CHAPTER 9 MICROSURFACING

9.1 OVERVIEW

This chapter provides an overview of the microsurfacing products presently used in California, including materials and specifications, mix design, project selection, details regarding construction, a troubleshooting guide to assist the Engineer if problems arise during the placement of these mixtures, and a list of suggested field considerations when placing a microsurfacing.

9.1.1 General Description

Microsurfacing is a mixture of asphalt emulsion, graded aggregates, mineral filler, water and other additives. The mixture is made and placed on a continuous basis using a travel paver (Slurry Surfacing Machine). The travel paver meters the mix components in a predetermined order into a pug mill. The typical mixing order is aggregate followed by cement, water, the additive and the emulsion. Figure 9-1 illustrates the process of slurry surfacing.

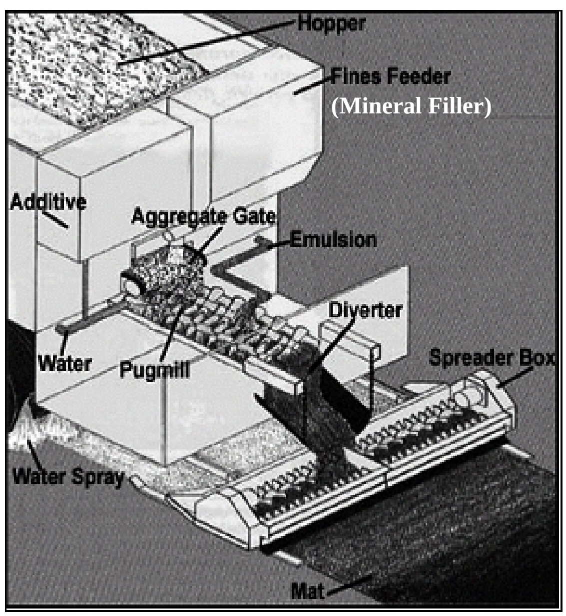


Figure 9-1 Schematic of a Slurry Surfacing Machine (Holleran, 2001)

The resulting slurry material is a free flowing composite material that is spread via a spreader box over the existing road surface. The consistency of the slurry material allows it to spread over the pavement, wetting it, and forming an adhesive bond to the pavement.

The slurry mixture contains asphalt emulsion that breaks onto the pavement surface through heterogeneous or homogenous flocculation. The asphalt particles coalesce into films, creating a cohesive mixture. The mixture then cures, by loss of water, into a hardwearing, dense-graded asphalt/aggregate mixture that is bonded to the existing pavement.

A slurry surfacing does not add any structural capacity to an existing pavement; they are applied as a maintenance treatment to improve the functional characteristics of the pavement surface. The types of slurry surfacing and the pavement characteristics they improve are discussed next.

9.1.2 Types of Slurry Surfacing

There are two main types of slurry surfacing in common use. These include:

- Slurry Seal
- Microsurfacing

Currently, Caltrans uses slurry seals routinely, while microsurfacing is still in the pilot stages of assessment.

Microsurfacing is a thin surfacing, and can be laid at two to three times the thickness of the largest stone in the grading. The emulsion in the system is always polymer modified and special additives are used to create a chemical break that is largely independent of weather conditions. In breaking, the emulsion forces water from the aggregate surface. Such systems can often be opened to traffic within 1 hour or less of its application under a range of conditions (Holleran, 2001a).

Microsurfacing can be used for the same applications as slurry seals. However, microsurfacing uses better quality aggregates and a fast setting emulsion of higher stiffness allowing thicker layers to be placed.

These aspects create the following extended performance characteristics and applications for microsurfacing:

- Correction of Minor Surface Profile Irregularities
- Rut Filling
- Higher Durability
- Ability to be Placed at Night or in Cooler Temperatures

Microsurfacing, like slurry seal, is not intended as a crack treatment and will not prevent cracks in the underlying pavement from reflecting through to the surface. Microsurfacing does not add any structural capacity to an existing pavement; it is applied as a maintenance treatment to improve the functional characteristics of the pavement surface.

9.2 MATERIALS

The main materials used in microsurfacing are:

- Asphalt Emulsion with Polymer Modification
- Water
- Aggregate
- Mineral Filler
- Additives

9.2.1 Asphalt Emulsion

Asphalt emulsions are defined in Chapter 2 of this advisory guide as dispersions of asphalt in water stabilized by a chemical system. In the case of slurry surfacing systems (like slurry seal and microsurfacing), the emulsion may be cationic or anionic; however, cationic emulsions are the most common. Caltrans Standard Specifications Section 94 (Caltrans, 2006) provides specifications for the main emulsion types. However, only polymer-modified (PM), quick-set (QS) emulsions are used in microsurfacing. Common polymer modified quick setting emulsions include:

- PMCQS-1h
- PMQS-1h
- MSE (Microsurfacing emulsion) (Caltrans, 2002)

These emulsions are specially formulated for compatibility with the aggregate and to meet the appropriate mix design parameters. Specifications for these emulsions are not included in the Standard Specifications (Caltrans, 2006). Unlike slurry seal, microsurfacing is still being researched by Caltrans and the specification is under development. The Caltrans Microsurfacing Pilot Study carried out in 2001 was the first step in the process of implementing microsurfacing to the Department. A non-standard specification has been developed under this study and it is referred to as the MSE emulsion. In reality, the MSE emulsion is a polymer-modified quick-set emulsion (Caltrans, 2002).

Emulsion specifications are based on standard emulsion characteristics, such as stability, binder content, and viscosity. In all microsurfacing systems, polymer is added to the emulsion. The polymer enhances stone retention, especially in the early life of the treatment. The added polymer also reduces thermal susceptibility. Polymers also improve softening point and flexibility, which enhance the treatment's crack resistance and, in the case of microsurfacing, allow thicker sections (two to three stones thick) to be placed. Thicker sections allow microsurfacing to be used for rut filling. Generally, microsurfacing and slurry seal mixtures with a polymer-modified emulsion do not impart significant resistance to reflective cracking.

Emulsions are usually modified with latex, which is an emulsion of rubber particles. The latex does not mix with the asphalt; rather, the latex and the asphalt particles intermingle to form a 3-D structure, as illustrated in Figure 9-2. The latex used is either neoprene or styrene butadiene styrene (SBR) for slurry seal. Microsurfacing is modified with either natural latex or SBR latex. When modified with latex, slurry seal emulsions are referred to PMCQS-1h or, more commonly, LMCQS-1h where "LM" stands for "latex-modified" (Holleran, 2001).

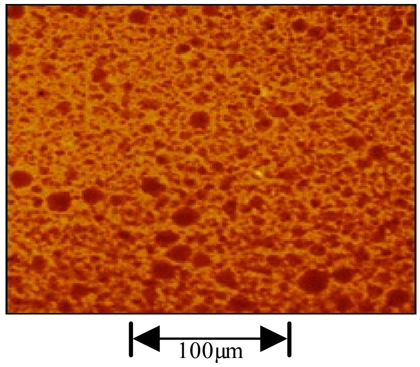


Figure 9-2 Micrograph of a Latex/Asphalt Cured Film (Holleran, 2002)

The main emulsions used for microsurfacing in California are latex modified CQS-1h type emulsions and microsurfacing emulsion (MSE) (Holleran, 2001, Caltrans, 2002).

Latex may separate from the emulsion due to the differences in density. If separation occurs, the latex must be remixed into the emulsion by circulation in the tanker before the modified emulsion is transferred to the slurry machine for application (Holleran, 2002).

Basic emulsion requirements are shown in Table 9-1. Key requirements include the binder content and residual properties. The viscosity is of importance as is the storage stability to ensure that the emulsion can be used effectively in the field.

Table 9-1 Typical Emulsion Properties for Microsurfacing and Polymer Modified Slurry Quick Set (Caltrans, 2002, Holleran, 2002)

Tests on Emulsion	Typical Specification	Method
Viscosity, SSF @ 25°C, sec	15 – 90	AASHTO T 59
Settlement, 5 days, %	< 5	ASTM D 244
Storage Stability, 1 day, %	< 1	AASHTO T 59
Sieve Test, %	< 0.30	AASHTO T 59
Residue by Evaporation, %	> 62	California Test 331
Tests on Residue from Evaporation Test	**Typical Specification**	**Method**
Penetration, 25°C	40 – 90	AASHTO T 49
Softening Point, °C	> 57	AASHTO T 53
G* @ 20°C, 10 rad/sec, MPa	Report Only	AASHTO TP 5
Phase Angle @ 50°C, 10 rad/sec, PA(max) – PA base	Report Only	AASHTO TP 5
Stiffness @ -12°C, MPa M-Vlaue	Report Only	AASHTO TP 1
Torsional Recovery, %	> 18% (LMCQS-1h)	California Test 332
Polymer Content	> 2.5% (LMCQS-1h)	California Test 401

9.2.2 Aggregates

The aggregate's key physical characteristics for suitable incorporation into a slurry surfacing mix are defined by:

- **Geology:** This determines the aggregate's compatibility with the emulsion along with its adhesive and cohesive properties.
- **Shape:** The aggregates must have fractured faces in order to form the required interlocking matrix (Holleran, 2001). Rounded aggregates will result in poor mix strength.
- **Texture:** Rough surfaces form bonds more easily with emulsions.
- **Age and Reactivity:** Freshly crushed aggregates have a higher surface charge than aged (weathered) aggregates. Surface charge plays a primary role in reaction rates.
- **Cleanliness:** Deleterious materials such as clay, dust, or silt can cause poor cohesion and adversely affect reaction rates.
- **Soundness and Abrasion Resistance:** These features play a particularly important role in areas that experience freeze-thaw cycles or are very wet.

Two gradations are specified for microsurfacing; namely, Type II and Type III (Caltrans, 2002). The gradation for each type is listed in Table 9-2.

Table 9-2 Caltrans Slurry Surfacing Aggregate Gradings (Caltrans, 1999a)

SIEVE SIZE	PERCENTAGE PASSING	
	TYPE II	TYPE III
3/8 in (9.5mm)	100	100
No. 4 (4.75 mm)	94-100	70-90
No. 8 (2.36 mm)	65-90	45-70
No. 16 (1.18 mm)	40-70	28-50
No. 30 (600-µm)	25-50	19-34
No. 200 (75-µm)	5-15	5-15

The primary difference among these gradations is the aggregate top size. This dictates the amount of residual asphalt required by the mixture and the purpose to which the microsurfacing is most suited. Type II microsurfacing is coarser and is suggested for urban and residential streets and airport runways. Type III microsurfacings have the coarsest grading and are appropriate for filling minor surface irregularities (microsurfacing only), correcting raveling and oxidation, and restoring surface friction. Type III microsurfacings are typically used on arterial streets and highways.

The role of fines (i.e., aggregate particles No. 200 [75 µm] and finer) in a slurry surfacing mix is to form a mortar with the residual asphalt to cement the larger stones in place. The fines content is essential for creating a cohesive hardwearing mix. Generally, the fines content should be at the mid-point of the grading envelope. Recent work suggests that the distribution of the sub-No. 200 (75 micron) fraction is critical to control the reaction rate in microsurfacing emulsions (Schilling, 2002). The general aggregate quality requirements for the various slurry systems are listed in Table 9-3.

Table 9-3 General Aggregate Properties (Caltrans, 1999a, Caltrans, 2002) and Aggregate Requirements (Schilling, 2002)

TEST	MICROSURFACING	TEST # AND PURPOSE
Sand Equivalent (min)	65	CT 217 (Clay Content)
Durability Index (min)	65	CT 229 (Resistance to wet/dry exposure)
Abrasion (LA Rattler) 500rev	35% max	ASTM 211 (Resistance to traffic)
Crushed Particles	100%	CT 205

9.2.3 Mineral Filler and Additives

In most slurry surfacing systems, cement is used as a mixing aid allowing the mixing time to be extended and creating a creamy consistency that is easy to spread. Additionally, hydroxyl ions counteract the emulsifier ions, resulting in a mix that breaks faster with a shorter curing time. Cement is also a fine material and, as such, absorbs water from the emulsion, causing it to break faster after placement. Fine materials, as previously discussed, also promote cohesion of the mixture by forming a mortar with the residual asphalt.

Additives other than cement vary and are features of particular systems. They can act as retardants to the reaction with emulsions, either as a prophylactic, slowing the emulsifier's access to the aggregate surface, or by preferentially reacting with the emulsifier in the system. Additives include emulsifier solutions, aluminum sulfate, aluminum chloride, and borax. Generally, increasing the concentration of an additive slows the breaking and curing times. This is useful when air temperatures increase during the day.

9.3 MIX DESIGN

The performance of a microsurfacing depends on the quality of the materials and how they interact during cure and after cure. The mix design procedure looks at the various phases of this process, which include:

- **Mixing:** Will the components mix together and form true, free flowing slurry?
- **Breaking and Curing:** Will the emulsion break in a controlled way on the aggregate, coat the aggregate, and form good films on the aggregate? Will the emulsion build up cohesion to a level that will resist abrasion due to traffic?
- **Performance:** Will the microsurfacing resist traffic-induced stresses?

The steps in microsurfacing design include:

- Prescreening of Materials
- Job Mix Design
- Final Testing

At each stage, mixing, breaking, curing, and performance issues are addressed.

9.3.1 Prescreening

Prescreening involves testing the physical properties of the raw materials. The emulsion type is selected based on job requirements and is checked against the requirements laid out in the specifications (Table 9-1). The aggregate is checked against specifications (Tables 9-2 and 9-3) and a simple mixing test is performed to assess compatibility with the emulsion. When both of these steps are satisfied, the job mix formula can be developed. During the overall process the materials may be changed at any time until satisfactory results are obtained.

9.3.2 Job Mix Design

Mixing Proportions

The International Slurry Surfacing Association (ISSA) test method detailed in Technical Bulletin 102 is normally used to determine the approximate proportions of the slurry mix components (ISSA, 1990). In this test which is typically conducted by the testing lab, a matrix of mix recipes are made up and the manual mixing time is recorded for each mixture. A minimum time is required to ensure that the mixture will be able to mix without breaking in the slurry machine. At this stage, phenomena such as foaming and coating are visually assessed. Also at this stage, the water content and additive content can be determined to produce a quality mixture. Figure 9-3 illustrates a good slurry mixture consistency which meets the requirements of Caltrans non standard special provision (NSSP) 37-600.

Figure 9-3 Good Mixture Consistency

The mixing time must be at least 120 seconds for microsurfacing at 77°F (25°C). The process may be repeated at elevated or reduced temperatures to simulate expected field conditions at the time of application. The best mix is chosen, based on good coating of mixing times in excess of the minimum required through the entire range of expected application temperatures.

Cohesion Build-up

Once the emulsion content is determined, three mixes are then made, one at the selected emulsion percentage from above, one at -2% of the selected emulsion content and one at +2% of the selected emulsion content. This allows a bracketing of the desired mix proportions. The ISSA test method TB 139 (ISSA, 1990) is used to determine the cohesion build-up in a slurry mixture. This test may be performed at the expected field temperatures to provide the most accurate estimate of the treatment's characteristics. Table 9-4 lists mix requirements for microsurfacing.

Abrasion Resistance (Wet Track Abrasion Test – WTAT)

Mixes are made at three emulsion contents, optimum, optimum +2%, and -2% of optimum. These mixes are then cured in circular molds for 16 hours at 140°F (60°C). The samples are then soaked for either 1 hour or 6 days, depending on the abrasion test (TB 100) (ISSA, 1990) and the material. Slurry design requires a 1-hour soaking while microsurfacing requires 1-hour and 6-day soaking periods. After soaking, a standard rubber hose is ground over the surface of the sample (while still submerged) for a set period of time. The wear loss is then calculated. The test equipment is shown in Figure 9-4, while the abrasion resistance requirements are listed in Table 9-4.

The results of the abrasion test are plotted along with the specification requirements. This allows selection of the minimum binder content of the mixture.

a) Mixer Equipped with sample Mold and Rubber Hose Attachment

b) Orbital Grinding of Sample Using Rubber Hose Attachment

Figure 9-4 Wet Track Abrasion Test Apparatus and Test in Progress (Holleran, 2001)

Table 9-4 Typical Mix Requirements (Caltrans, 2002, ISSA, 2005)

PROPERTY	TEST	MICROSURFACING
Wear Loss (Wet Track Test)	TB 100 (1 hr soak) (6 day soak)	0.11 lb/ft^2 (540 g/m^2) max 0.16 lb/ft^2 (800 g/m^2) max
Traffic Time (Wet Cohesion Test)	TB 139 (30 minutes) (60 minutes)	0.87 lb-ft (0.12 kg-m) min 1.4 lb-ft (0.20 kg-m) min
Adhesion (Wet Strip) Integrity SB	TB 114 TB 144	>90% 11 pts min (AAA, BAA)
Excess Binder	TB 109	0.11 lb/ft^2 (540 g/m^2) max
Deformation	TB 147	10% max

Upper Binder Limit

The upper binder limit is determined using the Loaded Wheel Test, as described in TB 109 (ISSA, 1991). In this test, the slurry seal specimen is compacted by means of a loaded rubber tired reciprocating wheel as illustrated in Figure 9-5. After 1000 loading cycles, the specimen is removed from the machine, washed and dried to constant weight. Then, the specimen is mounted again on the machine and hot sand is added on the surface. After another 100 cycles of compaction, the increase in weight of the specimen due to sand adhesion is noted. This provides a measure of the free asphalt on the surface of the sample. The more prone the mix is to flushing or bleeding under traffic loading the larger the amount of sand retained on the specimen. Figure 9-5 illustrates the test apparatus along with a series of tested samples.

a) Testing Apparatus

b) Tested Samples Showing Retained Sand

Figure 9-5 Loaded Wheel Test and Excess Asphalt Test Apparatus and Test Samples

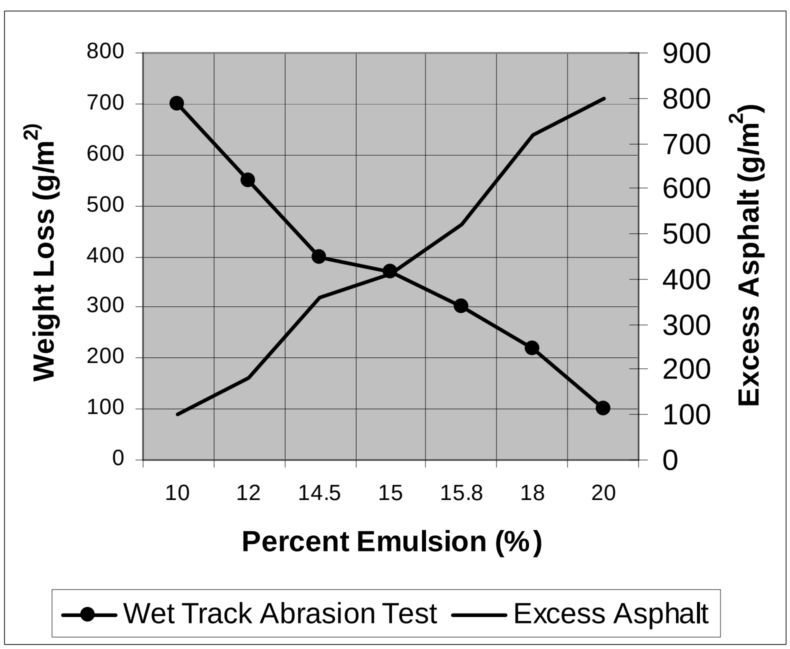


Figure 9-6 Determining Optimum Binder Content

Optimum Binder

The optimum percentage emulsion or binder content is found by plotting the results obtained from the Wet Track Test (TB 100) and the Excess Binder Test (TB 109) (ISSA, 1990). Figure 9-6 illustrates a typical plot of test results. The optimum binder content is close to the intersection of the two plotted lines, but the testing does not account for all the factors influencing the mix. For example, the optimum binder content at the intersection of the plotted results is adjusted for the expected traffic conditions. A rule of thumb is to select the highest binder content that passes both tests for low traffic conditions and the lowest binder content for heavy traffic conditions. Note that this requires an experienced designer to select the optimum and this must be based on field knowledge and experience. This is a weakness in the current design process.

9.3.3 Final Testing

Once the job mix components have been selected, the mix is tested to determine its properties and ensure compliance with the specifications listed in Table 9-4. If the mix conforms to the specifications, the emulsion content and aggregate grading is reported as the job mix formula.

Field adjustments may be made to the job mix formula to accommodate climatic variables during application. As a result of the mix design process, adjustments are limited to the amount of additives (cement and retardant) and water content required to ensure a good homogeneous mix at the time of application.

9.4 PROJECT SELECTION

9.4.1 Distress and Application Considerations

Slurry surfacing may be used for a range of applications, but job selection is critical and often pretreatments such as pothole patching crack sealing, and dig outs are required. Table 9-5 lists general job selection criteria for slurry surfacing treatments and typical application rates.

Table 9-5 Job Selection Criteria

APPLICATIONS	AGGREGATE TYPE	
	II	III
Void Filling	●	
Wearing Course (AADT) < 100	●	
Wearing Course (AADT) 100 – 1,000	●	●
Wearing Course (AADT) 1,000 – 20,000	●	●
Minor Shape Correction (0.4-0.8 in [10-20mm])		●
Application Rates in pounds of dry aggregate per square yard	10 – 15	20 – 25

The main use of microsurfacing materials is for pavement preservation as a part of a program of periodic surfacing before distresses appear. The main criteria for project selection are:

- Sound and well drained bases, surfaces, and shoulders.
- Free of distresses, including potholes and cracking. These must be repaired before slurry application. Potholes should be filled and compacted several weeks prior to slurry surfacing. Emulsion crack filling should be done several months prior to slurry surfacing.

Distress modes that can be addressed using microsurfacing include:

- **Raveling:** Loose surfaces or surfaces losing aggregate may be resurfaced using slurry seals or microsurfacing.
- **Oxidized pavement with hairline cracks:** These surfaces may be resurfaced using slurry seals or microsurfacing.
- **Rutted pavements:** Deformation resulting from consolidation of the surfacing only. Rutting due to base failure of significant plastic deformation of the HMA cannot be treated except as a temporary measure.
- **Rough pavements with short wavelength:** These irregularities may be treated with microsurfacing, provided the frequency of the irregularities is shorter than the spreader box width.

Distress modes that cannot be addressed using microsurfacing include:

- **Cracking** (including reflection cracking)
- **Base Failures** of any kind
- **HMA Layers** that exhibit plastic shear deformation

Microsurfacing will not alleviate the cause of these distresses. As a result, the distresses will continue to form despite the application of a slurry surfacing.

9.4.2 Performance of Microsurfacing

Microsurfacing performance is strongly affected by workmanship and the condition of the pavement at the time of application. When used as a preventive maintenance treatment, on pavements in relatively good condition, microsurfacing may last 7 to 10 years (Van Kirk, 2000), although longer life times have been claimed (Van Kirk, 2000). On average however, the life expectancy of a microsurfacing treatment is 5 to 7 years. When applied in ruts, the life of the treatment is dependant on the stability of the microsurfacing, the traffic level, and the condition of the underlying pavement.

The main mechanism of failure is wear. Through wear the surface oxidizes and is abraded over time. Premature treatment failure occurs from placement on highly deflecting surfaces, cracked surfaces, pavements with base failures, and on dirty or poorly prepared surfaces (resulting in delamination).

9.5 CONSTRUCTION

The main components of the construction process include:

- Safety and Traffic Control
- Equipment Requirements
- Stockpile/Project Staging Area Requirements
- Surface Preparation
- Application Conditions

- Types of Applications
- Quality Issues
- Post Construction Conditions
- Post-Treatments

Sections 9.6.2 titled “Field Considerations”, provides a series of tables to guide project personnel through the important aspects of applying a slurry surfacing.

9.5.1 Safety and Traffic Control

Traffic control is required both for the safety of the traveling public and the employees performing the work. Traffic control should be in place before work forces and equipment enter onto the roadway or into the work zone. Traffic control includes construction signs, construction cones and/or barricades, flag personnel, and pilot cars to direct traffic clear of the maintenance operation. For detailed Traffic Control requirements please refer to the Caltrans project specifications and the Caltrans Code of Safe Operating Practice (Caltrans, 1999).

Traffic control is required to ensure that the slurry surfacing has had adequate time to cure prior to reopening to traffic. The curing time for the slurry surfacing material will vary depending on the pavement surface conditions and the weather conditions at the time of application. Additional traffic control considerations are listed in the Field Considerations section (Section 9.6.2).

9.5.2 Equipment Requirements

Equipment requirements for slurry machines and microsurfacing machines are covered in Caltrans “Microsurfacing Pilot Study 2001” (Caltrans, 2002). There is not a Standard Specification available for microsurfacing at this time. Calibration requirements are discussed in California test method CT109. Modern equipment, as shown in Figure 9-7, can be used to place either slurry seal or microsurfacing.

The difference between slurry and microsurfacing equipment is in the spreader boxes used. A slurry seal spreader box is a drag box, as shown in Figure 9-8. The drag box is pulled behind the paver by means of chains. This box may or may not have augers; for quick set systems augers should be used. The slurry seal should be easy to work and spread, and not cause any hang-up in the box.

A microsurfacing spreader box, shown in Figure 9-9, has to move a much stiffer mixture than a slurry spreader box, do it quickly, and then spread it before the emulsion breaks. To accommodate this, two sets of augers are used and a texturing rubber is added at the rear of the box. The texturing rubber is usually spread using an outrigger. The outrigger creates the desired surface texture for the surface. Additionally, a microsurfacing box is rigidly attached to the rear of the paver, allowing a preset thickness of material to be placed.

Figure 9-7 Slurry Surfacing Machine

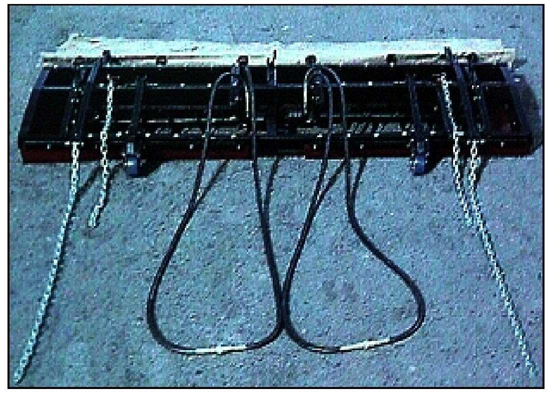
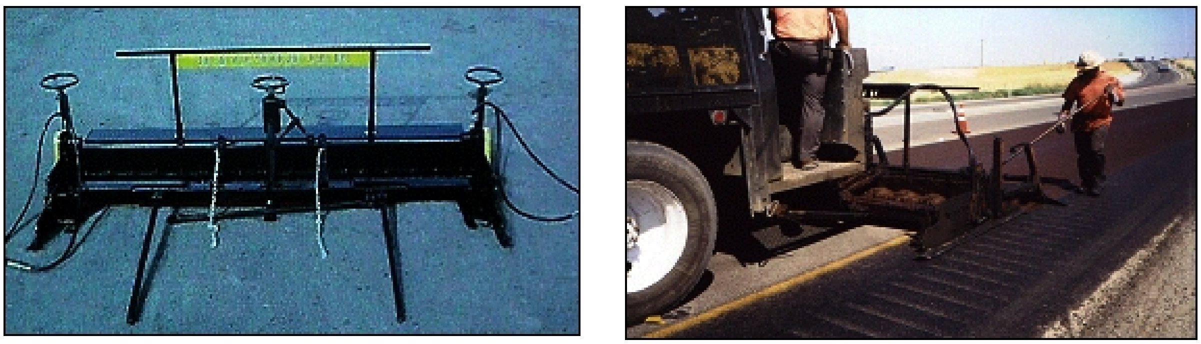


Figure 9-8 Slurry Seal Box with Augers



a) Typical Microsurfacing Spreader Box

b) Outrigger Texture Flap

Figure 9-9 Microsurfacing Equipment and Application

Rut Filling and Shoulder Equipment

Special boxes are used for rut filling applications when filling ruts greater than 0.5 in (12 mm) deep. When filling ruts less than 0.5 in (12 mm) deep, a steel strike-off box is used for the scratch courses (see Section below). Adjustable width edge boxes are used for shoulders and to create clean joints between shoulders and the traveled way. Figures 9-10 and 9-11 illustrate a rut filling box and an adjustable edge box, respectively.

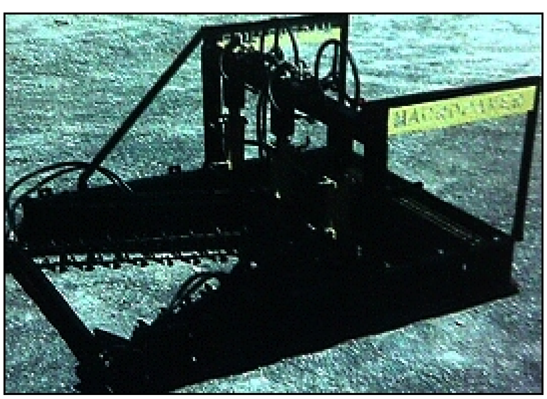


Figure 9-10 Rut Box

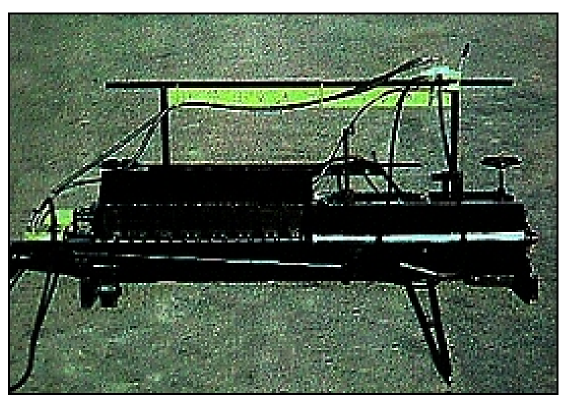


Figure 9-11 Adjustable Edge Box

Calibration

The design mix is proportioned by weight while the slurry surfacing machines deliver materials by volume. Due to this different nature of the measurements, it is essential that calibration be done with the actual job materials. No machine should be allowed to work on a Caltrans job without a proper calibration.

9.5.3 Stockpile / Project Staging Area Requirements

The stockpile and project staging area must meet some basic requirements. These requirements include:

- A Clean, Well-drained Pad for Aggregate Piles
- Front-end Loader for Loading Machines
- Flow Boy-type Vehicles in Continuous Operation
- A Salt-Free Water Supply
- An Emulsion Tanker
- An Additive Tanker

The stockpile and staging area should be as close as possible to the job site. Figure 9-12 illustrates a typical stockpile and staging area.

Figure 9-12 A Typical Stockpile and Project Staging Area

Operations should be scheduled to run as smoothly as possible and provide good traffic flow through the work zone. Aggregates that are measured to have moisture content below optimum should be remixed using the front-end loader to avoid segregation. In some cases aggregates that are separating in the stockpile or during loading may need to be sprayed with water to avoid fines loss.

9.5.4 Surface Preparation

The main objective of surface preparation is to provide a clean and sound surface on which the microsurfacing is applied. The first step of surface preparation is to restore the pavement's structural integrity and functional performance characteristics through crack sealing and patching (Chapters 4 and 5).

Immediately before the microsurfacing is applied, the road must be swept clean. If clay or hard-to-remove materials (such as organic matter) are present, high power pressure washing may be required.

If left on the road, these types of contaminants will cause delamination of the treatment in these areas. Thermoplastic road markings must also be removed prior to placing microsurfacing, or at least abraded to produce a rough surface. Paint markings require no pretreatment. Rubber crack sealant on the roadway should be removed prior to applying a slurry surface.

Utility inlets should be covered with heavy paper or roofing felt adhered to the surface of the inlet. The paper is removed once the slurry surfacing has sufficiently cured. In addition to covering the inlets, all starts, stops, and handwork on turnouts should be done on roofing felt to ensure sharp, uniform joints and edges. Figure 9-13 illustrates the various surface preparation steps along with illustrations of delamination resulting from poor surface preparation.

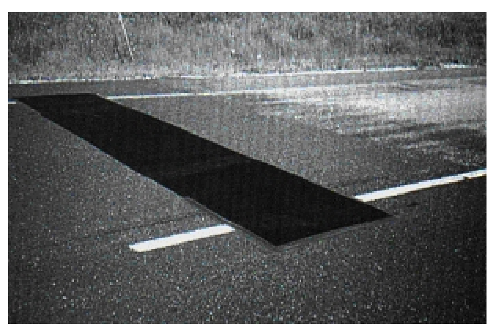
a) Sweeping

b) Dirty surfaces Result in Poor Adhesion (Delamination)

c) Cover Utilities with Kraft Paper

d) Microsurfacing Covers Inlet and Paper Cover

e) Peel Off Paper Covering Once Treatment has Cured



f) Starting Transverse Joints on Roofing Felt Produces Clean Joints

Figure 9-13 Surface Preparation Methods

9.5.5 Application Conditions

The application conditions required are addressed in detail in the Caltrans "Microsurfacing Pilot Study 2001", Appendix A (Caltrans, 2002). The basic requirement for success is that the emulsion must be able to break and form continuous films, as it is the only way a slurry mixture can become cohesive. As a result, humidity, wind conditions, and air and surface temperature are important and need to be considered. Modifications to additives should be made according to the changing environment during application. Because microsurfacing slurry systems use a chemical break, they can be placed at night.

Microsurfacing shall only be placed when the ambient temperature is 8°C (46°F) and rising and the high temperature for the day is expected to be at least 20°C. Microsurfacing shall not be placed if rain is imminent or if the ambient temperature is expected to fall below 2°C within 24 hours after placement. Slurry surfacing systems will typically resist rain induced damage after as little as one hour but typically require at least three hours to cure to a fully waterproof state. Additionally, breaking time for a slurry system is affected by ambient temperature. Figure 9-14 shows the effect of temperature on the breaking rate of emulsion.

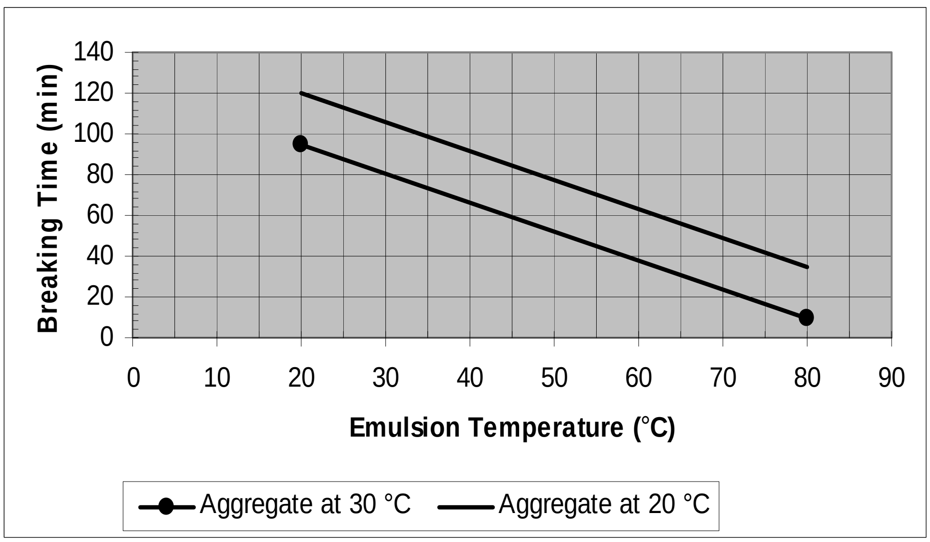


Figure 9-14 Effect of Temperature on Break Rate

9.5.6 Types of Applications

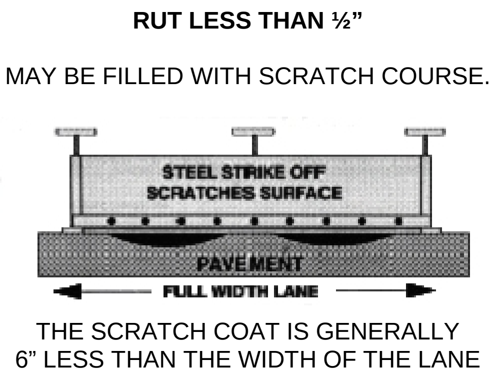
Full Width Seal

When applying a full width seal a standard spreader box is used. Three passes are typically used for a two-lane roadway. This allows clean edges and minimizes overlaps (usually 3 in (75 mm)). Overlapped seals should only be used when the pavement being sealed is level and in sound condition.

Scratch Coat

Scratch coats are used to level pavements with minor transverse irregularities that are narrower than the width of the spreader box, or on pavements with longitudinal ruts less than 0.5 in (12.5 mm) deep.

When applying a scratch coat a steel strike-off is substituted for the secondary strike-off in the standard microsurfacing drag box. The steel strike-off drags over the high spots of the pavement, filling in the irregularities. Such materials are highly friable and stone loss is often high. Scratch coats should always be covered with a surface seal. The scratch coat principle along with a photo of a finished section is illustrated in Figure 9-15.



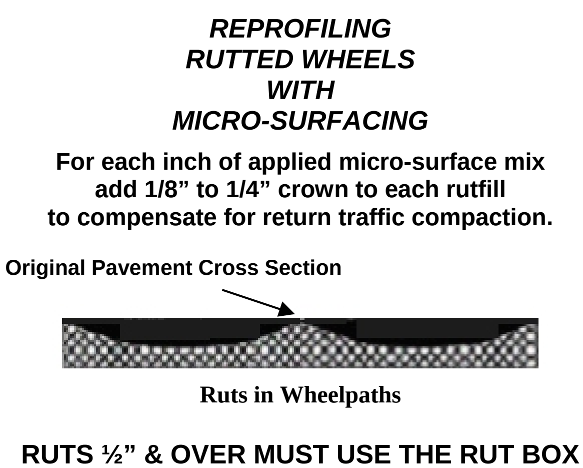
a) Scratch Coat Principle

b) Example of a Scratch Coat Treatment

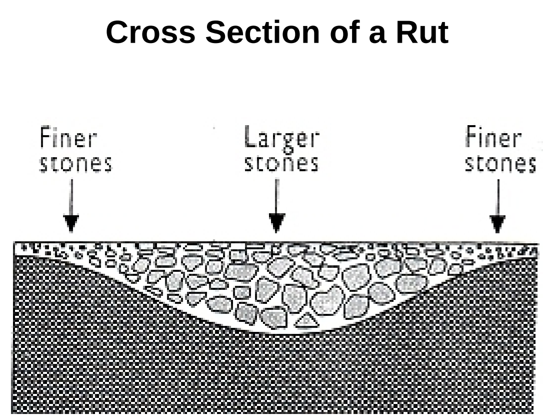
Figure 9-15 Scratch Coat Principles and Treatment

Rut Filling

Ruts may be filled with a high stability microsurfacing mix. A rut box is essential for this application; it channels mix into the ruts and leaves a crowned finish to compensate for post compaction due to trafficking. Generally, ruts filled in this manner are covered with a surface seal, but this is not essential. Rolling is often incorporated to ensure compaction of the mix placed in rutted surfaces. Figure 9-16 illustrates the principle behind rut filling and provides a cross sectional diagram of a filled rut. Rut filling should only be used on stable ruts that have resulted from long-term traffic compaction. If rutting is ongoing, the microsurfacing will not prevent its continued development. Figure 9-17 illustrates both suitable and unsuitable candidates for rut filling.



a) Principle of Rut Filling (Holleran, 2002)



b) Cross Section of a Filled Rut (Holleran, 2001)

Figure 9-16 Rut Filling Principle and Sectional Diagram

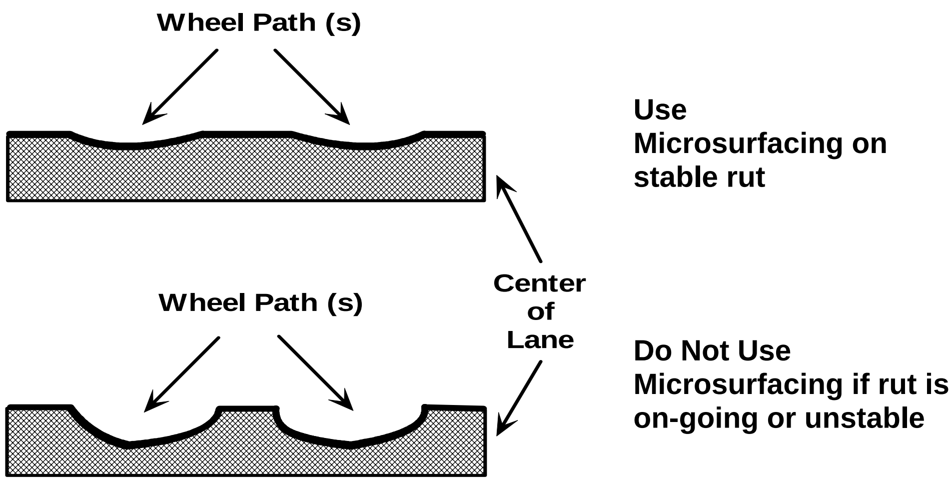


Figure 9-17 Suitable and Unsuitable Surfaces to Use Microsurfacing as a Rut Filler

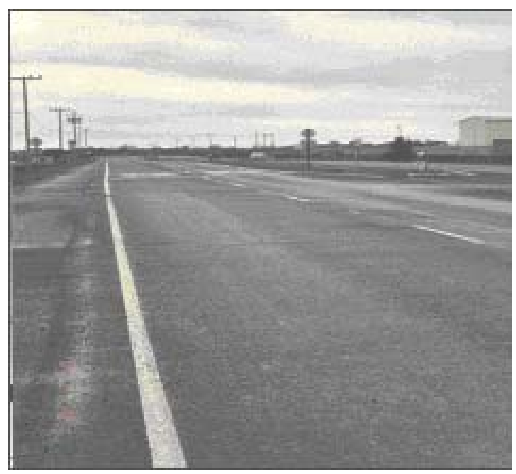
9.5.7 Quality Issues

Quality control is critical during the constriction process to achieve a uniform surface finish. The main areas of concern are discussed below.

Longitudinal Joints

Longitudinal joints may be overlapped or butt jointed. They should be straight or curve with the traffic lane. Overlaps should not be in the wheel paths and should not exceed 3 in (75 mm) in width. Figure 9-18 illustrates high quality and poor quality longitudinal joints.

a) High Quality Longitudinal Joint



b) Poor Quality Longitudinal Joints

Figure 9-18 Longitudinal Joints

Transverse Joints

Transverse joints are inevitable when working with batch systems; every time a truck is emptied a transverse joint is required. Transitions at these joints must be smooth to avoid creating a bump in the surface. The joints must be butted to avoid these bumps and handwork should be kept to a minimum. The main difficulty in obtaining a smooth joint occurs as the slurry machine starts up at the joint, particularly when working with microsurfacing that is difficult to work by hand and breaks quickly. Some contractors tend to over wet (add too much water) to the mix at start-ups. This leads to poor texture and scarring at the joints. Starting transverse joints on roofing felt can eliminate these problems. Figure 9-19 illustrates high quality and low quality transverse joints.

a) High Quality Transverse Joint

b) Low Quality Transverse Joint

Figure 9-19 Transverse Joints

Edges and Shoulders

Slurry sealed edges and shoulders can be rough and look poor. This occurs more often with microsurfacing applications, which break quickly, making them harder to work by hand than slurry seals. For microsurfacing, handwork should be kept to a minimum. The edge of the spreader box should be outside the line of the pavement and edge boxes should be used when shoulders are covered. Figure 9-20 illustrates high quality and poor quality edge and handwork.

a) High Quality Edges and Shoulder

b) Poor Quality Edges and Shoulder

Figure 9-20 Edges and Shoulders

Uneven Mixes and Segregation

Poorly designed slurry mixtures or mixtures with low cement content or too high a water content may separate once mixing in the box has ceased. This leads to a black and flush looking surface with poor texture. Separated mixes may lead to a "false slurry" where the emulsion breaks onto the fine material. In such instances delamination may occur, resulting in premature failure. These types of mixes can be recognized as non-uniform mixes that appear to be setting very slowly. Figure 9-21 illustrates segregation and delamination resulting from a false slurry.

a) Segregation

b) Delamination from a False Slurry

Figure 9-21 Poor Mixes

Smoothness Problems

Slurry surfacing systems follow the existing road surface profile and thus do not have the ability to significantly change the pavement's smoothness. However, when using stiffer mixes the spreader box may, if incorrectly set up, chatter or bump as the material is spread and produce a washboard effect. The chattering may be addressed by making the mixture slower to set, adjusting the rubbers on the box, or adding weight to the back of the spreader box. Figure 9-22 illustrates the washboard effect.

Figure 9-22 Wash Boarding Effect

Damage Caused by Premature Reopening to Traffic

The slurry seal or microsurfacing must build sufficient cohesion to resist abrasion due to traffic. Early stone shedding is normal, but should not exceed 3%. If a mixture is reopened to traffic too early it will ravel off quickly, particularly in high stress areas. It is important that the mixture has formed adequate cohesion before it is opened. Choosing the right time to reopen a surface to traffic is based largely on experience. However, a general rule of thumb for a slurry seal is that it can be opened when it has turned black; a microsurfacing can carry traffic when it is expelling clear water. Figure 9-23 illustrates raveling caused by premature opening to traffic.

Figure 9-23 Traffic Damage Caused by Early Trafficking

9.5.8 Post Construction Conditions

Emulsion systems do not lose all water in the first hours after placement; the total water loss process can take up to several weeks. During this period the surface will be water resistant; however, if the water freezes, it can cause rupture of the binder film and subsequent raveling. For this reason, projects should not be started without a 2-week window when freezing weather will not occur.

Asphalt emulsion based systems cannot re-emulsify; however, if not fully cured, these systems can be tender enough to re-disperse under the effects of traffic loading and excessive water, especially ponding water. In this process, broken aggregates or asphalt particles that have not fully coalesced into films are dispersed in water, which disintegrates the emulsion. Thus, while light rain 3 hours after placing a slurry seal is acceptable, heavy rain coupled with heavy traffic will likely lead to surface damage, especially in high shear (e.g., turning movement) areas. Figure 9-24 illustrates damage caused by heavy rain in a high shear location.

Figure 9-24 Damage Due to Post Application Heavy Rain with Shear

9.5.9 Post-Treatments

Rolling

Slurry seals will lose stone until the surface voids have been closed off, but it is acceptable for approximately 3% of surface stone to be lost. To limit the amount of loss, rolling with pneumatic rollers may be incorporated. For rut filling applications, rolling is almost always recommended. The roller should be light (6-7 tones maximum) and non-ballasted. One to two passes at a slow speed are recommended. This allows the water to be pressed to the surface, promoting evaporation and curing. Larger stones will be properly embedded, reducing early raveling. Figure 9-25 illustrates a typical roller operation.

Figure 9-25 Rolling a Slurry Surfacing

Rolling is always used on airports due to the low traffic and the seriousness of losing stone in areas where jet engines operate. Figure 9-26 illustrates the rolling of an airport taxiway.

Figure 9-26 Rolling of an Airport Taxiways

Sweeping

On heavily trafficked roads or where opening has lead to excessive stone loss, sweeping is essential. A suction broom is the best type of sweeper to use. Sweeping should be done just prior to opening to traffic and at periods determined by the level of stone loss. Figure 9-27 illustrates a suction broom.

Figure 9-27 Sweeping with a Suction Broom

Sanding

Sanding may be used to reduce the times that cross streets or intersections are closed. Sanding is the application of a fine layer of dry, washed sand that is broadcast over the slurry surface. Sanding may also be used on wet spots. Sanding should not be done until the slurry can withstand walking traffic. Figure 9-28 illustrates the use of sanding at a cross street.

Figure 9-28 Sanding at a Cross Street

9.6 TROUBLESHOOTING AND FIELD CONSIDERATIONS

9.6.1 Troubleshooting Guide

This section provides information to assist the maintenance personnel in troubleshooting problems with microsurfacing, along with "do's and don'ts" that address common problems that may be encountered during the course of a project. The troubleshooting guide presented in Table 9-6 associates common problems to their potential causes. For example, an unstable emulsion, too little water in the mix, incompatibility between the emulsion and the aggregate, and so on, may cause a slurry surface to delaminate.

Table 9-6 Trouble Shooting Microsurfacing Seal Job Problems

CAUSE	PROBLEM									
	BROWN	WHITISH	WON'T SET	POOR COATING	DELAYED OPENING TO TRAFFIC	BREAKS IN BOX	RAVELS	FLUSHES	DELAMINATION	SEGREGATION
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			•	•	•		•		•	•
CONDITIONS										
Too hot	•			•		•	•	•		
Too cold			•		•		•		•	
Rain	•		•	•	•		•	•	•	
High humidity		•	•							
SURFACE										
Fatty			•					•		

In addition to the troubleshooting guide, Table 9-7 lists some commonly encountered problems and their recommended solutions.

Table 9-7 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. • Make 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 runners of spreader box are running on fresh microsurfacing.
EXCESSIVE RAVEL	• 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 and at low speeds. • Wait until fully cured before allowing traffic. • Wait until mix is properly set before brooming or opening to traffic.

9.6.2 Field Considerations

The following tables are guides to the important aspects of performing a microsurfacing project. The tables list items that should be considered in order to promote a successful job outcome. The answers to these questions should be determined, as required, before, during, and after construction. The appropriate staff to do this will vary by job type and size. Some topics may need attention from several staff members. The field supervisor should be acquainted with its contents.

The intention of the table is not to form a report but to bring attention to important aspects and components of the slurry surfacing project process. Some information is product specific and contained in the relevant standard specifications, special standard provisions, or special provisions.

PRELIMINARY RESPONSIBILITIES	
PROJECT REVIEW	• Is the project a good candidate for microsurfacing? • Should a microsurfacing seal be used? • What is the depth and extent of any rutting? • How much and what type of cracking exists? • Is crack sealing needed? • How much bleeding or flushing exists? • Is the pavement raveling? • What is the traffic level? • Is the base sound and well drained? • Have the project bid/plan quantities been reviewed?
DOCUMENT REVIEW	• Bid specifications • Mix design information • Special provisions • Construction manual • Traffic control plan (TCP) • Material safety data sheet
MATERIALS CHECKS	• Has a full mix design and compatibility test been completed? • Is the binder from an approved source (if required)? • Has the binder been sampled and submitted for testing? • Does the aggregate meet all specifications? • Is the aggregate clean and free of deleterious materials? • Is the aggregate dry? • Is the emulsion temperature within application temperature specifications?

PRE-SEAL INSPECTION RESPONSIBILITIES	
SURFACE PREPARATION	• Is the surface clean and dry? • Have all pavement distresses been repaired? • Has the existing surface has been inspected for drainage problems?
EQUIPMENT INSPECTION CONSIDERATIONS	
BROOM	• Are the bristles the proper length? • Can the broom be adjusted vertically to avoid excess pressure?
CALIBRATION OF EQUIPMENT	• Has each machine been calibrated with the project's aggregate and emulsion? • Who carried out calibration and what documentation has been provided?
MICROSURFACING MACHINE	• Is the machine fully functional? • Has the machine been calibrated for this project's aggregate and certified. Is the spreader rubber clean and not worn? • Is the texture rubber clean and set at the right angle? • Are all paddles in the pug mill are intact? • Is the spreader box clean and is it a microsurfacing type box?
ROLLERS (IF USED)	• Do the roller tire pressures comply with the manufacturer's specification? • What type roller will be used on the project (pneumatic-tired roller recommended)? • Do the roller tire size, rating, and pressures comply with manufacturer's recommendations? • Is the pressure in all tires the same? • Do all tires have a smooth surface?
STOCKPILE	• Is the stockpile site well drained and clean? • Does the Contractor have all of the equipment required at the stockpile site (loaders, tankers, and so on)?

EQUIPMENT INSPECTION CONSIDERATIONS	
EQUIPMENT FOR CONTINUOUS RUN OPERATIONS	• Is all equipment free of leaks? • Are “Flow boys” or other nurse units clean and functional? • Are there enough units to allow continuous running with minimal stops for cleaning box rubbers?
SITE CONSIDERATIONS	
WEATHER REQUIREMENTS	• Have air and surface temperatures been checked at the coolest location on the project? • Do air and surface temperatures meet agency requirements? • Are adverse weather conditions expected? High temperatures, humidity, and wind will affect how long the emulsion takes to break. • The application of the slurry surfacing does not begin if rain is likely? • Are freezing temperatures expected within 24 hours of the completion of any application runs?
TRAFFIC CONTROL	• Do the signs and devices used match the traffic control plan? • Does the work zone comply with Caltrans requirements? • Flaggers do not hold the traffic for extended periods of time? • Unsafe conditions, if any, are reported to a supervisor (contractor or agency)? • The pilot car leads traffic slowly, 24 mph (40 km/h) or less, over fresh microsurfacing? • Signs are removed or covered when they no longer apply?
APPLICATION CONSIDERATIONS	
DETERMINING APPLICATION RATES	• Have agency guidelines and requirements been followed? • Have rut filling and leveling course application rates been calculated or estimated separately? • Has a full mix design been done? • Is more material applied to dried-out and porous surfaces? • Is more material applied on roads with low traffic volumes? • Is less material applied to smooth, non-porous, and asphalt-rich surfaces? • Has moisture content been adjusted in the application rate?

PROJECT INSPECTION RESPONSIBILITIES	
MICROSURFACING APPLICATION	• Has a test strip been done and is it satisfactory? • Have field tests been carried out and are the results within specification? • Are enough trucks on hand to keep a steady supply of material for the slurry machine? • Does the application start and stop with neat, straight edges? Will an edge box be used? • Is a rut box is used for ruts deeper than ½" (12 mm)? • Is a leveling course used with a steel strike-off for ruts less than ½" (12 mm)? Two courses are used where rut filling or leveling is employed. • Does the application start and stop on building paper or roofing felt? • Are drag marks present due to oversize aggregate or dirty rubbers? • Are rubbers cleaned regularly and at the end of each day? • Does the machine take a straight, even line with minimal numbers of passes to cover the pavement? • Is the mix even and consistent? • Are fines migrating to the surface? • Is the application stopped as soon as any problems are detected? • Does the application appear uniform? • Does the surface have an even and uniform texture? • Is the application rate checked based on amounts of aggregate and emulsion used? • What is the time between spreading, foot traffic, and opening to vehicular traffic?
ROLLING	• Does rolling wait until the mat is stable? Roller is 5-6 tones (7) maximum. • Is the entire surface rolled only once? • Do the rollers travel slowly, 5 mph (8-9 km/h) maximum?
TRUCK OPERATION	• Are trucks staggered across the fresh seal coat to avoid driving over the same area? • Do trucks travel slowly on the fresh seal? • Are stops and turns made gradually? • Do truck operators avoid driving over the microsurfacing? • Do truck operators stagger their wheel paths when backing into the paving unit?
LONGITUDINAL JOINTS	• Is the meet line overlapped a maximum of 3 in (75 mm)? • Do the spreader box runners avoid running on fresh mat? • Are the meet lines made at the center of the road, center of a lane, or edge of a lane not in the wheel paths?

PROJECT INSPECTION RESPONSIBILITIES	
TRANSVERSE JOINTS	• Do all applications begin and end on building paper? • Mixture is not too wet at start up? • Is the building paper disposed of properly?
BROOMING	• Does brooming begin after the microsurfacing can carry traffic? • Does brooming dislodge the microsurfacing? • Is the surface raveling? Follow-up brooming should be done if raveling is high or if traffic is high.
OPENING THE MICROSURFACING TO TRAFFIC	• Does the traffic travel slowly - 24 mph (40 kph) or less over the fresh microsurfacing? • Are reduced speed limit signs used when pilot cars are not used? • After brooming, have pavement markings been placed before opening to traffic? • Have all construction-related signs been removed when opening to normal traffic?
CLEAN UP	• Have all loose aggregate from brooming been removed from traveled way prior to opening to traffic? • Have all binder spills been cleaned up?

9.7 REFERENCES

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