Best Practices for Slurry Surfacing Systems

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

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Disclaimer

The opinions expressed in this document are those of the authors and do not necessarily reflect the view of the AASHTO TSP-2 ETF or the AASHTO Committee on Pavements and Materials (COMP), or individual committee members and reviewers

Forward

Slurry Surfacing Systems have been used for almost one hundred years; the process was developed and used in Germany in the 1920's. At that time, the product consisted of a mixture of fine aggregates, asphalt binder, and water. It was mixed by introducing the ingredients into a tank outfitted with an agitator. However, it was not until the 1960's that real interest was shown in the use of slurry seals as a pavement maintenance treatment. The work by Benedict on mix design procedures and specifications (2) is still in use today and incorporated into the mix design and performance guides published by the International Slurry Surfacing Association (ISSA).

Micro surfacing was also pioneered in Germany in the late 1960's and early 1970's. It consisted of placing thicker layers of materials into wheel track ruts on the autobahn and was first introduced into the USA in the 1980's. Slurry surfacing systems is a term adopted by the International Slurry Surfacing Association in 2003 as a response to the continued evolution of science and technology to refer to all forms of slurry seal and micro surfacing.

About the same time, the National Cooperative Highway Research Program (NCHRP) contracted with Doug Gransberg of Iowa State University to undertake a Synthesis of Best Practices for Micro surfacing that was published as NCHRP Synthesis 411(12) Much of the information related to this report is drawn from these documents along with information published by ISSA, the AASHTO TSP-2 Emulsion Task Force (ETF) and the AASHTO Committee on Pavements and Materials. Over the past several years, the ETF has developed standards for slurry and micro surfacing design and materials that have been published by the AASHTO Committee on Pavements and Materials (COMP). Construction Guides for these techniques are currently being developed for COMP approval. The AASHTO TSP-2 ETF has also developed QA guides for Slurry Surfacing Systems which are under review by AASHTO.

This report is a summary of best practices for slurry surfacing systems. It discusses the following:

- Background and terminology
- Applications for slurry surfacing systems
- Materials used in slurry surfacing systems
- Mix design and performance tests
- Specifications
- Construction
- Quality control and inspection
- Problem solving

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1.0 Introduction

Slurry seals were developed and used for the first time in Europe in the late 1920's.[1] The product consisted of a mixture of very fine aggregate, asphalt binder, and water, and was mixed by introducing the components into a tank outfitted with an agitator. It proved to be a novel approach, a new and promising technique for maintaining road surfaces, and marked the beginning of slurry seal development. However, it was not until the 1960's, with the introduction of improved emulsifiers and continuous flow machines that real interest was shown in the usage of slurry seal as a maintenance treatment for a wide variety of applications: from residential driveways to public roads, highways, airport runways, parking lots, and a multitude of other paved surfaces.[2] Slurry seals containing anionic emulsion typically take a long time to break and cure because the process is dependent on the environmental conditions at the placement site. The time required before traffic is permitted on the surfacing might be an entire day. The use of cationic based emulsion for slurry seals were a response to traffic time issues and are commonly used in the U.S because of their earlier set times.

Micro surfacing was pioneered in Europe in the late 1960's and early 1970's.[1] European scientists were looking for a way to use conventional slurry in thicker applications that could be applied in narrow courses to fill wheel ruts and not destroy the wide, expensive thermoplastic pavement markings on German Autobahns. Micro surfacing was the result of combining high quality aggregates and bitumen, and then incorporating special polymers and emulsifiers that allowed the product to remain stable even when applied in multi-stone thicknesses. In addition, the chemistry is such that it often permits traffic on the surface within one hour. Micro surfacing was introduced in the United States in 1980, as a cost-effective way to treat the surface wheel-rutting problem and a variety of other road surface problems.[1]

1.1 Terminology

The International Slurry Surfacing Association (ISSA) has identified the following terms relating to slurry surfacing [3]

- *Slurry Surfacing Systems* – All forms of slurry seal and micro surfacing
- *Slurry Seal* – A mixture of aggregate, emulsified asphalt, water, and additives properly proportioned, mixed, and spread over a properly prepared surface. Slurry seal is applied in a monolayer. A mono-layer is considered one stone thickness (based on the largest stone in the gradation) spread on the pavement surface.
- *Polymer Modified Slurry Seal* – A slurry seal designed with an emulsified asphalt that has been modified with a polymer. Modifying emulsified asphalt may improve the bond between the asphalt and the aggregate and may improve durability and toughness of the slurry surfacing system.
- *Micro Surfacing* – A mixture of cationic polymer modified asphalt emulsion, 100% crushed aggregate, water, and other additives, properly proportioned and spread over a prepared surface. The special purpose polymers and additives used in micro surfacing allow multiple stone thickness applications for projects such as rut filling and highway leveling / resurfacing.

1.2 Purpose of Document

The purpose of this report is to summarize existing knowledge, practices, and state of the art for slurry and micro surfacing, to identify key gaps in the state of the art, and to identify research needs to improve current practice. The report is divided into the following sections.

a. Materials requirements
b. Mix design
c. Performance tests
d. Specifications
e. Construction
f. Quality Assurance
g. Problem solving

2.0 Slurry Surfacing Systems

This section discusses the benefits and site selection of slurry surfacing systems. Much of this information comes from the ISSA Design and Inspector's Manual for Slurry Surfacing Systems.(3)

2.1 Benefits

Slurry surfacing systems provide life extending benefits as well as surface condition improvements (International Roughness Index (IRI), overall Pavement Condition Index (PCI), reduced permeability, increased friction, etc.) and are considered a cost-effective treatment strategy, preserving past investments in existing highways, roads and streets.

1. *Extending Pavement Service Life*
   Although the application of a slurry surfacing system treatment does not increase the structural capacity of the pavement, it does preserve the integrity of the structure. This is primarily achieved by reducing the environmental damage that would otherwise deteriorate the pavement from the top down.

   The integrity of the pavement structure should be determined prior to selecting a slurry surfacing system treatment. This can be accomplished by a detailed pavement distress analysis by an experienced pavement engineer. Given a good pavement structure, proper timing of the application and selection of a suitable slurry surfacing system, a well-constructed treatment can extend pavement service life by 5-7 years and much longer in many cases.

2. *Decreasing Pavement Permeability*
   Permeability exists in asphalt pavements from the time of initial construction through the service life of the pavement. The aging process is closely linked to the crude source of the asphalt, the environment, and interconnected air voids near the pavement surface through which oxygen and moisture can infiltrate. Water entering through the asphalt concrete surface carries dissolved oxygen and trace chemicals which contribute to the oxidation of the asphalt. As this process progresses, the asphalt pavement becomes brittle. Oxidation leads to weathering, raveling, and cracking of the pavement surface. By placing a protective layer on the existing surface, the permeability of the surface is reduced. Consequently, weathering, raveling, and age accelerated surface cracking are less likely to occur.

3. *Improving Surface Friction*
   Aggregate particle shape and gradation, pavement finishing techniques and pavement wear contribute to pavement surface texture. Research indicates that about 14 percent of all crashes occur in wet weather, and that 70 percent of these crashes are preventable with improved pavement texture/friction.(1) Inadequate friction contributes to accidents in dry weather as well, especially in work zones and intersections where unusual traffic movements and braking action are common.

Slurry surfacing systems with proper macro texture provide good surface friction when 100% crushed and durable aggregates are used, and application rates and construction practices are appropriate. Durable aggregates can be determined by using a battery of tests such as vacuum-saturated absorption testing, the Micro-Deval Test, and the L.A. Abrasion Test.

4. *Addressing Moderate Bleeding / Flushing*
   Application of a micro surfacing treatment may successfully correct moderate flushing and reduce bleeding in an existing pavement. Generally, two layers are needed to substantially reduce the probability that the excess asphalt in the existing layer will migrate into the micro surfacing. In addition, the micro surfacing design should consider the flushing condition and reduce the residual asphalt content accordingly. The severity of the problem will dictate whether micro surfacing is the appropriate solution. If so, these repairs should be addressed in cooler application conditions to help reduce the migration of the excess binder into the micro surfacing.

2.2 Project Selection

Slurry surfacing treatments are more cost effective and produce longer performance benefits when proactively applied to roads still in good condition than they are when applied reactively to roads in poor condition. The correct approach to pavement preservation is to "place the right treatment on the right road at the right time." Traditional approaches waited until deficiencies became evident even to the untrained observer, at which time the owner was forced into the unfavorable choices of either applying major rehabilitation or complete reconstruction. The correct approach of effectively using slurry surfacing systems is to think in terms of preservation and address minor deficiencies early (before serious, irreversible underlying structural damage occurs). In this way, pavement life can be substantially extended at comparatively low cost. The misuse of this type of treatment will give the treatment, specifying agency, and the contractor a bad name and will result in the elimination of its use in the future.

2.2.1 When should Slurry Surfacing be used?

Slurry Seals
Slurry seals with emulsions are primarily used as a preventative treatment to seal the pavement, improve aesthetics and surface texture, and serve as the wearing surface. Slurry seals should be used to [4], [5]:

- Seal and protect sound pavements.
- Stop oxidation of underlying surface by placing a new wearing course over it.
- Restore surface texture by providing a new skid-resistant wearing surface.
- Improve waterproofing characteristics.
- Stop or prevent raveling of underlying pavement.
- Provide a new high friction surface to bridge decks.

- Improve aesthetics by offering a dark, uniform appearance for enhanced striping and other traffic delineation.

Three types of slurry seals are generally used, including the following:

- Type I – This aggregate gradation is used to fill surface voids, address moderate surface distresses, and provide protection from the elements. Although not a substitute for crack sealing, the fineness of the mixture provides maximum crack penetration. It is frequently used on airfields, parking lots, and residential streets where a lighter, finer surface texture is desired.
- Type II This aggregate gradation is used to seal/fill surface voids, address more severe surface distresses, and provide a durable wearing surface. It is the most common gradation used in slurry surfacing systems. It is often used on pavements to correct distresses caused by weathering and raveling while producing a durable wearing surface for low, medium and heavy traffic volumes. This gradation is commonly used on airfields, parking lots, municipal streets, county roads and state highways.
- Type III This aggregate gradation, which is the most coarse, gives maximum coefficient of friction and an improved durability due to the depth of the application, as the larger aggregate size increases the thickness of the mat placed. It is best-suited to higher-traffic pavements such as expressways, major highways, and arterials. When used in micro surfacing, this gradation is ideal for rut filling and reestablishing profiles with minor surface irregularities.

Micro surfacing
Both slurry seals and micro surfacing offer many of the same basic benefits. Micro surfacing offers additional uses and benefits:

- Correction of surface profile or smoothness
- Filling of wheel path ruts (up to 1.5" in multiple lifts)
- Can be placed at night due to chemical break vs. evaporative break for slurry seal.
- Carrying traffic sooner after placement
- Longer-lasting treatment with heavier traffic

Micro surfacing can be applied to either asphalt (HMA) or Portland Cement Concrete (PCC) pavements and can provide a long-lasting surface treatment for both pavement types. When placing Micro Surfacing on PCC pavements a tack coat of the same Micro Surfacing emulsion diluted 3:1 with water should be placed prior to Micro Surfacing application. A double application of Micro Surfacing is recommended in this case.

Micro surfacing can also be applied over chip seals; this application is referred to as a Cape seal. Slurry Surfacing is "green technology" that require less energy to produce and construct. The Pavement Preservation and Recycling Alliance (PPRA) has a "Sustainability" module that includes a Cost and Green Calculator so that a comparison can be made between the conventional approach of pavement maintenance versus the preservation and recycling approach. This calculator allows the engineer to quickly choose the most cost- effective treatment and can be found at https://roadresource.org.

2.2.2 When should Slurry Surfacing not be used?

Slurry Seal

Slurry seals should not be used to:[(4), (5)]

- Correct surface profile
- Fill potholes
- Alleviate cracking
- Correct rutting
- Pavement or base failures
- Improve the structural integrity of the existing pavement.

If a project has the distresses listed above, repairs need to be made prior to slurry sealing. Best practices would be to place a pavement preservation treatment prior to the pavement reaching a Pavement Condition Index (PCI) of less than 80.

Figure 1 shows PCI values from 0–100 and their corresponding pavement condition rating.

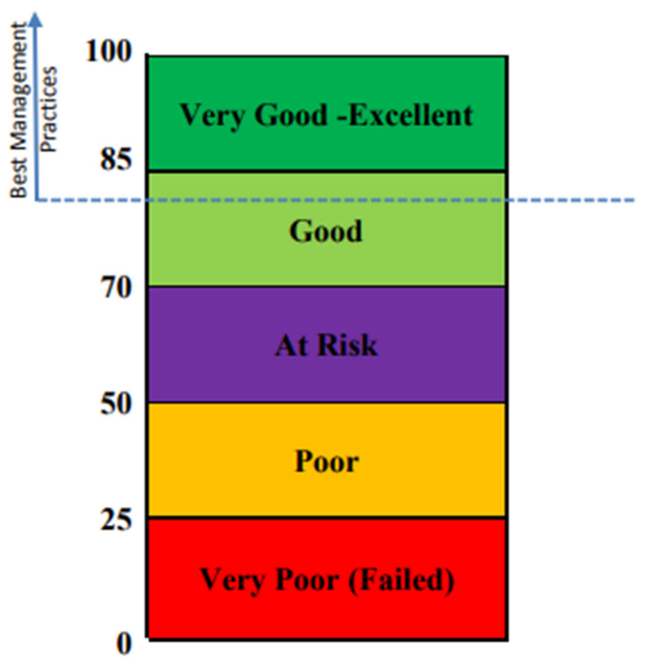

Figure 1: StreetSaver Pavement Condition Index Classifications [(22)]

Micro surfacing

Micro surfacing should not be used to:

- Fill potholes
- Improve the structural integrity of the existing pavement
- Improve traffic capacity

3.0 Material Requirements

This section discusses the types of materials used in slurry surfacing systems and their requirements. Much of this information comes from the 2021 ISSA Design and Inspector's Manual for Slurry Surfacing Systems.[3]

3.1 Emulsified Asphalts

Although early slurry seal emulsified asphalts were anionic (SS-1h), these emulsified asphalts are rarely used now. The traditional designation for slurry seal and micro surfacing emulsified asphalts has been CSS-1h because their emulsified asphalt and residue properties typically fall into the ranges given for that specification in AASHTO M208. If the CSS-1h specification is used, the cement mixing test is waived. Since 2018 the CQS-1h specification was added to M208, removing the cement mixing and 24-hour storage stability requirements, and more appropriately describing in the name the quick-setting characteristics desired for these emulsified asphalts.

Polymer-modified slurry seal emulsified asphalts are oftentimes designated as CQS-l m and are required to pass a specification like that of CQS-1h. The amount of polymer to be used when formulating these emulsified asphalts may or may not be specified by the agency. Micro surfacing emulsified asphalts are usually designated CQS-1hp (or CSS-1hp) and are required to contain a minimum of 3% polymer solids by weight of asphalt. These emulsified asphalts usually have a minimum softening point on residue requirement of 135°F. Both the requirements for CQS-1hp and CQS-1p type micro surfacing emulsified asphalts can be found in AASHTO M316 Table 2.

3.2 Additives

Additives are generally used to accelerate or retard the breaking and setting of the slurry systems. The additive type, their use range, and the properties that they impart to the mixture should be noted on the mix design for the slurry system. They can be either dry or liquid and, since some are proprietary, each supplier manufactures the product to their specific requirements. Typical additives include emulsifier solutions and aluminum sulfate. Varying the concentration of an additive allows the contractor to control the breaking and curing times.

3.3 Aggregates

According to all ISSA Recommended Performance Guidelines [6, 7, 8] and AASHTO Provisional Standards [9, 10], aggregate requirements for slurry, polymer-modified slurry, and micro surfacing systems consist of quality tests and gradation. Quality tests are Sand Equivalent, Sodium or Magnesium Sulfate soundness, and Los Angeles abrasion.

Three types of gradation are used depending on the application. Type I is the finest and is used to fill surface voids, address moderate surface distresses, and protect the surface from environmental damage. Type II is the most common gradation and is used to seal/fill surface voids, address more severe surface distresses and provide a durable wearing surface for medium to heavy traffic. Type III, the coarsest gradation, is used to give maximum coefficient of friction and is best suited to higher-traffic pavements. When used in micro surfacing, this gradation is ideal for rut filling and reestablishing profiles with minor surface irregularities. For most micro surfacing applications, the ISSA guidelines [6] recommend the use of Type II or Type III gradations. Tables 1 and 2 provide a summary of these gradation requirements.

Table 1: Gradations for Slurry Seals

SIEVE SIZE	TYPE I PERCENT PASSING	TYPE II PERCENT PASSING	TYPE II PERCENT PASSING	STOCKPILE TOLERANCE
3/8 (9.5 mm)	100	100	100	
#4 (4.75 m)	100	90 - 100	70 - 90	± 5%
#8 (2.36 mm)	90 - 100	65 - 90	45 - 70	± 5%
#16 (1.18 mm)	65 - 90	45 - 70	28 - 50	± 5%
#30 (600 um)	40 – 65	30 - 50	19 - 34	± 5%
#50 (330 um)	25 – 42	18 - 30	12 - 25	± 4%
#100 (150 um)	15 - 30	10 - 21	7 - 18	± 3%
#200 (75 um)	10 - 20	5 - 15	5 - 15	± 2%

After ISSA A105 (2020)

Table 2: Gradations for Micro Surfacing

SIEVE SIZE	TYPE II PERCENT PASSING	TYPE III PERCENT PASSING	STOCKPILE TOLERANCE
3/8 (9.5 mm)	100	100	
#4 (4.75 m)	90 - 100	70 - 90	± 5%
#8 (2.36 mm)	65 - 90	45 - 70	± 5%
#16 (1.18 mm)	45 - 70	28 - 50	± 5%
#30 (600 um)	30 - 50	19 - 34	± 5%
#50 (330 um)	18 - 30	12 - 25	± 4%
#100 (150 um)	10 - 21	7 - 18	± 3%
#200 (75 um)	5 - 15	5 - 15	± 2%

After ISSA A143 (2020)

3.4 Water

The water added in the mixing process needs to be free of salts and other contaminants and should be potable. If it is not, it can affect the breaking and curing of the system.

It should be noted that the potable issue refers to the pH and cleanliness of the water. If it is potable, both should be within an acceptable range. Contractors using off-line water sources should have the design lab verify its compatibility during the design process.

3.5 Mineral Filler

Mineral fillers are typically used to improve mixture consistency and/or adjust mixture breaking and curing properties. Portland cement, hydrated lime, limestone dust, fly ash, or other approved fillers meeting the requirements of ASTM D242 shall be used, if required by the mix design. Typical use levels are 0 - 3 percent and may be calculated as part of the aggregate gradation. On some occasions, mineral filler may be used solely to improve the gradation of the aggregate provided the requirements in Tables 1 and 2 are met.

4.0 Mix Design Process

This section of the report discusses the following key points:

- History and current practices used in slurry surfacing mix design
- Performance demands addressed during the mix design process

4.1 Current Practices

The current procedures are the result of extensive work done by Ben Benedict in the 1960's and 1970's with materials readily available to him in southwestern Ohio. They represent Mr. Benedict's desire to develop a design system that could be used to evaluate the mixture components in the laboratory prior to construction. It must be remembered that Mr. Benedict did not have the capabilities of testing machines and computers that are now used to compile and evaluate data. Additionally, he performed most of the work using his own funds. Ultimately, his work resulted in the mix design procedures contained, today, in the International Slurry Surfacing Association (ISSA) Technical Bulletins, Performance Guidelines A105, A115, A143 and ASTM International Practices D-3910 and D6372.

The ultimate purpose of a mix design procedure is to recommend a "combination" of emulsified asphalt, aggregate, water, and additives to produce a mix that will perform under specific short-term and long-term conditions. Future traffic estimates and environmental conditions at the time of placement should also influence the design of the mix.

Current mix design tests for both slurry and micro surfacing, as outlined in ISSA A105, A115, and A143, and the AASHTO Design Practice appear in Tables 3 and 4 below. Since it is important to establish the proportions of the required materials within the ranges established by the actual job specifications, Tables 5 and 6 provide recommendations on ranges for the residual asphalt content, mineral filler, additives, and water typically used in slurry and micro surfacing applications.

Table 3: Mix Design Tests for Slurry Seal

TEST	ISSA TB NO.	SPECIFICATION
Mix Time @ 77°F (25°C)	TB 113	Controllable to 180 Seconds Minimum
Slurry Seal Consistency	TB 106	0.79 – 1.18 inches (2.0 – 3.0 cm)
Wet Cohesion @ 30 Minutes Minimum (Set) @ 60 Minutes Minimum (Traffic)	TB 139 (For quick-traffic systems)	12 kg-cm Minimum 20 kg-cm or Near Spin Minimum
Wet Stripping	TB 114	Pass (90% Minimum)
Wet-Track Abrasion Loss One-hour Soak	TB 100	75 g/ft^2 (807 g/m^2) Maximum
Excess Asphalt by LWT Sand Adhesion	TB 109 (Critical in heavy-traffic areas)	50 g/ft^2 (538 g/m^2) Maximum

After ISSA A105 (2020)

Table 4: Mix Design Tests for Polymer Modified Slurry Seal

TEST	ISSA TB NO.	SPECIFICATION
Mix Time @ 77°F (25°C)	TB 113	Controllable to 150 Seconds Minimum
Wet Cohesion @ 30 Minutes Minimum (Set) @ 60 Minutes Minimum (Traffic)	TB 139 (For quick-traffic systems)	12 kg-cm Minimum 20 kg-cm or Near Spin Minimum
Wet Stripping	TB 114	Pass (90% Minimum)
Wet-Track Abrasion Loss One-hour Soak	TB 100	60 g/ft^2 (647 g/m^2) Maximum
Excess Asphalt by LWT Sand Adhesion	TB 109 (Critical in heavy-traffic areas)	50 g/ft^2 (538 g/m^2) Maximum

After ISSA A115 (2020)

Table 5: Mix Design Tests for Polymer Microsurfacing

TEST	ISSA TB NO.	SPECIFICATION
Mix Time @ 77°F (25°C)	TB 113	Controllable to 120 Seconds Minimum
Wet Cohesion @ 30 Minutes Minimum (Set) @ 60 Minutes Minimum (Traffic)	TB 139	12 kg-cm Minimum 20 kg-cm or Near Spin Minimum
Wet Stripping	TB 114	Pass (90% Minimum)
Wet-Track Abrasion Loss One-hour Soak Six-day soak	TB 100	50 g/ft2 (538 g/m2) Maximum 75 g/ft2 (807 g/m2) Maximum
Lateral Displacement Specific Gravity after 1000 Cycles of 125 lb. (56.71 kg)	TB 147	5% Maximum 2.10 Maximum
Excess Asphalt by LWT Sand Adhesion	TB 109	50 g/ft^2 (538 g/m^2) Maximum
Classification Compatibility	TB 144	11 Grade Points Minimum (AAA,BAA)

After ISSA A143 (2020)

Table 6: Component Materials and Ranges for Slurry Seals

COMPONENT MATERIALS	SUGGESTED LIMITS
Residual Asphalt	Type I: 10 - 16% Type II: 7.5 - 13.5% Type III:6.5 - 12% (Based on dry weight of aggregate)
Mineral Filler	0.0 - 3.0% (Based on dry weight of aggregate)
Additives	As needed
Water	As required to produce proper mix consistency

After ISSA A143 (2020)

Table 7: Component Materials and Ranges for Microsurfacing

COMPONENT MATERIALS	SUGGESTED LIMITS
Residual Asphalt	5.5 – 10.5% by dry weight of aggregate
Mineral Filler	0.0 - 3.0% (Based on dry weight of aggregate)
Polymer Content	Minimum of 3.0% solids based on bitumen weight content
Additives	As needed
Water	As required to produce proper mix consistency

After ISSA A105 (2020)

The current mix design procedure first specifies laboratory tests and the resulting required properties of the individual components which are supplied by the contractor for proposed use on the job. Once the components are verified as acceptable in quality, the materials are combined in various proportions to verify their compatibility as well as to test the short and long-term performance of the resulting mix. Therefore, the designer goes through an iterative process, adjusting quantities (and materials if necessary), until the desired mix properties are obtained. When the results of these tests meet the criteria specified by the agency, the mix design is forwarded to the contractor for submittal to the buyer for acceptance. The current process is schematically illustrated in the flowchart presented in Figure 2.

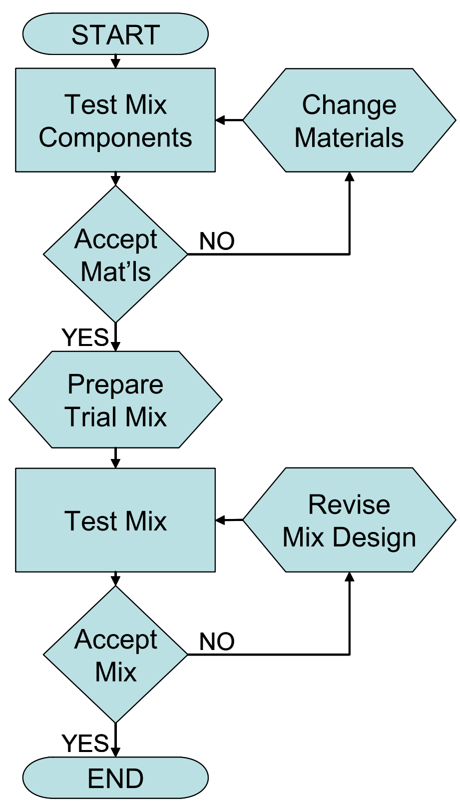

Figure 2: Current mix design process

Ideally the contractor and the mix design lab should work closely together during the mix design process. In addition, the contractor should carefully review and sign off on the mix design before submitting it for agency approval to ensure it is appropriate for the project and will work in the field.

Typical application rates for slurry seal and micro surfacing are noted in Tables 7 and 8. As noted in each table, the applications rates vary with the type of slurry surfacing being applied.

Table 8: Application Rates for Slurry Seal

AGGEGATE TYPE	LOCATION	SUGGESTED APPLICATION RATE
Type I	Parking Areas Urban and Residential Streets Airport Runways	8 - 12 b./yd2 (4.3 - 6.5 kg/m2)
Type II	Urban and Residential Streets Airport Runways	10 - 18 lb./yd2 (5.4 - 9.8 kg/m2)
Type III	Primary and Interstate Routes	15 - 22 lb./yd2 (8.1 - 12.0 kg/m2)

After ISSA A105 (2020)

Table 9: Application Rates for Microsurfacing

AGGEGATE TYPE	LOCATION	SUGGESTED APPLICATION RATE
Type II	Urban and Residential Streets Airport Runways Scratch or Leveling Course	10 - 20 lb./yd2 (5.4 - 10.8 kg/m2) As Required
Type III	Primary and Interstate Routes Wheel Ruts Scratch or Leveling Course	15 - 30 lb./yd2 (8.1 - 16.3 kg/m2) As Required (See Appendix B) As Required

After ISSA A143 (2020)

4.2 Performance Demands

Laboratory tests relate to known short-term and long-term performance demands. In general, the design process focuses, in the short-term, on ensuring the mixture can be applied successfully and returned to traffic in a time frame acceptable to the agency. It focuses, in the long-term, on the in-service performance of the pavement over time. The following questions are addressed during the current mix design process using the referenced test methods.

4.2.1 Short term-Will the materials mix and spread?

The **mixing and spreading characteristics** of the system address the issue of constructability, i.e. material compatibility and rheology (consistency and viscosity) of the mixture, over time. The mixture should be designed so that the emulsified asphalt, aggregate, mineral filler, water, and control additives can be mixed and applied through the machine without segregation and in a continuous fashion. It must also remain workable for the length of time needed to complete any handwork.

Mixture Consistency is the first concern when formulating a slurry surfacing mix. While the proper consistency of a micro surfacing mix is like that of oatmeal, a slurry seal mix, when placed with a spreader box that does not contain augers, may need to have a more fluid consistency. It should be noted that augers are always a good thing.

The least amount of water possible should be added to the mixture to facilitate mixing. Adding more water than necessary may lead to flushing of the binder and delayed setting of the mix and is not an effective method of significantly increasing mix time. Slow-set slurry seal consistency is measured using ISSA TB-106 "Test Method for Measurement of Slurry Seal Consistency"; however, this test is not appropriate for quick-set systems or micro surfacing.

Once the proper water content has been established, material compatibility can be explored. The chemical and physical properties of the system components influence the time over which the mixture will remain in a free-flowing condition. Component proportions should be optimized at job application conditions to ensure adequate mix time for the materials to be placed. ISSA TB-115 "Determination of Slurry Seal Compatibility" consists of several tests including verification of mixture consistency and adequate mix time for application and handwork.

4.2.2 Short term -When will the mixture break, set, and support traffic?

The **breaking and setting characteristics** of the system should be such that the mixture breaks after all handwork is complete and then sets to a rain-safe condition relatively quick. The mixture should cure within a reasonably defined period to allow return to traffic without raveling, displacement, or flushing.

The **break** is defined as the time when the slurry system transitions from a workable fluid state to an unworkable solid state. After the break, the mixture can no longer be mixed or finished. The time available for mixing can be measured using ISSA TB-113 "Test Method for Determining Mix Time for Slurry Surfacing Systems".

The **set** is defined as the time after placement when the emulsified asphalt has coalesced to the point that no free emulsified asphalt is available for dilution or washing away by water and an absorptive paper towel would not be stained when depressed lightly into the surface of the mix. ISSA TB-139 "Test Method to Determine Set and Cure Development of Slurry Systems by Cohesion Tester" quantifies the set time as the point at which the slurry system reaches a minimum of 12 kg-cm torque.

Traffic readiness is defined as the time when the cohesive strength (the bonds between asphalt coated aggregate particles) of the mixture has developed sufficiently to support slow-moving, straight-rolling traffic without damage to the system. ISSA TB-139 quantifies the traffic time as the point at which the slurry system reaches a minimum of 20 kg-cm torque or when the Mode of Rupture is observed to be at least a "near spin".

4.2.3 Long Term-Will the mixture perform over time?

The **long-term performance** of slurry surfacing systems is dependent on their mechanical properties and their ability to maintain these properties over time and under service conditions. These treatments should maintain good friction resistance and resist raveling, de-bonding, bleeding, moisture damage and loss of cohesiveness over the life of the treatment.

To quantify system **abrasion resistance** (raveling) under wet conditions ISSA TB-100 "Test Method for Wet Track Abrasion of Slurry Surfacing Systems" [(3)] is run using various soak times and at various emulsified asphalt contents. The results are used to determine the minimum amount of residual binder necessary to hold the system together.

To quantify **resistance to deformation**, the results from ISSA TB-147 "Test Method for Measurement of Stability and Resistance to Compaction, Vertical and Lateral Displacement of Multilayered Fine Aggregate Cold Mixes" and ISSA TB-109 "Test Method for Measurement of Excess Asphalt in Bituminous Mixtures by Use of a Loaded Wheel Tester and Sand Adhesion" are used to establish the maximum amount of residual binder the system can support without exhibiting rutting or bleeding.

Water resistance (stripping) is evaluated using ISSA TB-114 "Test Method for Wet Stripping of Cured Slurry Surfacing Mixtures".

5.0 Specifications

This section discusses the current practices in terms of specifications. Much of this information comes from NCHRP synthesis of highway practice 411.[12]

5.1 Types of Specifications

The types of specifications that currently exist for slurry surfacing systems include:

- Method or prescriptive specification. This type of specification includes a description of the materials, equipment, and process to be used to complete the work.
- Warranty specification. In this type of contract, the owner requires a certain performance for a specified period. Generally, the owner will pay a premium for this type of work. Warranty performance criteria include items related to friction, raveling, rutting and delamination. If there are problems with the pavement during the warranty period and the cost for the contractor to repair them equals or exceeds the amount of pay held by the agency until the warranty period expires, the contractor may decide to forfeit the payment instead of addressing the issues with the pavement.

At present, most of the specifications used are of the method type. Specific items covered in the method specification are discussed in the next section.

5.2 Items Covered in the Method Specifications

The major items covered in method specifications include the following:

- The section on **material and mix requirements** describes the required tests and specifications for the materials and the mixture.
- Equipment requirements specify the mixing equipment type (truck mount and/or continuous) and spreading equipment details for use on the project. Typically, slurry and micro surfacing applications do not require use of rollers; however, if there may be little compaction from normal traffic (for example, on an airport runway or parking lot), roller type would be specified in this section. Equipment calibration and traffic control requirements would be covered here, as well.
- The sections on the **construction process** describe paving details including surface preparation, application rates, and test strips.
- Most specifications contain some form of **quality control** requirements. These can include some or all the following:
    - Aesthetic workmanship requirements concerning the overall appearance of the mat in addition to joints, seams, handwork, and edge lines
    - Materials sampling and compliance testing per fixed amount of surfacing placed
    - Mix compliance testing such as field consistency and mix extraction of samples pulled from the machine.

- Some of these type specifications call for a 1-year **warranty on materials and workmanship**. In that case the contractor's focus is on the aesthetic workmanship requirements listed above in addition to items like streaking, drag marks, damage caused by early opening to traffic and delamination.
- The **method of pay** in these specifications is either based on the area covered or on tons of aggregate and gallons of emulsified asphalts used.

6.0 Construction

This section discusses the construction of slurry surfacing systems. Much of this information comes from the 2021 ISSA Design and Inspector's Manual for Slurry Surfacing Systems.[3]

Some of the most important prerequisites for a successful slurry surfacing job include choosing the proper pavement to maintain, preparing a bid document that addresses specific project needs and then ensuring that agency expectations are understood by the contractor.

6.1 General Considerations

Agencies should consider the following when choosing pavements for these maintenance applications:

- Existing pavement condition
    - The existing pavement must be structurally sound and the base, well-drained.
    - There should be no alligator cracking present. Significant local areas can be patched.
    - Slurry surfacing systems will not correct reflective cracking. Significant cracks, ¼" and above should be sealed prior to application.
    - Rutting can only be addressed by micro surfacing.
    - Areas with bleeding or flushing, depending on severity, should be addressed with reduced residual asphalt contents. These repairs should be done in cooler temperatures.

The following are other project concerns that should be addressed:

- Site preparation
    - Base failures, major pavement damage, curb and gutter problems and utility issues should be addressed.
    - Cracks larger than ¼" should be sealed, but adequate time should be left for the seal to cure, and excessive buildup should be kept to a minimum.
    - The pavement should be free of loose aggregate and soil, vegetation and oil spots before paving begins.
    - Pavement markings should be removed, particularly thermoplastic marking in excess of 4". Conventional paint with reflective glass beads embedded does not require removal unless there is significant buildup from multiple applications.
    - Utilities should be protected by covering them with roofing felt or plastic sheeting.

Other details to consider are:

- Traffic levels and traffic control requirements

  - Daytime applications are appropriate for both slurry seal and micro surfacing, but only micro surfacing should be placed at night.
  - Jobs in urban environments require more traffic control details than those in rural settings.
- Climate and weather
- Application rates appropriate for the demand of the existing surface. These items and more are discussed in this chapter.

6.2 Preconstruction Meeting

The Agency should arrange for and conduct a pre-construction meeting with the prime contractor. The Agency may include a project manager, project engineer, inspector, material testing technician, and others as deemed necessary. A representative of the prime contractor, each sub-contractor and material suppliers should attend. Detailed minutes should be recorded by the project engineer or designee and distributed to all parties in attendance. Although the pre-construction meeting is focused on administrative and operational considerations, the greatest value of the meeting is achieved by all parties discussing, clarifying, and fully understanding all aspects of the contract. The objectives are shown in Table 10.

Table 10: Pre-construction Meeting Objectives

Pre-Construction Meeting Objectives
1. Introduce team members and establish the project lines of communication and authority. 2. Review the project schedule prepared by the contractor. 3. Coordinate the submission of the mix design, samples, and other required documents. 4. Address questions regarding contract specifications that may require clarification or decision from the Agency. 5. Review safety procedures and special project requirements. 6. Review the traffic control plan, public notification, and procedures to notify public services such as police, fire, ambulance, trash pickup, transit service, etc. 7. Establish punch list timing and project acceptance procedures. 8. Designate Agency responsibilities for daily acceptance of material quantities and final project acceptance. 9. Establish procedures and requirements for progress payments. 10. Agree on locations for temporary facilities, stockpiles, and staging areas. 11. Discuss sources of water and specific requirements for metering. 12. Identify material testing requirements and frequency, including contractor QC plan, if required. 13. Agree on timing of early and final surface preparation. 14. Submit relevant Safety Data Sheets (SDSs). 15. Agree on application timing of temporary and permanent pavement markings.

6.3 Construction Process

Construction guides developed as a part of NCHRP project 14-37, modified by the AASHTO TSP-2 ETF for micro surfacing, and approved by AASHTO COMP 5b are included in Appendix A. These guides include the details of achieving a good micro surface. Guides have not yet been developed for slurry seals but should be similar when completed as a part of NCHRP project 14-44. This project is expected to end in March 2022.

6.3.1 Stockpile

The stockpile or staging area is where the contractor will store equipment and materials for the duration of the project. It should be in a centralized location to reduce haul times, which will result in higher production levels. It should be a structurally sound, hard surface, such as gravel or pavement, and should be located on high ground that remains dry after rain events. It is the contractor's responsibility to keep the staging area clean and orderly.

Equipment noise and potential dust issues should be taken into consideration and therefore the stockpile should not be located too close to houses. Easy access to the project is also a plus. Keep in mind that there will be an increased amount of truck traffic due to the incoming and outgoing materials. Access to a fire hydrant is an added benefit as the contractor will need water throughout the day.

Most agencies have property that will serve well for a stockpile. In cases where agency property is unavailable, the agency usually assists the contractor in locating local landowners for a stockpile area.

Precautions should be taken to ensure that the stockpiled materials do not become contaminated or contaminate the staging area. Despite normal precautions taken with the aggregate, an occasional stone having dimensions greater than the treatment application thickness may get into the aggregate bin. These oversized stones eventually become lodged under the lower edge of the rear screed and cause unsightly longitudinal grooves (drag marks) in the finished surface.
Some aggregate types tend to dry in lumps or balls when exposed to rain, as well. The drier these lumps become, the more difficult it is to break them up into individual aggregate particles. If oversized stones or lumps are a problem, a screening plant at the stockpile should be used to remove the oversized material. Best practice is to screen aggregate directly into the application equipment or support vehicles. In arid climates and where dust abatement regulations prohibit the use of screening plants, it is important to take other precautions to guard against this type of contamination. In this case, working closely with the quarry and trucking firms to eliminate contamination may be necessary.

Figure 3: Stockpile and screening aggregate

6.3.2 Surface Preparation

There are two different stages of surface preparation: early and final. The early stage should be completed well in advance of project start-up. The final stage should be completed immediately before the project begins.

Early Stage

The early stage of surface preparation includes:

- Underground utility repairs, such as culverts and water leaks;
- Concrete curb and gutter, driveway, sidewalk repairs, and pavement edge deterioration.
- Surface patching of the areas showing high levels of distress;
- Full depth repairs showing base failure;
- Significant defects on the pavement surface;
- Structural leveling with hot mix asphalt;

- Trimming of low hanging limbs to ensure access to the pavement for the application equipment;
- Correct the surface where height restrictions are a problem;
- Grading the shoulders back;
- Herbicide treatment, making for easier removal of the vegetation and retard future growth;
- Crack sealing: It is recommended that cracks ¼” and larger be sealed prior to the installation of slurry surfacing systems. It is also recommended that this crack sealing phase of construction be performed well in advance of resurfacing. Crack sealing too close to the resurfacing process can cause potential application issues. Crack treatments should be completed with a compatible sealer and the amount of sealer remaining on the pavement surface should be minimal. There are two different methods of crack sealing: blow and seal, or rout and seal. It is recommended that you consult with your ISSA contractor or crack seal supplier to determine the appropriate method. Go to the ISSA website (www.slurry.org) to download A175 “Recommended Performance Guidelines for Crack Treatment”.

Any items above not completed in a timely fashion or left unaddressed will negatively affect final project performance.

Figure 4: Crack Sealing

Figure 5: Structural Leveling

Final Stage

The final stage of surface preparation includes surface cleaning, protection of structures and utility castings and removal of pavement markings.

- **Surface cleaning**. Prior to applying the slurry surfacing, existing vegetation shall be removed. The pavement shall be swept, and all loose materials removed. Acceptable methods for sweeping include the use of vacuum assisted and rotary brooms.

  Forced air may be suitable in some situations, such as areas that may be difficult to access with larger equipment. Also, blowing aides in the removal of fine particulates that cannot be easily removed by the sweeping operation. These finer particulates can serve as a bond breaker and must be removed prior to the application of the slurry surfacing system.

  In areas where mud and dirt have been tracked onto the pavement, it may be necessary to use pressurized water to remove the objectionable material. If pressurized water is not available, water combined with brooming, may satisfactorily remove the objectionable material from the pavement.

  In certain circumstances (such as parking lots and streets with curb side parking), the contractor may encounter oil spots on the pavement. It is recommended that industrial detergents, pressure washing, and/or grinding be used to remove any material that may serve as a bond breaker. Severity of oil damage may require that removal and replacement of the pavement is necessary.

Figure 6: Sweeping the Roadway

- **Protection of structures and utility castings**: Prior to applying the slurry surfacing, protecting areas not scheduled to be covered is extremely important. These include utility structures, such as manhole covers, catch basins, and valve boxes. Other areas include bridge decks, decorative crosswalks, concrete valley gutters and airplane tie downs. Taping plastic sheeting or roofing felt to these structures is a proven method for their protection. Once the utility has been taped off, it is important to mark a reference point or to use a flexible chip seal marker to assist in locating the utility once it has been covered by the slurry surfacing.

  The use of plastic sheeting or roofing felt may also be used to protect the limits of the project. Decorative pavements such as stamped asphalt or concrete crosswalks can also be protected in this manner.

  Once the material has cured, the contractor shall remove the masking materials from the jobsite and dispose of them in an acceptable manner. Access to underground utilities is important to agencies for the obvious reasons. Therefore, removal of the masking should take place on the same day as the application and prior to opening the pavement to traffic.

Figure 7: Protection of Manhole Cover

- **Removal of pavement markings**: The four types of pavement markings are paint, raised pavement, snow plowable, and thermoplastic:
  - **Paint markings**-Most painted pavement markings will not require any special treatment and the slurry surfacing will bond properly to the marking. However, sometimes new pavement paint markings or markings that have a substantial paint buildup can represent potential bonding concerns for slurry surfacing systems. In these cases, the paint should be removed or abraded to produce a rough surface. In other cases, the paint can be tacked to ensure a good bond.
  - **Raised pavement markings**-Raised markings are usually made with plastic, ceramic, or occasionally metal, and come in a variety of shapes and colors. Many devices include a lens or sheeting that enhances their visibility by reflecting automotive headlights. Removal of the markers is highly recommended and after the slurry surfacing is completed new markers should be installed.

Snow plowable pavement markings-Snow plowable markers are generally recessed in the pavement and have a reflective lens. It is recommended that these markers be removed in advance of any slurry surfacing application. Suitable asphalt patching material should be used to repair the void left from the removal process. Masking of snow plowable markers is not generally acceptable as ponding during rain events as well as reduced reflectivity are a common result. It is recommended that you replace these markers after the slurry surfacing installation.

Thermoplastic pavement markings -It is recommended that all thermoplastic pavement markings more than 4 inches wide be removed or at least abraded prior to slurry surfacing installation. The acceptable methods of removal include grinding or water blasting and 80-85% removal will ensure a good bond. Water blasting should not be used in areas with extensive cracking.

Figure 8: Grinding thermoplastic pavement markings

6.3.3 Traffic Control

Traffic control plans and devices shall meet or exceed the minimum requirements of the Manual on Uniform Traffic Control Devices and should meet or exceed the State and local agency requirements.

Traffic control should consider the following:

- Safety of the traveling public;
- Safety of the employees performing the work;
- Product protection; and
- Traffic control devices.

In addition, suitable methods shall be used by the contractor to protect the slurry systems from damage from all types of vehicular traffic. It is important to remember that opening to traffic does not constitute acceptance of the work.

Figure 9: Traffic Control

6.3.4 Notification

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

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

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

Figure 10: Notification of Upcoming Work

6.3.5 Equipment Calibration

The application equipment is calibrated to produce a mixture that is consistent with the JMF in the approved mix design. Mix design components are proportioned by weight while the application equipment delivers materials by volume. It is essential that calibration be completed using the actual job materials, immediately prior to each job start-up and in the presence of the Agency representative. No application equipment should be allowed to work on a job without a proper calibration.

1. **Calibration Theory**
   In slurry surfacing systems, the mix design component proportions are based on the weight of dry aggregate. Therefore, corrections for moisture in the aggregate are necessary. Setting the application equipment feed rates of aggregate, mineral filler, emulsified asphalt, water, and additive is critical to the successful application of a slurry surfacing system. Additionally, if multiple pieces of application equipment are utilized on the project, calibration of each one is necessary to ensure mixture consistency. The component material output factors identified in the calibration process will assist the contractor and agency in quantifying daily material usage as well as aiding in the verification of application rates.

A proper calibration is based upon the following:

- All JMF weights are based on the **dry** weight of aggregate. The aggregate in the field or at the calibration site may include moisture, and the weights must be corrected to account for it.
- The emulsified asphalt and aggregate must be mixed according to the prescribed proportions of the JMF, which means calibrating to a common unit such as revolutions of the jackshaft, head pulley, or sprocket. Generally, the head pulley is used because the aggregate counter is very accurate and readable at that location. Most contractors will typically refer to the rock/aggregate counter during calibration. This counter is used to quantify both emulsified asphalt and aggregate output. For electronically controlled application equipment, manufacturers' recommended calibration procedures should be followed.
- A sufficient amount of each component must pass through the application equipment to calculate accurate results, based on measurement equipment.

2. Calibration Procedures

Slurry surfacing application equipment requires calibration because it does not mix in batches. Rather, current equipment continuously feeds components (aggregate, asphalt emulsified asphalt, mineral filler, water and additive) to the front of the pugmill (mixing chamber), while a homogeneous mix of all these components is continuously delivered to the spreader box.

Continuous feed should not be confused with continuous paving. In a truck mounted operation, the materials are fed as a continuous feed of raw materials, and the application equipment places material until the paver is empty and then returns to the stockpile for refill.

In a continuous paving operation, the materials are also fed as a continuous feed of raw materials, but the application equipment stays on the jobsite, while mobile support units (also called nurse trucks) bring the raw materials to the application equipment, thereby allowing the paving operation to be continuous.

Inspector's Note: *Since all application equipment calibrations use the head pulley which turns the aggregate belt, it is easiest to start with no aggregate on the machine and calibrate other items first. This eliminates the need to clean out the aggregate hopper after calibration.*

3. Test Strips

The intent of the test strip is to assure that adequate workmanship, aesthetics, and cure time of the mixture is achievable when applied with the personnel, equipment and materials intended for use during execution of the project. The test strip should be performed in similar conditions to those expected during actual application. Proper test strip evaluation items include:

- Proportion optimization- Are adjustments needed within the ranges of the job mix formula to produce the desired mixture properties?
- Application rate verification- Is the contractor able to adjust the application to meet the target application rate?
- Uniformity of surface texture- Has the contractor exhibited the ability to produce the desired uniform surface texture?
- Equipment in good condition? - Is all the equipment scheduled for use on the project in good working condition? Good running order
- Adequate workforce- Does the contractor have an adequate workforce?
- Cure time- Defined below in Section 6.3.6
- Workmanship- Is the workmanship provided by the contractor acceptable?
- Proper alignment- Has the contractor exhibited the ability to align the machine (edge line, curb and gutter, start and stop lines) according to the limits of the project?

Construct a test section to verify the system performance is acceptable to the Agency Representative. The materials used for the test section must be those that were approved for use in the mix design.

Construct a 500 to 1000 ft, one lane width test section to be evaluated for acceptance by the agency. When multiple pieces of application equipment are used, a test section should be placed with each one to compare them for variances in proportioning, application rates, surface texture and appearance.

6.3.6 Applications

Thorough attention to detail is critical during the application process to ensure a successful final product.

Ambient Conditions for Application

The basic prerequisites for successful system application and performance require a proper break and cure. Environmental factors, such as temperature, humidity, wind, and imminent rainfall play a role in the application process of all slurry surfacing systems. As a result, a thorough understanding and consideration of these factors in the formulation of the emulsified asphalt and JMF is essential to optimize product performance.

The breaking, setting and curing time of slurry surfacing systems is influenced by temperature, humidity, and direct sunlight or shade. Slurry surfacing systems shall not be applied if the pavement or air temperature is below 50°F (10°C) and falling but may be applied when both pavement and air temperatures are above 45°F (7°C) and rising. Slurry surfacing systems shall not be applied when there is the possibility of freezing temperatures at the project location within 24 hours after application.

Whereas lower temperatures will extend the break and set times of slurry surfacing systems, higher temperatures will accelerate the break and set. On warm days, it is common to increase the use of spray bars to fog the pavement. The spray of water helps cool the surface, counteract any surface tension and prevent the emulsion from breaking on contact with the pavement. Spray bars may not be needed on cool days.

Elevated temperatures, whether ambient, surface or of any mix component, will cause a reduction of available mix time and may require additional water or chemical additive in the mix to counteract the higher air and pavement temperatures. Modifications to additives (usage/dosage) should be made according to the changing environment during application. Humidity may impact the rate of breaking and setting of the slurry surfacing material. Expected environmental conditions should be communicated to the design lab so that emulsion and mixture formulations can be optimized for actual project conditions.

A slight breeze is advantageous to the setting and curing of slurry surfacing systems. In less humid conditions the breeze may accelerate the breaking and setting process of the slurry surfacing material. Work should not be started if rain is imminent. Micro surfacing will typically resist damage caused by rain after as little as one hour after placement.

Application of slurry seal is generally not suitable for night work, unless a quick set emulsion is used since it doesn't depend on curing by evaporation. Lower evaporation rates at night result in longer breaking and curing times. Whereas slurry seal is not suitable for night work, micro surfacing can be placed at night because it relies primarily on chemical breaking and curing.

Slurry Surfacing System Bonding

The integrity of the slurry surfacing system treatment is ensured by creating a strong bond to the existing pavement. Some of the methods include:

- **Pavement Pre-Wetting** – Pre-wet the surface by fogging through the spray bars of the application equipment ahead of the spreader box when the surface is dusty, oxidized, or hot. If asphalt flushing or bleeding exists, fogging may be required to minimize adhesion of the asphalt to the tires and skids on the application equipment. The rate of application of the fog spray should be adjusted during the day to suit temperatures, existing pavement surface texture, humidity, and dryness of the pavement surface. Water used in the pre-wetting of the surface should be applied such that the entire surface is damp with no apparent flowing water in front of the spreader box.

Figure 11: Pre-wetting the pavement prior to placement

- **Tack Coat -** A tack coat preceding a slurry surfacing system treatment may reduce the absorptive nature of the road surface thus improving application success. However, in most cases a tack coat is not required unless the existing road surface is extremely dry, raveled or is concrete or brick. A tack coat, when used for a slurry surfacing system, should consist of one-part emulsified asphalt and three parts water, applied with a distributor at 0.05 to 0.15 gallons per square yard (0.45 to 0.68 liters per square meter), depending on the surface texture. The actual rate will depend on the residual asphalt content of the diluted emulsified asphalt and on the texture and absorptive characteristics of the existing surface. The emulsified asphalt may be CSS-1h, SS-1h, or the same as used for the slurry surfacing treatment.

Figure 12: Tack coat before micro surfacing is placed

Scratch Coats

Scratch coats are only used with micro surfacing primarily to level pavements with longitudinal ruts less than 0.5 in (12.5 mm) deep. They may also be used to correct minor transverse irregularities that are narrower than the width of the spreader box or for structurally sound roads with surface distresses, such as raveling or weathering. When applying a scratch coat, a steel strike-off or strike-off of stiff rubber, is substituted for the primary strike-off in the standard full-width micro surfacing spreader box. The rigid strike-off scratches over the high spots of the pavement, filling in the irregularities. The concept is to fill the depressed areas and leave very little material on the high ridges. It may be common to see scratch/drag marks in this leveling course as the application rate will be minimal in places.

Figure 13: Scratch course

Spreader Box

There are many types and variations of spreader boxes, but they all perform the same function, which is to spread the mixture in a uniform manner onto the pavement. Spreader boxes range from simple, light, non-adjustable units to large boxes equipped with augers, special runners, and hydraulic controls. Specialized boxes may be used for rut filling, special shoulder work, and variable width spreading. The spreader box choice depends on the slurry surfacing treatment type and specified application rate of the material. The type of box required for each project should be specified. If ruts are deeper than ½" then a rut box should be specified. If there are multiple width changes in the pavement, an adjustable on-the-fly box should be specified.

- Cleanliness is mandatory in a spreader box. The box must be cleaned at the end of every work period and may require cleaning (especially the rear rubber) during the workday if excessive buildup of mixture causes streaking in the finished surface.
- Ensure no loss of mixture from the spreader box. Side rubbers (when required) should be sized so that edges are kept neat. The primary strike-off rubber should provide a uniform

application across the full width of the mat and may be changed in thickness, width, and hardness to achieve desired results.

- The spreader box should pull smoothly and evenly without vibration. Machine speed should be relatively consistent. Excessive speed can cause the box to vibrate or jump leaving transverse ripple lines (wash boarding) in the finished surface. If using a drag (typically a short length of burlap), excess speed may create a rippled and uneven mat. The most important factor in determining the allowable speed of application is the result and quality of the treatment. Speed of application is affected by application rate, gradation of aggregate, consistency of the mixture, and existing surface texture.

One potential problem associated with slurry surfacing system treatments is drag marks. Drag marks are created when oversize aggregate particles, broken mix or road contaminants become lodged under the primary strike-off and are pulled along leaving a groove in the surface. Drag marks can be minimized by using a screening plant at the stockpile to eliminate oversized aggregate particles, proper cleaning of the spreader box to eliminate broken mix in the box and proper surface preparation to reduce road contaminants. There are two methods of repairing drag marks once the material has been applied on the pavement surface. The traditional method is to repair the groove with a squeegee.

A secondary strike-off will also correct drag marks. It may also improve the surface texture and surface cosmetics. The secondary strike-off mounts directly behind the primary strike-off and is in contact with the fresh mix. It removes most surface imperfections without requiring a person to remove them with a hand tool. The secondary strike off does not remove the cause of the drag mark, so that still must be removed by hand. But it will correct the imperfections in the surface while the oversized aggregate is removed.

An improperly used drag can cause large stones to roll into positions where they are not properly imbedded in the mat. The drag length, height, and thickness should be adjusted for each specific aggregate gradation or slurry surfacing system. Drags need to be replaced when they become torn or inflexible. They shall be kept in a completely flexible condition at all times so replacement may be needed multiple times a day.

Figure 14: Secondary strike off correcting drag marks

Rut-Filling

Rut-filling should only be performed with micro surfacing and should only be used on stable ruts that have resulted from long-term traffic compaction rather than failures in the base or sub-base. If rutting is ongoing, the micro surfacing will not prevent its continued development.

Ruts less than 0.5 inch (12.5 mm) deep should be addressed with a full-width scratch coat for leveling before the final surface is placed. Ruts of 0.5 inch (12.5 mm) or more should be filled individually with a rut box, generally starting with the outside rut first and inside rut last. Ruts filled either with a scratch coat or rut box should be covered with full-width micro surfacing after a minimum of 24 hours of traffic. This allows for return traffic compaction.

The rut box channels the largest aggregate particles into the deepest areas of the rut. The rut box should be adjusted to create a crown to compensate for traffic compaction.

Rut-filling is typically constructed with a Type III gradation. Deep ruts may require multiple lifts and asphalt content on the low side of the allowable range unless the existing pavement condition is dry and absorptive. Asphalt contents that are higher than necessary may create stability problems.

Attempting to fill ruts with a surface course is not recommended. Ruts not filled using a separate rut-filling process will negatively affect surface course application rate and performance. A single rut of 0.25 in (6.4 mm) or less deformation will increase the total average surface course application rate as the rut must be filled to the level of the existing pavement during the application process.

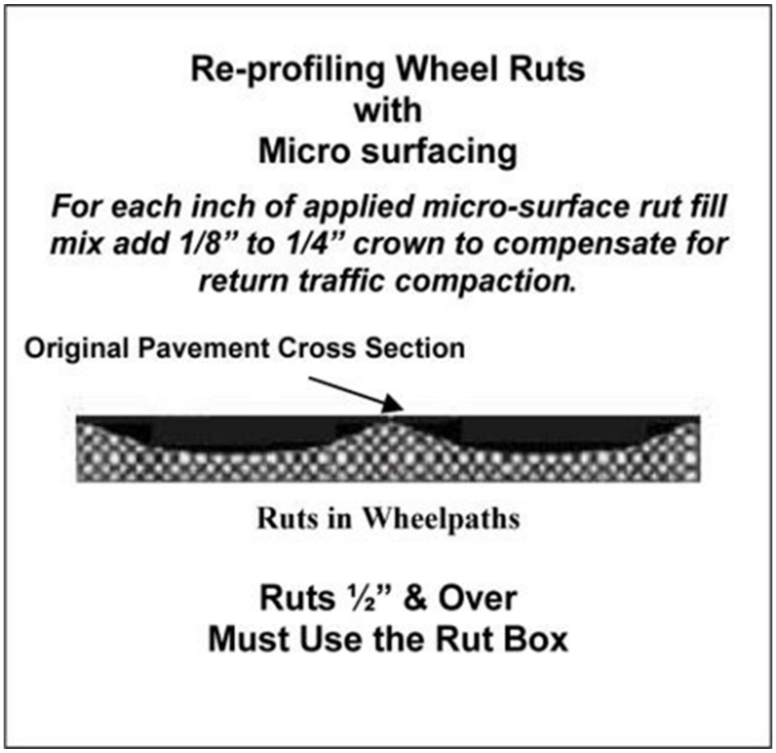

Figure 15: Wheelpatch re-profiling illustration

Hand Work

Many projects will include areas that are not accessible to the spreader box. These areas can be completed by the use of squeegees or asphalt lutes. If the spreader box uses a drag mop, one must also be used on the squeegees to obtain a matching texture. Handwork should be used minimally.

When handwork is being performed, wetting the existing pavement reduces surface tension and helps the squeegee operators to place and finish the mixture. The finished slurry surfacing should be uniform and closely resemble the appearance of the box applied material. Mix that has broken during handwork should be removed.

Figure 16: Good Handwork

Figure 17: Bad Handwork

6.3.7 Application Rates

Application rates may vary during the project due to changes in the existing pavement surface demand. The correct application rate of the treatment can have a significant impact on the success of the project. Excessive application rates may result in rippling, displacement, and segregation. Inadequate application rates may cause excessive raveling and reduced service life. The three primary factors that influence application rate are aggregate gradation, existing pavement surface texture, and mixture consistency.

- **Aggregate Gradation**. For aggregate on the coarse side of the gradation specification, application rates should be higher. Otherwise, the largest aggregate particles will not adequately embed in the emulsified asphalt binder. Insufficient embedment may cause drag marks when larger stones are caught by the strike-off rubber. Raveling may result from insufficient embedment, as well. Conversely, for aggregate on the fine side of the gradation specification, application rates should be lower to avoid flushing of the surface.

  By design, slurry seals are to be applied in a layer equal to the largest stone in the gradation. Slurry seal applied at less than, or more than, the recommended application rate, or in multiple layers without adequate cure time, may create an unstable treatment leading to raveling, flushing, rutting, or wash boarding.

  Multi-stone depth thickness requires the use of a micro surfacing. Micro surfacing applied as a surface treatment will vary in thickness and weight per unit area when the surface texture of the pavement changes. Typical application rates for Type II and Type III gradations can be referenced in A143 in Section 11. The exact rate will depend on the aggregate gradation and the texture of the existing surface.

- **Existing Surface Texture.** The existing surface void content will directly affect the application rate of the slurry surfacing system. When the existing surface is badly raveled or otherwise coarse and open, more material is needed to fill the surface voids. When the surface is nearly smooth or almost flushed, additional material beyond the desired application rate would not be needed.

- **Mixture Consistency.** The consistency of a slurry surfacing system mixture is important. If the consistency is too fluid the mixture may segregate as larger aggregate particles sink and emulsion and fines float to the surface. This may lead to lower application rates. If the consistency is too dry, higher application rates may result due to increased build-up of the mixture.

6.3.8 Inspection Points

Oversight of quality during construction is a shared responsibility between the agency and the contractor and is important to achieving a successful project. Working together, they should identify and resolve potential problems and challenges as they arise during the project. Areas requiring special attention are discussed below.

1. **Longitudinal Joints**
   High quality longitudinal joints should be straight and on lane lines and uniformly follow the traffic lane on curved sections. They may be constructed as an overlap or butt joint. If overlapped, it must correspond to the lane lines and should not exceed 3 inches (76 mm) in width. They should be smooth and neat in appearance, avoiding excessive build-up or uncovered areas.

Figure 18: Good longitudinal joint

Figure 19: Unacceptable longitudinal joint

2. **Transverse Joints**
Each time the application equipment stops, a transverse joint must be constructed when paving resumes. Transverse joints should be smooth and neat in appearance and handwork should be kept to a minimum. Excessive buildup or uncovered areas should not be permitted. When possible, transverse joints should be constructed as a butt joint rather than an overlap joint. The use of roofing felt may assist the contractor in constructing acceptable transverse joints.

Figure 20: Correct transverse joint

Figure 21: Unacceptable transverse joint

3. **Edge Lines**
   The edge of the spreader box should produce a very straight and clean edge line and correspond to the original edge of the pavement. Normally the existing paint line at the edge of the pavement is adequate for the operator to use as a guide mark. If the operator has difficulty in achieving a straight edge line a string line or pilot line should be used as a guide mark for alignment. All transitional areas will need a string line or pilot line to produce the desired results.

Figure 22: Good edge line

Figure 23: Unacceptable edge line

4. **Final Surface Texture**
   Slurry surfacing systems designed according to ISSA Recommended Guidelines that are properly installed will yield a consistent surface texture throughout the project. Slurry surfacing systems can be applied to result in a wide range of final surface textures depending on a variety of factors (See the list below). Slurry surfacing systems can have an aggressive surface texture and when applied properly can maintain a high friction surface for the duration of their useful life. In the picture below, a uniform surface texture is being constructed on the left with a more magnified view of the texture on the right.

   Factors that influence the final surface texture are:

   - Existing pavement surface texture
   - Mix consistency
   - Adherence to job mix formula
   - Type of screed rubber
   - Spreader box operation and maintenance

- Use and orientation of secondary strike-off
- Use of fabric drags
- Application rate
- Speed of application machine (too fast may cause wash boarding)
- Opening to traffic too early
- Aggregate gradation, and
- Rolling (if required in airports and parking lots).

5. **Ride Quality**
   Slurry surfacing system treatments generally follow the existing road surface profile and so do not significantly change the pavement's ride quality. However, micro surfacing may correct minor surface irregularities, thus improving the ride quality to a moderate extent.

6. **Early Traffic Damage**
   Slurry surfacing system treatments must build sufficient cohesion to resist abrasion due to traffic. Minimal raveling is not unexpected when initially opened to traffic, especially in areas where hand work has been done or in cool weather. If this condition occurs, loose aggregate should be swept up to prevent additional damage. It is the contractor's responsibility, in partnership with the agency representative, to determine the appropriate timing for return to traffic.

   Slurry surfacing systems may sometimes be tender in their infancy. Minor abrasion and tearing may occur under high torsion in the early weeks after placement. High pavement and ambient temperatures will compound these occurrences.

Figure 24: Early traffic damage

7. **Application Rate Verification**
   The overall performance of the slurry surfacing system is directly related to the proper application rate of the material. It is recommended that the application rate be verified a minimum of four (4) times per day. The factors determined during the calibration process, including the date, are necessary for the verification of the application rate. In most cases, application rates are based upon pounds of dry aggregate per square yard.

   Example: The section to be checked is 500 feet long and 12 foot wide. Multiply 500 X 12 and divide by 9 to determine square yards of 667. Then, from the calibration determine the total pounds of aggregate per count on the aggregate belt. Assume 33 lbs./count and for the 500-foot section there were 400 counts for a total amount of aggregate of 13,200 pounds of aggregate. Divided by 667 (square yards in section) yields an application rate of 19.79 pounds of dry aggregate per square yard.

6.3.9 On-Site Sampling and Testing of Materials

During the process of producing, hauling, and stockpiling materials, good quality control procedures require tests to:

- Ensure that only material consistent with the JMF is used in the slurry surfacing system, and
- Provide a permanent record as verification that the materials meet project specifications.

Proper sampling techniques must be followed for all materials. Material sampling techniques shall follow "Sampling of Aggregates" (AASHTO Test T2 & ASTM Test D75) and "Sampling Bituminous Materials" (AASHTO T40 & ASTM D140) for emulsion sampling. Test frequencies shall conform to those shown in Table 13.

Table 11: Test Frequencies

Test	Frequency
1. "Materials Finer than 75 micrometer (No. 200) Sieve in Mineral Aggregates by Washing" (ASTM C117, AASHTO T11) and "Sieve Analysis of Fine and Coarse Aggregates" (AASHTO T27, ASTM C136). Ensures aggregate is within the stockpile tolerance of the mix design gradation.	One test per 500 tons of aggregate unless a problem arises requiring more frequent testing.
2. 2. Standard Test Method for Oversized Particles in Emulsified Asphalts (ASTM D6933). Ensures emulsion is free of oversized asphalt particles (No. 20 Sieve).	One test per day or one test for each transport load delivered to the project site. A Certificate of Analysis (COA) for each load would also be acceptable.
3. Ensure mineral fillers are the same type as designated in the mix design.	Once prior to starting the project and again if the source changes.

The most common practice to determine individual material quantities and application rate is to obtain data from the proportioning devices on the previously calibrated slurry surfacing application equipment. Due to the challenges associated with sampling the mixture directly from the application equipment, a much less common practice is to take representative samples and then to run the residual asphalt content according to ASTM D2172 & AASHTO T164 "Standard Test Method for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures".

Quality assurance during construction is a responsibility shared by the project inspector and the contractor. Elements of construction that should be periodically checked for compliance with the project specifications are shown in Table 14.

Table 12: Quality Assurance Guide for Slurry Surfacing System Construction

Quality Assurance Guide
1. Traffic control, signage, etc. are consistent with the Manual on Uniform Traffic Control Devices (MUTCD) and the project-specific traffic control plan, 2. Pavement surfaces are clean and prepared to receive treatment, 3. Air and pavement temperatures are suitable during and after treatment application, 4. Structures and castings are protected prior to treatment application and their locations are properly referenced, 5. On-site sampling and materials' acceptance testing are completed according to the frequency in Table 13, 6. If necessary, changes to work due to field conditions and ongoing acceptance testing are implemented, and 7. Application rates are consistent with project requirements.

6.3.10 Opening to Traffic

Opening slurry surfacing system treatment applications to traffic is a function of the time it takes the emulsion to break and the mixture to cure. The air/pavement temperatures and humidity affect the curing time. Generally, as the temperature increases and the humidity decreases, it takes less time for the emulsion to break and the mixture to expel the water. Conversely, cooler and/or more humid conditions, as well as shaded areas, may require longer curing times before opening to traffic.

Micro surfacing can normally handle straight-rolling traffic approximately one hour or less after placement without damage. In locations with stop and go and/or turning traffic, or in residential areas, especially during unusually hot or cool weather, additional curing time may be required. It is ultimately the contractor's responsibility to determine the appropriate time to open the freshly applied material to traffic.

6.3.11 Opening to Traffic

Accuracy in quantity measurements is an essential part of inspection for both parties to the contract. To ensure accuracy and agreement on the quantities requires a coordinated effort between the inspector and the contractor. The contract will specify the methods of measurement and payment for the project. Methods vary among agencies but usually fall into one of the following categories:

Option 1. Unit Area (square feet, square yard or square meter)

Measurement and payment by the unit area:

- Calculate the surface area of all treated pavements.

Option 2. Ton of Mix (metric)

Measurement and payment by the composite ton is usually specified to include the dry aggregate, mineral filler, and emulsified asphalt. In this option, the agency is likely to get more materials, but at a greater cost.

1. Determine the tons of dry aggregate applied daily by one of the following methods:
    - Use calibration factors to calculate dry aggregate used, or
    - Use certified belt scales to weigh the wet aggregate and then deduct the water using the daily moisture content.
2. Determine the tons of mineral filler used daily by one of the following methods:
    - Use the calibration factor to calculate the mineral filler used, or
    - Count the number of bags used.
3. Determine the tons of emulsified asphalt used daily by one of the following methods:
    - Use the calibration factor to calculate the emulsified asphalt used.
4. Add 1, 2 and 3 for total tons of mix.

Option 3. Ton of Dry Aggregate and Gallon (Liter or Ton) of Emulsified Asphalt

Measurement and payment by the ton of dry aggregate and gallon (liter or ton) of emulsified asphalt requires the calculations outlined in Option 2.

1. Determine the tons of dry aggregate applied daily.
    - Use calibration factors to calculate dry aggregate used.
2. The mineral filler will be considered part of the aggregate. Determine the tons of mineral filler used daily by one of the following methods:
    - Use the calibration factor to calculate the mineral filler used, or
    - Count the number of bags used.
3. Add 1 and 2 for total tons of dry aggregate.
4. Determine the gallons (liter or ton) of emulsified asphalt used daily.
    - Use the calibration factor to calculate the emulsified asphalt used.

6.3.12 Project Close Out

The inspector and contractor should cooperate to accomplish the following objectives:

- Assemble the required documentation and submittals required by the contract,
- Complete all the remaining punch list items,
- Perform a final inspection, and
- Agree on final measurement and payment quantities.

7.0 Quality Assurance

7.1 Introduction

AASHTO R 10 provides standard definitions for terms used in quality assurance procedures.

QA is defined as all those planned and systematic actions taken by the Agency and Contractor to provide the necessary confidence that the procured material and workmanship will satisfy the quality requirements of the contract.

QA includes Quality Control (QC), Acceptance and Independent Assurance (IA).

QC is the system used by the Contractor to monitor, assess and adjust production and placement processes to ensure that the material and workmanship will meet the specified quality. QC is the responsibility of the Contractor.

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

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

7.2 Quality Control (QC)

7.2.1 General

The slurry systems contractor (the Contractor) shall establish, implement, and maintain a QC program to control all equipment, materials, production, workmanship, and associated processes during construction. The Contractor's QC program shall include preconstruction activities including slurry system mix design, site preparation, material handling and transportation, and stockpiling. The program shall include procedures required for sampling, testing, inspection, monitoring, documentation, and corrective action during transport, stockpiling, placement and finishing operations.

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

7.2.2 Reference Documents

a. AASHTO R 10 Standard Practice for Definition of Terms Related to Quality and Statistics as Used in Highway Construction

b. AASHTO R 18 Standard Recommended Practice for Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
c. AASHTO R 38 Standard Practice for Quality Assurance of Standard Manufactured Materials
d. AASHTO R77 Standard Practice for Certifying Suppliers of Emulsified Asphalt
e. AASHTO M 316 Standard Specification for Polymer-Modified Emulsified Asphalt
f. AASHTO R 90 Sampling Aggregates Products
g. AASHTO T 11 Standard Method of Test for Materials Finer Than 75-micro m (No. 200) Sieve in Mineral Aggregates by Washing
h. AASHTO T 27 Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates
i. AASHTO R 66 Standard Practice for Sampling Asphalt Materials
j. AASHTO T 49 Standard Method of Test for Penetration of Bituminous Materials
k. AASHTO T 53 Standard Method of Test for Softening Point of Bitumen
l. AASHTO T 59 Standard Method of Test for Emulsified Asphalts
m. AASHTO T 96 Standard Method of Test for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
n. AASHTO T 104 Standard Method of Test for Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate
o. AASHTO T 176 Standard Method of Test for Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
p. AASHTO MP 28-17 Standard Specification for Materials for Micro Surfacing
q. AASHTO MP 32-17 Standard Specification for Materials for Slurry Seal
r. AASHTO PP 83-16 Provisional Standard Practice for Micro Surfacing Design
s. AASHTO PP 87-17 Provisional Standard Practice for Slurry Seal Design
t. ISSA A143 Recommended Performance Guideline for Micro Surfacing
u. ISSA A105 Recommended Performance Guideline for Emulsified Asphalt Slurry Seal
v. ISSA A115 Recommended Performance Guideline for Polymer Modified Slurry Seal
w. Title 23 CFR Part 637 Construction Inspection and Approval

7.2.3 Definitions

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

7.2.4 Personnel

a. Responsibilities and Requirement of QC Staff - at a minimum, provide the name of the person responsible for each position listed below, including their telephone number, email, and their qualifications/certifications.
   I. QC Plan Manager. The person responsible for the execution of the QC Plan and liaison with the Agency. This person shall be on the job and have the authority to stop or suspend construction operations.
   II. QC Technicians. The person(s) responsible for conducting QC tests and inspection to implement the QC Plan. QC Technicians shall have Level 2 Aggregate Testing certification from the American Concrete Institute (ACI), or other certification program approved by the agency
b. Certified Contractor Staff - at a minimum, the contractor's superintendent, project foreman and placement machine operator shall possess a valid AASHTO TSP·2 slurry systems certification. The foreman and placement machine operator shall always be on the job while the slurry system is being constructed. The superintendent may oversee the construction operation of up to 3 projects at any one time.

7.2.5 QC Testing Laboratories and Equipment

The following describes the requirements for testing labs and equipment:

a. The mix design laboratory that is accredited. The Contractor shall provide the name of the lab formulating the mix design. This lab shall maintain accreditation by the AASHTO Accreditation Program (AAP) or other accrediting body.
b. The laboratory that performs the QC for production can be either qualified or agency approved. The Contractor shall provide the name of an agency approved lab for all tests within the relevant scope of testing. Testing and sampling equipment and measuring devices shall meet the requirements of the specified standards and test methods. The lab shall maintain records of the calibration and maintenance of all sampling, testing, and measuring equipment, and all documents required by the accreditation or agency program.
c. Placement machine calibration – prior to the commencement of work, the production equipment shall be calibrated in the presence of the Agency representative utilizing the materials to be used on the project. Calibration will be performed consistent with procedures in FHWA-HIF-19-036, Slurry Seal Checklist, 2019 or FHWA-HIF-19-031, Micro Surfacing Checklist, 2019.

7.2.6 QC Activities

QC activities shall include monitoring, inspection, sampling and testing. The Contractor's QC activities shall cover all aspects that affect the quality of the materials and workmanship of the slurry system. The minimum QC activities and frequencies required are listed in Table 13 or per agency specific requirements.

a. Component materials
b. Transportation material handling
c. Mix design by a qualified lab
d. Test strip construction and assessment

e. Placement and finishing
f. Performance
g. Review of material certifications supplied by vendors and suppliers.

Table 13: Minimum QC Requirements for Emulsions and Aggregate

Property	**Test Procedure**	**Lot Size**	**Min. Test Frequency**	**Point of Sampling**	**Sampling Method**
Emulsion Properties	AASHTO M208 or AASHTO M316	Per Batch (max. 30,000 gal)	1 per Lot	Plant	AASHTO R66
Distillation of Emulsified Asphalt*	AASHTO T59	Per Batch (max. 30,000 gal)	1 per Lot	Plant	AASHTO R66
Settlement and Storage Stability of Emulsified Asphalts, 24-hr	AASHTO T59	Per Batch (max. 30,000 gal)	1 per Lot	Plant	AASHTO R66
* Emulsified asphalt samples for residue content will be taken at the point of delivery from the delivery tanker using AASHTO R 66 and shall be determined by either AASHTO T59 or agency approved method. Verify residue binder content of mix is consistent within ±0.3% of mix design.					
Residue Properties of Emulsified Asphalt					
Elastic Recovery for AASHTO M316	AASHTO T301	Per Batch (max. 30,000 gal)	1 per Lot	Plant	AASHTO R66
Penetration of Bituminous Materials at 77°F (25°C)	AASHTO T49	Per Batch (max. 30,000 gal)	1 per Lot	Plant	AASHTO R66
Aggregate					
Gradation	AASHTO T27 or T11	Once per every 1500 tons per day	1 per Lot	Stockpile	AASHTO R90
Sand Equivalency	AASHTO T 176	Source		Source	AASHTO R90
Soundness	AASHTO T 104	Source		Source	AASHTO T2
Hardness (LA Abrasion)	AASHTO T 96	Source		Source	AASHTO T2
Aggregate samples will be taken at the project stockpile site using AASHTO R 90 Method B. Gradation test results should be provided within 24 hours					

7.2.7 Contractor's Quality Control Plan

The Contractor shall submit a written project specific, signed QC Plan to the Agency for approval at least 15 days prior to placement. The QC Plan shall detail the Contractor's plans, policies, procedures, and organization deemed necessary to measure and control materials, equipment, and slurry system placement operation.

The QC Plan shall be maintained to reflect the current status of the operations. Changes must be approved by the agency prior to implementation:

At a minimum, the QC Plan shall detail the following:

a. **Scope and Reference Documents**. Reference all applicable standards, guidelines, technical bulletins, standard specifications, and project special provisions.
b. **Definitions**. Making terms used in the QC Plan clear and distinct.
c. **Quality Control Personnel**. Company personnel, subcontractors responsible for QC testing. Material suppliers reporting test results.

d. **Quality Control Testing Facilities and Equipment**. Accredited laboratories used for mix designs. Agency approved or accredited laboratories for QC activities, including facilities and equipment used for material sampling and testing.
e. **Materials Control**. Identify all materials and sources used in the treatment, plus handling, storage requirements and stockpiling provisions.
f. **Quality Control Sampling and Testing**. Lot size defined for sampling, sampling identification system, sampling methods, test procedures, test frequency, storage and retention procedures.
g. **Production Equipment**. Identify all equipment to be used for construction and provide specification sheets for major equipment.
h. **Pre-Production Activities.** Equipment calibration procedure and frequency, equipment checks and inspection frequencies, pavement surface preparation procedures, and related production activities (e.g., traffic control, tack coat, etc.)
i. **Placement and Workmanship**. Identify protocols for proper workmanship, production QC activities, test frequencies, breaking time, inspection methods, yield checks to verify application rates, and cleanup responsibilities (daily and at end of project)
j. **Documentation**. Describe testing procedures and determine when corrective action is required. The contractor will provide examples of reporting forms, production QC test results, daily production records, non-conformance reports, and document retention details.
k. **Non-Conformance and Corrective Action**. Establish and maintain an effective and positive system for controlling non-conforming materials as indicated by inspection and test results. Investigate the cause of any non-conformance to prevent recurrence and take prompt corrective action to correct conditions that have resulted, or could result, in the incorporation of non-conforming materials into the work. All non-conforming materials shall be positively identified to prevent use and intermingling with conforming materials. Include procedures and personnel responsible for directing corrective action including suspension of work and disposal or reworking of non-conforming materials. Detail how the results of QC inspections and tests will be used to determine corrective actions, define rules to gauge when a process is out of control and associated corrective action to be taken. At minimum establish corrective action procedures for each control requirement listed above.

7.2.8 Records and Documentation

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

All QC test results shall be submitted to the Agency within 24 hours or upon request. A material certification shall be submitted from each supplier for each batch of material delivered to the jobsite, including test results.

The QC records shall contain all test and inspection reports, forms and checklists, equipment calibrations, supplier material certificates, and non-conformance and corrective action reports. The QC records shall indicate the nature and number of observations made, the number and type of deficiencies found, the quantities conforming and non-conforming, and the nature of corrective action taken as appropriate for materials as well as workmanship. The QC records shall always be available to the Agency and shall be retained for the life of the contract. The Contractor's documentation procedures will be subject to approval by the Agency prior to the start of work, and to compliance checks by the Agency during the progress of the work.

7.2.9 Compliance with Specifications

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

7.3 Agency Acceptance

7.3.1 General

As the owner of the final micro surface, slurry seal, or polymer modified slurry seal, the Agency must ensure the contractor has constructed the project in accordance with the specifications. The Agency will conduct acceptance sampling, testing, and inspections consistent with AASHTO R 10. The agency may conduct verification testing should the QC results be used for Acceptance.

7.3.2 Acceptance Activities

Typical acceptance activities should include the following:

a. Assure the Contractor has followed the approved QC Plan.
b. Materials – Monitor the Contractor QC testing.
c. Agency to sample and test:
    i. Aggregate – Gradation and deleterious materials, once per day or at the discretion of the Agency.
    ii. Asphalt Emulsion – Once per project or at the discretion of the Agency.

    Note: Actual frequency and lot size will be per each Agency's Frequency Guide Schedules for Verification, Sampling and Testing.
d. Traffic control conforms to plans and specifications and complies with the Manual on Uniform Traffic Control Devices.
e. Surface Preparation – Monitor pre-treatment activities, verify surface has been swept clean, pavement is dry, utility castings are protected, and drainage inlets are covered.
f. Placement Machine(s) Calibration – Witness the calibration of equipment.
g. Production Inspection:
h. Monitor and verify correct application rates of material placed.
i. Monitor workmanship for even joints, straight lines, and uniform texture free of drag marks or unsightly appearance.

7.4 Independent Assurance Program (IA)

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

8.0 Problem Solving and Check Lists

8.1 ISSA 2021 Design and Inspection Manual

ISSA reports that the conditions discussed below may be experienced with a slurry seal, polymer modified slurry seal, and micro surfacing systems. They also identify the possible causes and solutions to the condition. Table 14 summarizes the information which will be highlighted in the new Design and Inspection manual.

Table 14: Problems, Possible Causes, and Potential Solutions

Condition	Possible Causes	Solutions
Non-uniform color	• Application equipment not calibrated • Environmental conditions such as rain, cool temperatures, variations in humidity • Mix formulation: Too much water, high dosage of emulsifier, additive or mineral filler dosage	• Application equipment should be accurately calibrated to produce mix identical to JMF • Do not apply slurry surfacing systems if pavement and air temp is below 50 F and falling or rain is imminent. May apply if pavement and air temp is 45 F and rising • Overly stable mixtures lead to delayed curing and discoloration. Adjust dosage of mineral filler and emulsifier. Too much water will cause discoloration.
Raveling	• Insufficient binder or application rate to thin • Cooler temperatures • Premature opening to traffic • Poor quality raw materials	• Check JMF and application rates. • Ensure application temperatures are suitable (see above) • Do not release traffic early • Confirm material properties adhere to specifications
Flushing	• Mix contains too much water or emulsified asphalt • Excessive overlapping or application rates • Variable surface condition	• Verify JMF and equipment calibration • Minimize overlap and verity application rates • Properly prepare surface by patching, reprofiling, scratch course, etc. Apply appropriate treatment for existing surface condition.
Breaking too fast	• High temperatures of the emulsion of the pavement • Mineral filler not correct • High fines content, poorly formulated emulsion	• Ensure the application equipment is calibrated, the mix components are consistent with the JMF, and the temperatures are correct • Consult material supplier
Breaking too slowly	• Low ambient temperatures • Shady or cloudy conditions • Poorly formulated emulsion	• Suspend operations if temperatures are not within the recommended application range, Ensure the mixture is consistent with the JMF, in shady area, place the mix early in the day to allow more time for curing
Unsatisfactory handwork	• Inadequately trained personnel • High temperatures accelerate the break • Handwork in large area not accessible to application equipment	• Adequately staffed crew needs to be properly trained • Perform handwork during the cooler part of the day • Use set control additives, pre-wet existing pavement, have enough adequately trained crew members

Tire marks and surface abrasion	• Can be scuffed due to power steering during hot and humid weather	• Use polymer modified emulsion • Roll the surface with a rubber-tired roller
Delamination	• Inadequate cleaning of the surface • Improper drainage	• Clean the existing surface well • Tack coats can be applied • Ensure proper drainage at edge of pavement
Tire pull-off	• Equipment passes over freshly placed slurry • Large patties of mix are deposited on the pavement	• Operator can use the hand hose to wet the tires and existing pavement to minimize pickup • Remove loose material from pavement prior to surfacing
Unwanted slurry on concrete gutters	• Poor workmanship • Excess liquids in the mix • Poor spreader box maintenance	• Need experienced line drivers • Need a stable homogeneous mix. Check calibration of application equipment • Check and replace worn or poorly functioning spreader box seals
Wash boarding	• Fabric drag installed too high allowing bouncing • Excessive forward speed, ski wear, and improper spreader box set-up	• Drag should be mounted on spreader box close to the pavement surface • • Correct the equipment related problems and control the speed of operations
Surface irregularities	• Low application rates • Oversized aggregate • Spreader box cleanliness	• Ensure proper application rates • Use of scalping screen to remove oversized materials • Keep spreader box and strike-off rubber clean
Poor longitudinal joints	• Lack of pilot line to guide driver • Improper box width for width of pavement • Improper box operation, poor workmanship	• Pilot lines should be used as a guide • Place longitudinal joints on lane lines, no gaps or uncovered areas • Spreader box should be operated in such a way to minimize build-up. Limit use of partial width passes •
Poor transverse joints	• Improper box operation, material placed too heavy/light • Excessive handwork • Butt joint not constructed	• Operate spreader box to maintain consistent application elevation at transition • Don't overwork that can lead to segregation • Do not overlap joints
Poor edge lines	• Crew could not follow the edge or curb line • Excessive liquid in the mix	• Need to have trained crews, use a pilot line • Follow the JMF, check equipment calibration

8.2 FHWA Check Lists

In 2019, FHWA updated their checklists for slurry seals and micro surfacing. These documents include information on the following:

- Document review
- Project review
- Materials checks
- Pre-application inspection
- Equipment inspection
- Weather requirements
- Applications rates including equipment calibration
- Traffic control
- Project inspection responsibilities
    - Slurry seal application
    - Longitudinal joints
    - Transverse joints
    - Sweeping
    - Rolling
    - Opening to traffic
    - Cleanup responsibilities

In addition, they identify common problems and solutions for the problems shown in Table 14. These documents can be found at the following link:

https://www.fhwa.dot.gov/pavement/preservation/ppcl00.cfm

Web based training on slurry surfacing systems can be also taken from ISSA at www.slurry.org. Another excellent resource on slurry seal and micro surfacing can be found at www.roadresource.org.

9.0 Conclusions and Recommendations

9.1 Conclusions

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

However, it is important that the projects for slurry surfacing systems be selected correctly and be constructed properly. Agency inspection is also important. The agency, who is the owner, often gets what it inspects as opposed to what it expects.

9.2 Recommendations

Just because these are best practices as of 2022, does not mean the technology or practices should not continue to improve. Equipment changes, changes in material and mix design and testing methods should and will continue to get better.

10.0 References

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