENDIX B. TYPICAL CAPE SEAL SPECIFICATIONS FOR LOCAL AGENCIES

B-1 CITY OF ROSEVILLE

A sample specification for Cape seal can be found from the following website:

https://www.csuchico.edu/cp2c/_assets/documents/specs/city-of-roseville2013_Cape-seal-special-provision.pdf

B-2 CITY OF LOMPOC

A sample specification for slurry seal can be found from the following website:

https://www.csuchico.edu/cp2c/_assets/documents/specs/appendix-a-1-slurry-seal-sample-spec-1-20-2019.pdf.

A sample specification for microsurfacing can be found from the following website:

https://www.csuchico.edu/cp2c/_assets/documents/specs/appendix-a-2-microsurfacing-sample-spec-1-20-2019.pdf

TERMINOLOGY

Terminology

- **Cape Seal:** This multi-layer treatment type is a combination of a chip seal with a slurry seal or microsurfacing seal as the top layer. The chip seal may have an emulsion binder or a hot applied binder such as an asphalt rubber. Cape seals typically increase the durability of the road and produce a smooth surface.

- **Chip Seal:** A bituminous binder is applied followed by aggregate application and rolling to embed the aggregate into the binder.

- **Corrective Maintenance:** This maintenance type is conducted in response to defects that affect operations of a facility and integrity of pavement sections. This form of maintenance is also known as reactionary maintenance and can be conducted throughout the lifespan of a pavement. It is typically used to fix localized defects and return a pavement to an acceptable service quality. Maintenance activities include patching of potholes and replacement of concrete slabs.

- **Distresses:** Deterioration resulting from factors including the environment, construction and design practices, material selection, or load on pavement. There are two distinct categories of distresses: functional and structural.

  ○ **Functional distress:** Deterioration affecting the pavement's ability to serve its function of being a safe, smooth, and quiet surface for comfort while driving. Using preservation treatments, minor functional problems can be addresses as long as there are no structural problems.

  ○ **Structural distress:** Deterioration resulting from excess weight and loading, lack of thickness and support for the pavement structure. Considerable deterioration does not allow for the distresses to be addressed using preservation treatments.

- **Functional distress:** Deterioration affecting the pavement's ability to serve its function of being a safe, smooth, and quiet surface for comfort while driving. Using preservation treatments, minor functional problems can be addresses as long as there are no structural problems.

- **Structural distress:** Deterioration resulting from excess weight and loading, lack of thickness and support for the pavement structure. Considerable deterioration does not allow for the distresses to be addressed using preservation treatments.

- **Flush coat:** Also known as a fog seal, a flush coat is a light application of asphalt emulsion to lessen the loss of chips and helps protect motorists from broken windshields.

- **High-traffic-volume Roadway:** Rural roadways have an ADT greater than 5,000 vehicles per day and urban roadways have an ADT greater than 10,000 vehicles

per day.

- **Major Rehabilitation:** To extend the service of a pavement and/or improve load-carrying capabilities through structural enhancement.

- **Microsurfacing:** This treatment type relates to slurry seals; however, the main variation between the two is the quality of the materials. With this treatment, the polymer and asphalt residual content is greater than that of slurry seals, and the aggregate quality is better. In addition, the cost is greater than slurry seals; however, the cure time is more time-efficient than slurry seals.

- **Minor Rehabilitation:** The distresses addressed are non-structural enhancements to improve the lifespan, surface cracking, and restore the pavement to serve its function. The distresses could be a result of environmental factors. These are typically referred to as pavement preservation techniques occurring midway in a pavement's lifespan when the quality of the roadway begins to diminish.

- **Pavement Condition Index (PCI):** This index is most commonly used by the Metropolitan Transportation Commission (MTC) as a value ranging from 1–100 directly related to the condition of the pavement.

- **Pavement Preservation:** The practice of utilizing a cost-effective system that allows for the tracking and recording to extend and enhance the quality and life of a pavement. In addition, preservation would serve as a way to improve safety and provide good ride quality. The system primarily focuses on preventive maintenance as a cost-effective way to treat roadways and improve the quality of the road.

- **Preventive Maintenance:** Cost-effective strategy for treatment to roadway system accounting for ways to preserve the roadway and prevent deterioration in addition to improving or maintaining the condition of the roadway. This is typically performed early, before significant structural deterioration can appear. Some activities include joint sealing, crack sealing and filling, as well as utilizing chip seals and slurry seals.

- **Routine Maintenance:** Maintenance performed routinely to preserve the roadways condition or to return the roadway to a proper level of service. Some maintenance activities include crack filling and/or sealing, as well as maintaining the drainage system, both of which are performed throughout a pavement's life.

- **Slurry Seal:** Combination of emulsion and aggregate spread with a slurry paver which is used for public roads, highways, airport runways, parking lots, and a multitude of other surfacing projects throughout the world. It has been accepted and incorporated into many maintenance programs as a cost-effective maintenance treatment.

- **Slurry Surfacing:** Is a generic term which includes slurry seals and microsurfacing, as a pavement preservation treatment which provides an economical means for maintaining and improving the functional condition of an existing pavement while sealing it from water intrusion. Microsurfacing is a more durable product than slurry

seals and should have a longer life as a maintenance treatment.

- **Surface Type:** Surface type is the uppermost layer of a pavement structural section and is dependent on the type of material used, whether it be HMA or Portland cement. The surface type also depends on the functional class (arterial, collector, residential).

- **Treatment Category:** Treatments with application times and objectives alike. For instance, one group of treatments is meant to hinder and prevent deterioration; other treatments would include maintenance, rehabilitation, and construction of roadways.

- **Treatment Type:** A certain treatment used to treat specific distresses on a roadway. These treatments would include chip seals, slurry seals, microsurfacing, HMA overlays, and diamond grinding. For some situations, treatment combinations are required to ensure quality performance of the roadway.

ABREVIATIONS AND ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AAPT	Association of Asphalt Paving Technologists
ADT	Average Daily Traffic
AEMA	Asphalt Emulsion Manufacturers Association
AGC	Associated General Contractors
AI	Asphalt Institute
APWA	American Public Works Association
AR	Asphalt Rubber
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
Caltrans	California Department of Transportation
CalRecycle	California Department of Resources Recycling and Recovery
CCPIC	City and County Pavement Improvement Center
CP2C	California Pavement Preservation Center
DOT	Department of Transportation
FHWA	Federal Highway Administration
HMA	Hot Mixed Asphalt
IRI	International Roughness Index
ISSA	International Slurry Surfacing Association
LCCA	Life Cycle Cost Analysis
LCC	Life Cycle Cost
MSA	Maintenance Superintendents Association
MTAG	Maintenance Technical Advisory Guide
MTC	Metropolitan Transportation Committee
MTI	Mineta Transportation Institute
NDOT	Nevada Department of Transportation
PaveM	Caltrans Pavement Management System
PCI	Pavement Condition Index
PCR	Pavement Condition Rating
PME	Polymer Modified Emulsion
PMS	Pavement Management System
TCV	Total Cracking Value
TDA	Tire-Derived Aggregate
TRB	Transportation Research Board
UNR	University of Nevada, Reno
WPCV	Wheel Path Cracking Value
WSDOT	Washington State Department of Transportation

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Dr. Hicks is currently program manager for the CP2 Center at CSU Chico. Prior to joining the Center, he taught at Georgia Tech and Oregon State University for 30 years rising to a Distinguished Professor of Civil Engineering and the Associate Dean for Research for the College of Engineering. He retired from OSU in 1997, and upon retirement embarked on a consulting career with MACTEC Engineering (now Wood LLC) providing on call consulting services to the California Department of Transportation, and other organizations. As a part of this project he led the development of the MTAG and helped set of the CP2 Center in 2006. He is a registered Civil Engineer in the states of California, Oregon and Alaska.

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PEER REVIEW

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