Slurry Systems Certification

Session Guide

National Center for Pavement Preservation
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PREFACE

The Purpose of Certification

The intent of the certification process is to provide assurance to highway agencies that pavement professionals and pavement practitioners certified in specific treatments have successfully completed a recognized program and passed an examination designed to assess the knowledge required for providing high quality thin surface treatment construction. Recipients of a certification possess particular qualifications and have demonstrated their competence to ensure the successful placement of a designated thin surface treatment.

In recent years, pavement preservation treatments have assumed a critical role in safeguarding America's highway system from the detrimental effects of harsh environmental conditions and ever increasing traffic. Pavement preservation is a pillar of sound asset management and ensures that the overall condition of the road network can be sustained at a desired level. Therefore, the successful placement and performance of pavement preservation treatments is an essential foundation for the realization of long-term financial planning and the ability of agencies to achieve their pavement condition goals cost-effectively.

The Congressional Act cited as "Moving Ahead for Progress in the 21st Century Act", known as "MAP-21", established a set of national goals and a process for performance reporting. Part of the law contains provisions for pavement performance and development of asset management plans. Consequently, successful construction and performance reliability are critical for every agency responsible for the condition of pavements in their jurisdiction.

Benefits of Certification

Agency personnel certified in specific thin surface treatments will ensure that future investments in those treatments are properly designed, constructed, and perform as intended. Certification would give agency employees the knowledge necessary to monitor contractor performance.

Company personnel certified in their product will have the confidence to make proper day-to-day decisions and will ensure that good quality control is maintained throughout their projects. Company certification promotes a common understanding by all personnel of the processes involved in production and placement of their product.

Certified consultants become aware of the treatment processes and quality assurance practices to perform the duties and functions required by the client.

Certified Personnel

It is understood that project oversight is completely defined and managed by the agency, but the contractor is ultimately responsible for their product quality and workmanship. The value of certified personnel is to alleviate potential problems by:

a. Serving as on-site technical experts in the treatment.
b. Providing peer-to-peer training for other staff and workers.
c. Reviewing the Contractor's Quality Control Plan for the project, including material sources, test requirements, equipment requirements; and treatment mix design documents, if applicable.
d. Witnessing on-site calibration of placement equipment used for construction.
e. Responding to treatment issues that may arise in the field.

In addition to the concerns that can potentially arise on any project, safety is paramount. Safety in construction is not a matter to be taken lightly and needs to be foremost in every aspect of the project at all times. Construction materials, machinery, and handling techniques all come with their own dangers. Road user and worker safety and accessibility should be an integral and high-priority element of every project from planning through design and construction.

Work zone crashes involving vehicles or construction equipment often lead to fatalities and injuries. Work zones are inherently dangerous and are not places to cut corners or cheat on safety. Your life and the lives of others are in jeopardy, so pay attention and know what it takes to keep everyone safe.

SESSION 1: PROJECT SELECTION

1.1 **Overview** - The project selection process is challenging because it encompasses a wide range of pavement designs, paving materials, traffic loadings, topography, and subgrade support conditions. In addition, climatic conditions and existing drainage characteristics further complicate the selection process. There are three commonly used methodologies that should be considered in project selection. These are pavement management, field sampling and forensic investigation, and on-site review. Ideally all three methods should be used whenever possible, but this is seldom practical due to logistics and time.

1.2 **Pavement management** provides the tools necessary to capture the existing pavement condition and forecast future performance so that agencies can identify the optimal timing for treatment application. A robust pavement management system should allow an agency to integrate the operation and preservation of their road and highway network with their long-range delivery and planning objectives. Most pavement management systems are being used to make project selection decisions and they can easily identify reconstruction and rehabilitation candidates through pavement condition analysis. However, project level selections of individual candidates become much more difficult because of inherent constraints which limit the accuracy of the data being collected. This is because obsolete or insufficient data may have been used in the decision making process. Important condition data, such as raveling, flushing/bleeding, and pavement oxidation, is generally absent because it is difficult to collect and quantify. For these reasons, care should be taken to avoid project selection decisions for thin surface treatments based solely on the output of the pavement management system.

1.3 **Field sampling and forensic investigations** have been used to reduce the probability of premature pavement failures. Predicting pavement failure is difficult and normally begins with a thorough review and analysis of original construction records. Studies may employ non-destructive testing such as ground penetrating radar (GPR) and falling weight deflectometers (FWD) to determine the existing pavement structure. Field sampling such as coring and trenching are used to validate suspicions of weak pavement structures. Overall, whatever method is used, forensic investigations should begin early in the candidate selection process to allow the maximum opportunity to correct problems and avoid a premature failure.

1.4 **On-site pavement reviews** are generally made to identify and quantify existing distress. There are two classes and several types of distress associated with each type of pavement. Generally, pavement distress and failure may be structural and / or functional. Structural distress is associated with the pavement’s inability to carry its design load. Functional distress is related to accessibility, ride quality (roughness), and safety issues (e.g., skid resistance, hydroplaning, etc.). Conversely, functionally distressed and / or failed pavements (e.g., very rough) may or may not exhibit any structural distress. Pavements exhibiting structural distress (e.g., severe alligator cracking) will also exhibit functional distress and eventually fail. Pavements with structural distress are not candidates for thin surface treatments. Each class of pavement distress (functional or structural) contains several distress types.

1.5 **Pavement distresses** should be identified using a minimum of four factors: location, type, severity, and extent or amount.

Distress Location – The location of each type of distress relative to the common location referencing system must be identified. In addition, for some distress types such as longitudinal cracks, slippage cracks, patches, and polished aggregate, the location of the distress across the pavement surface (e.g., inside or outside the wheel path) should also be observed and recorded.

Type - Distress type (such as transverse cracks, longitudinal cracks, rutting, etc.) should be identified and recorded. Some distress types are specific to certain pavement types. For example, rutting is associated only with flexible and composite pavements.

Severity - Most distress types can be found at various severity levels. Highway agencies typically categorize distress severity as low, medium, or high. Although these levels are somewhat subjective, they do describe distinct stages of distress progression that relate well to pavement preservation needs. Some agencies such as the Michigan Department of Transportation use additional severity levels. Regardless of the number of severity levels used by an agency, photographs of each severity level of each distress are an indispensable part of the distress identification process and training. The “how to measure” subsection (presented under each distress type in the next section) gives specific directions on how to measure the particular distress and the units of measurement.

Extent (Amount) - The amount or extent of each type of distress must also be observed and recorded. For some distress types such as transverse cracks, the amount expresses the number of occurrences. For others, such as longitudinal cracks and alligator cracks, the quantity is expressed by the extent either in linear feet or surface area.

1.6 **Structural Distress** – Pavements exhibiting significant structural distresses should not be considered for thin surface treatments. Isolated structural distresses need to be removed and patched.

Note: The extent of the distress should be marked out, cut with a diamond saw, and the failed material removed. Often all materials down to and including some subgrade must be replaced with new materials, compacted in 4-inch lifts, and capped with a compacted asphalt patch. The patch will require a tack coat along the edges of the repair area prior to placement and compaction of the new asphalt surface. The new asphalt patch should be slightly overfilled by 0.25 inch to allow for traffic compaction. The edges of the patched area should be sealed with a crack sealant.

Alligator Cracks are a series of interconnecting cracks caused by fatigue failure of the asphalt concrete (AC) surface (or stabilized base) under repeated traffic loading. The cracks start at the bottom of the asphalt layer and eventually propagate upward to the pavement surface.

Alligator cracks are a load-associated distress caused mainly by the pavement design (inadequate design of the asphalt layer thickness or under- estimating the traffic load and volume), or construction processes (relatively soft pavement layers and / or roadbed soil). Adverse environmental conditions (temperature and moisture) tend to accelerate the start and propagation of the cracks. As alligator cracks occur only in areas that are subjected to continual traffic loadings, they will not occur over the entire pavement unless the entire surface is subjected to traffic loading. Alligator type cracks that occur over the entire pavement surface, including those areas that are not subjected to traffic loading are more likely to be caused by movement in the roadbed soil due to frost-heave.

Alligator fatigue cracks are measured in square feet or square meters of surface area. The major difficulty in measuring this type of distress is that two or three severity levels often exist within one distressed area.

Pumping and Water Bleeding involve the ejection of water and fine materials under pressure through cracks under moving wheel loads. Pavement surface staining or the accumulation of fine material close to the crack is evidence of pumping. Water bleeding occurs when water accumulates in voids beneath the pavement surface and slowly seeps out of cracks or construction joints in the pavement surface.

Stripping is the loss of bond between aggregates and asphalt binder that typically begins at the bottom of the HMA layer and progresses upward. Although not completely understood, some aggregates have an affinity for water rather than asphalt. These aggregates tend to be acidic and suffer from stripping after exposure to water. Over time, stripping leads to decreased structural support and failure. Thin surface seals tend to accelerate the stripping process, leading to rapid failure.

1.7 Combined Structural and Functional Distress – Often a distress first appears as a structural distress and later incorporates characteristics of a functional distress. The reverse progression can also occur when a functional distress deteriorates to a severity that impacts the structural integrity of the pavement. If addressed early in the distress cycle, thin surface treatments have proven to be highly effective in correcting the distress. Examples of these distresses include potholes, raveling, weathering, slippage cracks, swell, rutting, and block cracking.

Potholes are bowl shaped depressions of various sizes in the pavement surface that are caused by breaks in the pavement surface due to alligator or block cracking, localized disintegration of the pavement surface, and / or freeze thaw cycles accompanied by the presence of moisture and accelerated by the action of traffic. Potholes may be found anywhere along the pavement surface mainly in the wheel path. They are considered as structural and functional types of distress and are measured by depth and surface area in square feet.

Raveling and weathering are the wearing away of the pavement surface caused by the dislodging of aggregate particles (raveling) and loss of asphalt binder (weathering). Eventually, such surface wearing propagates downward and weakens the pavement structure. These distresses are caused by three primary mechanisms:

1. Horizontal shear stress due to traffic,
2. Presence of water (which enters the pavement through interconnecting voids) and high hydrostatic pressure caused by traffic, and
3. Long term emissions from motor vehicles (hydrocarbons act as solvents to asphalt).

Raveling and weathering are considered as functional and structural types of distress.

Slippage cracks are crescent or half-moon shaped cracks generally having both ends pointing in the direction of traffic. This type of cracking is caused by a low strength asphalt mixture and a poor bond between the surface course and the next layer of the pavement structure. Slippage cracks occur when parts of the AC surface move laterally away from the rest of the surface due to induced lateral and shear stresses caused by traffic loadings. The cracks may be found along the pavement surface, generally in the wheel path. Slippage cracks are considered both functional and structural types of distress.

Swell is an upward bulge in the pavement surface typically accompanied by surface cracking. Swell is mainly caused by frost action or swell in the roadbed soil or by blow-up of the underlying PCC slab. Swell may be found anywhere along the pavement surface and is considered to be both a functional and structural distress type.

Rutting is a surface depression in the wheel paths. These ruts in the wheel paths may or may not occur with pavement uplift adjacent to the sides of the rut. In many instances, ruts are noticeable only after a rainfall, when the wheel paths are filled with water. Rutting is caused by inadequate compaction during construction, soft asphalt mix, softening of the materials beneath the pavement due to moisture infiltration, or studded tires. Rutting is considered to be both a functional and structural distress type.

Block cracking divides the asphalt surface into approximately rectangular pieces. The blocks range in size from approximately 1 to 100 square feet. Block cracking is caused mainly by shrinkage / hardening of the asphalt binder and daily temperature cycling that results in daily stress / strain cycling. The occurrence of block cracking usually indicates that the asphalt has hardened significantly. Block cracking is not a load associated distress although load can increase the severity of block cracking. Low tensile strength asphalt mixture also accelerates the initiation of block cracking. Wider and spalled cracks cause higher pavement roughness and lower structural integrity. Block cracking normally occurs over a large portion of the pavement area, but sometimes it may occur only in non-traffic areas. It is considered to be both a functional and structural distress type.

1.8 Functional Distresses - Are related to accessibility, ride quality, and safety issues and can usually be corrected by a thin surface treatment. In general, proactive treatment applications applied at varying times will result in varying costs and pavement performance. The benefits and costs of the treatment are tied to the condition and rate of deterioration of the pavement at the time the treatment was applied. Examples of functional distresses include bleeding, corrugation, depressions, longitudinal and traverse cracking, polished aggregate, and lane-shoulder drop off.

Bleeding is a film of bituminous material on the pavement surface, creating a shiny, glass like, reflective surface that usually becomes quite sticky. Since the bleeding process is not reversible during cold months, asphalt will accumulate on the surface. Bleeding is caused by an excessive amount of the asphalt cement in the mix and / or low air void content. High temperatures cause the asphalt to expand filling up the voids first and then flushing to the pavement surface. It should be recognized that traffic loads may cause increased densities (lower air voids) in the wheel path of the AC course, thereby enhancing asphalt bleeding.

Bleeding may occur anywhere on the pavement surface. If traffic loads are causing additional compaction (densification) of the asphalt course, then bleeding could be more severe in the wheel path than in any other location. Asphalt bleeding is considered a functional distress. Bleeding areas have lower friction (skid resistance), which is considered a safety hazard.

Corrugation is a form of plastic movement of the asphalt surface typified by ripples across the pavement surface. They occur in areas where vehicles accelerate (start) and / or decelerate (stop) and are more pronounced in the proximity of the wheel path. Corrugation may be caused by lack of stability of the asphalt mix, especially at high temperatures, excessive moisture in the roadbed soil, contamination of the asphalt mix, low air voids, high asphalt content, or a combination of the above causes.

Depressions are localized pavement surface areas having elevations slightly lower than those of the surrounding pavement. In many instances, light depressions are only noticeable after rain, when trapped water creates "birdbath" areas. Depressions can be caused by time-dependent settlement of the foundation soil or can be "built-in" during construction. Hence, depressions could be located anywhere along the pavement surface.

Longitudinal cracks are parallel to the pavement's centerline or traffic direction, whereas **transverse cracks** extend across the traffic lane or lanes. The two types of cracks are not caused by traffic loadings, although load and moisture accelerate their propagation. Longitudinal cracks may be caused by a poorly constructed paving lane joint, whereas longitudinal and transverse cracks may be caused by shrinkage of the asphalt pavement surface due to low temperatures or hardening of the asphalt binder, reflective cracking in the lower asphalt courses, segregation in the asphalt layer, or settlement of material in utility trenches.

Low temperatures cause high tensile strains in the pavement surface. Under these conditions, the cracks will start at the top (where temperature is colder) and propagate toward the bottom of the asphalt layer. Segregation lowers the tensile strength of the asphalt course, which increases the potential for top-down cracking. In contrast, reflective cracks or cracks due to settlement of the material in utility trenches start at the bottom of the asphalt layer and propagate upward.

Polished aggregate lowers the pavement's skid resistance and occurs when aggregate is worn due to traffic. Polishing, which occurs mainly in the wheel paths, is caused by the presence of soft aggregates in the asphalt mixture combined with repeated traffic loadings.

Severity for polished aggregate is undefined. The degree of polishing can be determined by conducting skid resistance tests. Areas with polished aggregates are measured in square feet or square meters. Polished aggregate can be detected both by visual observation and tactilely, by running the fingers over the polished surface.

Lane-shoulder drop off is a difference in elevation between the traffic lane and the shoulder. If the shoulder is at a lower elevation than the adjacent traffic lane, it signifies settlement or pumping of the material from underneath the shoulder. If the shoulder is at higher elevation than the traffic lane, it signifies heaving of the shoulder due to frost action or swelling soils. Hence, lane-shoulder drop off is not caused by traffic loading and is a serious safety concern.

1.9 Ride Quality – Often ride quality is considered only a measure of comfort experienced by the driver and passenger, but it is also related to good braking and acceleration. Over time, poor ride quality can adversely affect driver safety, fuel efficiency, vehicle wear and tear, and pavement durability.

The International Roughness Index (IRI) provides an accepted method for judging the ride quality of roadway pavements. The lower the IRI value, the flatter the paved profile. For example, an IRI of 0.0 inch/mile relates to a perfectly flat profile. There exists no upper limit on IRI, but in practice, IRI values above 220 in/mi are poor-riding pavements. Ride is reported every 1/10 mile and should be computed in accordance with AASHTO Standard R43-07 on Standard Practice for Determination of International Roughness Index for Quantifying Roughness of Pavements.

In general, the pavement condition thresholds for ride quality (IRI) are:

Good	less than 95 inches/mile
Fair	95 to 170 inches/mile (*Note: in urban areas, the threshold is relaxed to 220 in/mi*)
Poor	greater than 170 inches/mile (*Note: in urban areas, greater than 220 in/mi*)

Pavements with unsatisfactory ride characteristics cannot be corrected with a thin surface treatment. If the ride is rough before a thin surface treatment it will remain rough after the treatment is applied.

In recent years, micro milling has become an accepted method of milling pavement due to its ability to improve ride quality. It is frequently used in combination with thin surface treatments to improve the unsatisfactory ride quality prior to treatment placement.

Micro milling should not be confused with standard milling or fine milling. Micro milling is limited to around one-inch in depth for a single pass and has a lower production rate than other types of milling. The finished pavement texture is smooth with good friction characteristics and a quiet riding surface. A forward operating speed of 20 to 30 feet per minute is common for a micro milling machine.

SESSION 2: MATERIALS

2.1 Composition of Slurry Systems

The slurry systems materials include emulsified asphalt, water, aggregate, Portland cement or other approved mineral filler and additives. However, slurry seals and micro surfacing use significantly different emulsified asphalt.

2.2 Emulsified Asphalt

Significant advantages of emulsified asphalt compared with hot asphalt and cut-back binders, are the lower application temperatures, compatibility with other water-based binders like rubber latex and cement, and low-solvent content. The properties of the emulsion components, including the asphalt binder, emulsifiers, acids or alkalis, and other additives, determine the physical properties and reactivity of the emulsion.

Emulsifiers

Emulsifiers are surface active agents (surfactants) that interface between oil (asphalt) and water. The choice and concentration of emulsifier largely determines the charge on the asphalt droplet and the reactivity of the emulsion produced. Emulsifiers can be classified into anionic (-), cationic (+), or nonionic (not ionizing in water solutions) charges. As the concentration of the emulsifier increases, the particle size of the emulsion is reduced. Slow setting (SS) emulsions, which contain higher concentrations of emulsifier, generally have smaller particle size than Rapid setting (RS) grades. The three principal roles of emulsifiers are shown in Figure 2-1.

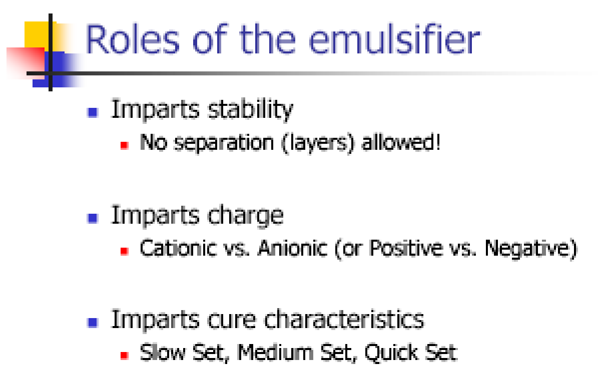


Figure 2-1 Roles of the Emulsifier

Emulsion Manufacturing

To make an asphalt emulsion, the asphalt is dispersed into tiny droplets by running it through a colloid mill along with a soap solution as illustrated in Figure 2-2. The mill contains a rotating part (called a rotor) and a stationary part (called a stator) with a very small gap between the two through which the asphalt and emulsifier solution are forced. It is in this area that the asphalt is sheared into droplets which are stabilized by the emulsifier molecules. The finished emulsion is stored in a vertical tank.

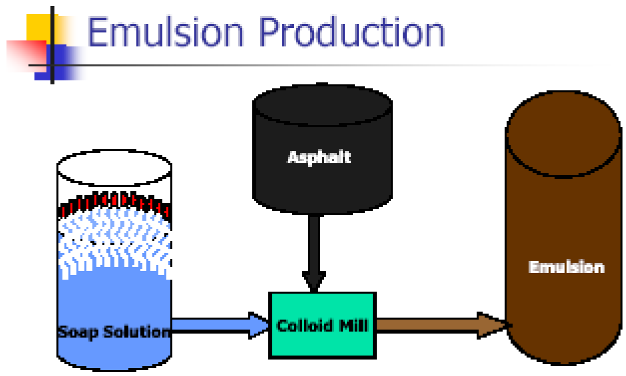


Figure 2-2 Emulsion Production

Asphalt Chemistry
Some asphalt may have components that are hard to emulsify while other asphalt may require more emulsifier than another to get the same particle size. For hard to emulsify asphalts, adding some of the emulsifier to the asphalt may help to make a better emulsion. The study of asphalt chemistry goes well beyond the scope of this session.

Emulsions in Slurry Systems
Slurry seal technology has evolved over the years from using slow-setting anionic emulsions to very rapid cure systems based on the use of cationic emulsions. Today's slurry seals may or may not include polymer modification. Slurry technology derives its success from the development of appropriate emulsions, newer equipment, and additive systems. These technologies combine with well-defined aggregate characteristics to ensure production of a mix that resists raveling.

Micro surfacing emulsions are specially formulated cationic emulsions designed to work with aggregate in a specific composition. The emulsion is formulated tothe aggregate to produce a mix which is designed to ensure against rutting, raveling, bleeding, or premature aging. Micro surfacing emulsions are always highly polymer modified.

The importance of having a proper mix design for a slurry seal or micro surfacing cannot be overstated.

Asphalt Emulsion Classifications
Asphalt emulsions are classified according to the charge on the droplets and according to their reactivity. Cationic emulsions have droplets which carry a positive charge. Anionic emulsions have negatively charged droplets.

Rapid-setting (RS) emulsions set quickly in contact with clean aggregates of low-surface area, such as the chippings used in chip seals (surface treatments).

Medium-setting (MS) emulsions set sufficiently less quickly that they can be mixed with aggregates of low surface area, such as those used in open-graded mixes. Slow-setting (SS) emulsions will mix with reactive aggregates of high surface area. RS emulsions are reactive and are used with un-reactive aggregates; SS emulsions are un-reactive and are used with reactive aggregates. The actual setting and curing time in the field will depend on the technique and materials being used as well as the environmental conditions.

In naming emulsions according to ASTM D977 and D2397, cationic RS, cationic MS, and cationic SS emulsions are denoted by the acronyms CRS, CMS, and CSS, whereas anionic emulsions are called RS, MS, and SS, followed by numbers and text indicating the emulsion viscosity and residue properties. For example, SS-1H would be a slow-setting (i.e., low reactivity) anionic emulsion with low viscosity and a hard asphalt residue. CRS-2 would be a reactive cationic emulsion of high viscosity.

Micro surfacing emulsified asphalts are CQS-1P or CQS-1hP. These emulsions must meet the requirements of AASHTO Standard Specification M 316.

The QS (quick-setting) and CQS (cationic quick-setting) designations for quick-setting emulsions have been introduced for emulsions intermediate in reactivity between MS and SS, which do not need to pass the cement mix test, and are used primarily in quick-set slurry surfacing applications. Typical asphalt emulsion grades are shown in Table 2-1.

Grades	Anionic	Cationic
Rapid Setting	**RS-1**	**CRS-1**
	RS-2, RS-2P, S	**CRS-2, CRS-2P.M,L**
	HFRS-2	**HFRS-2P**
Medium Setting	**MS-2, MS-2h**	**CMS-2**
	HFMS-2 (AE-200)	**CMS-2s**
	HFMS-2s	
Slow Setting	**QS-1, SS-1**	**CQS-1P, CSS-1**
	SS-1h	**CQS-1hP, CSS-1h**
	AE-T	**CSS-1hL, CSS-1hM**
	AE-P, AE-PL	

Table 2-1 Asphalt Emulsion Grades

Local authorities have many other naming schemes associated with emulsions containing particular properties. In state DOT specifications, letters such as P or LM may indicate polymer-modified or latex-modified asphalt emulsion, S may indicate high solvent content, and terms such as AEP (asphalt emulsion prime), PEP (penetrating emulsion prime), and ERA (recycling agent emulsion) may indicate emulsions with specific uses.

2.3 Mix time

A more stable emulsion, such as SS, gives more mix time, but will also result in longer cure times. Keeping this in mind, it is preferable to design a system for the minimum acceptable mix time. Consequently, the required mix time should not be much greater than that needed for mixing at the pugmill plus a little more for the mixture to enter the spreader box and be applied to the roadway. It may be necessary to add a few more seconds to feather a joint, but because extensive amounts of hand work are not needed in this case, the added mix time would be minimal.

2.4 Mineral Fillers

The purpose of mineral fillers is to assist the emulsion break and help set the cure time. Typical composition is 0 to 3 percent by dry weight of aggregate and may be considered part of the aggregate gradation. Mineral fillers must comply with the AASHTO Standard Specification M 17.

Portland Cement

In most slurry surfacing and micro surfacing, Portland cement is used as a mixing aid allowing the mixing time to be extended and creating a creamy consistency that is easy to spread. Additionally, hydroxyl ions counteract the emulsifier ions, resulting in a mix that breaks faster with a shorter curing time. Cement also has a fine consistency and, as such, absorbs water from the emulsion, causing it to break faster after placement. Fine materials promote cohesion of the mixture by forming a mortar with the residual asphalt. Refer to the AASHTO Standard Specification M 85.

Fly Ash

When fly ash is used as filler it is important that tests be conducted to ensure that it is compatible with the emulsion - sometimes it is not. Some contractors are of the opinion that using more than 1% fly ash will significantly reduce skid resistance due to the hard rounded surfaces of the fly ash particles. Hydrated lime also can be used as filler. Refer to the AASHTO Standard Specification M 295.

Others

Hydrated lime and limestone dust are sometimes used in particular slurry systems. Refer to AASHTO Standard Specification M 303.

2.5 Curing

Some of the more obvious factors that affect the curing rate of the mat are water content, system mix time, emulsion pH, and emulsion particle size. Figure 2-3 shows the principal factors affecting curing.

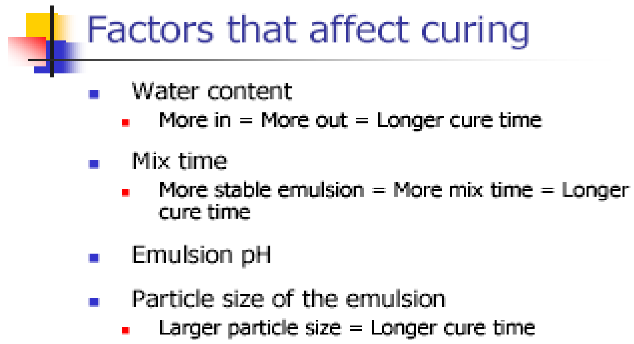


Figure 2-3 Factors Affecting Curing

2.6 Polymers and Polymer Modified Binders

Polymers are large molecules that enhance the properties of virgin asphalt. Depending on the basic polymer units or monomers used, a wide range of properties can be achieved. It is possible to categorize polymers in a number of ways: glassy (stiffness) or rubbery (elastomeric) properties. Often this is termed plastomeric or elastomeric. Plastomers will deform but will not return to their original dimensions when the load is released. Elastomers will deform and return to their original dimensions when the load is released. However, this is very dependent on conditions such as temperature, rate of loading and strain level.

The selection of polymer modification should almost always be based on improved performance related to cost. Although there are a substantial number of polymers in use today for a variety of products, only a relative few are commonly used in asphalt mixtures. Examples of polymers commonly used in asphalt mixtures include:

- Styrene Butadiene Copolymer (radial and linear) (SBS)
- Styrene Butadiene Rubber (SBR)
- Polybutadiene (PB)
- Polyethylene (PE)
- Ethylene Vinyl Acetate (EVA)
- Ethylene Methyl Acrylate (EMA)
- Atactic Polypropylene (PP)
- Epoxies and Urethanes
- Crumb Tire Rubber

2.7 Additives

Additives may be added to the emulsion mix or any of the component materials to provide the control of the quick-traffic properties. They must be included as <u>part of the mix design</u> and be compatible with the other components of the mix. They act as retardants to the reaction with emulsions, either as a prophylactic that slows the emulsifier's access to the aggregate surface, or by preferentially reacting with the emulsifier in the system. Other additives include emulsifier solutions, aluminum sulfate, aluminum chloride, and borax. Generally, increasing the concentration of an additive slows the breaking and curing times. This is useful when temperatures increase during the day.

2.8 Aggregates

Different types of aggregate are better suited to certain binders as a result of electrostatic charges. Basically, the binder and aggregate must have opposite charges. If this is not true, the binder will not form a strong bond with the aggregate, and it will ravel. In addition, porosity and the presence of water also affect binder-aggregate compatibility. Aggregate, which is quite porous, will actually lead to excessive absorption of the binder. Loss of aggregate shortly after construction is indicative of poor adhesion between the binder and aggregate.

Like most things in nature, most aggregates are negatively charged, with limestone being the exception - it is positively charged. Figure 2-4 shows the relative charges of the principal aggregates.

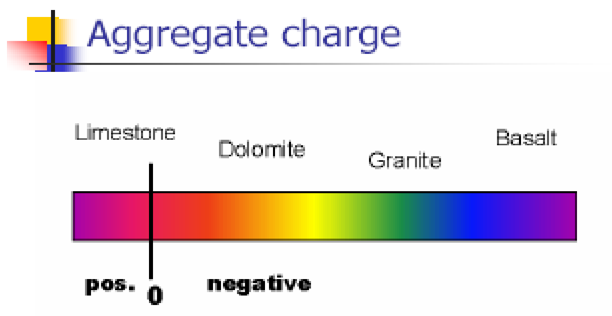


Figure 2-4 Aggregate Charge

Slurry Seal Aggregates

When tested in accordance with AASHTO T 27 and AASHTO T 11 *(Sieve Analysis of Fine and Coarse Aggregates)*, the target (mix design) aggregate gradation (including the mineral filler) must be within one of the following gradation bands: The Type I slurries contain the finest material and are used for lightly trafficked roads or parking lots. Type II slurries are coarser and are suggested for reducing raveling and oxidation on roadways with moderate to heavy traffic volumes. Type III slurries have the coarsest material and are appropriate for filling minor surface irregularities, correcting raveling and oxidation, and restoring surface friction. Type III slurries are typically used on arterial streets and highways. The gradation for each type is listed in Table 2-2.

Sieve Size	Percentage Passing		
	Type I	Type II	Type III
3/8 (9.5mm)	100	100	100
# 4 (4.75 mm)	100	90-100	70-90
# 8 (2.36mm)	90-100	65-90	45-70
# 16 (1.18mm)	65-90	45-70	28-50
# 30 (600-µm)	40-65	30-50	19-34
# 50 (330-µm)	25-42	18-30	12-25
# 100 (150 -µm)	15-30	10-21	7-18
# 200 (75-µm)	10-20	5-15	5-15

Table 2-2 Slurry Surfacing Aggregate Gradations

The role of fines (i.e., aggregate particles passing the #200 sieve) in all slurry system mixes is to form a mortar with the residual asphalt to cement the larger stones in place. The fines content is essential for creating a cohesive hard-wearing mix. The general aggregate quality requirements are listed in Table 2-3.

Test	Slurry Seal Type			Test # and Purpose
	I	II	III	
Sand Equivalent (min)	45	45	45	ASTM D 2419

Table 2-3 General Aggregate Requirements

Micro Surfacing

Three gradations are specified for micro surfacing: Type I, Type II and Type III. The primary difference among these gradations is the aggregate top size. This dictates the amount of residual asphalt required by the mixture and the purpose for which the micro surfacing is most suited. The Type I micro surfacing is the finest and is used for lightly trafficked roads or parking lots. Type II micro surfacing is coarser and is suggested when raveling and oxidation are present on roadways with moderate to heavy traffic volumes. Type III micro surfacing has the coarsest grading and is appropriate for filling minor surface irregularities, correcting raveling and oxidation, and restoring surface friction. Type III micro surfacing is typically used on major arterial streets and highways. The gradations are listed in Table 2-4.

Sieve Size	Percentage Passing			
	Type I	Type II	Type III	Stockpile Tolerance
3/8 (9.5mm)	100	100	100	-
# 4 (4.75 mm)	100	90-100	70-90	± 5%
# 8 (2.36mm)	90-100	65-90	45-70	± 5%
# 16 (1.18mm)	65-90	45-70	28-50	± 5%
# 30 (600-µm)	45-65	30-50	19-34	± 5%
# 50 (330-µm)	25-42	18 - 30	12 - 25	± 4%
# 100 (150-µm)	15 - 30	10 - 21	7 - 18	± 3%
# 200 (75-µm)	10 - 20	5-15	8-15	± 2%

Table 2-4 Micro Surfacing Aggregate Gradations

Recent work suggests that the distribution of the fraction passing the #200 sieve is critical to control the reaction rate in micro surfacing emulsions. The general aggregate quality requirements for all slurry systems are listed in Table 2-5.

Test	Micro Surfacing	Slurry Seal Type			Test # and Purpose
		I	II	III	
Sand Equivalent (min)	65	45	45	45	AASHTO T 176
Soundness (max loss)	25%	n/a	n/a	n/a	AASHTO T 104 (Magnesium Sulfate: 4 cycles)
L.A. Abrasion Resistance	30% max	35%	35%	35%	AASHTO T 96 (loss at 500 rev)
Crushed Particles	100%	n/a	n/a	n/a	ASTM D 5821

Table 2-5 Aggregate Requirements

Physical Properties of Aggregate
Key physical characteristics considered in all slurry system mixes are:

- Geology - determines the aggregate's compatibility with the emulsion along with its adhesive and cohesive properties,
- Gradation - particle size distribution,
- Shape - aggregates with fractured faces form a needed interlocking matrix, whereas rounded aggregates result in poor mix strength,
- Texture – a rough surface bonds more easily with emulsions,

- Cleanliness – deleterious materials including clay, dust, or silt can cause poor cohesion and adversely affect reaction rates,
- Soundness and Abrasion Resistance - are particularly important in areas that experience freeze-thaw cycles or are very wet, and
- Reactivity - recently crushed aggregates have a higher surface charge than aged aggregates. Surface charge has a primary role in reaction rates.

Water Quality
The water should be potable and free of harmful soluble salts or reactive chemicals and any other contaminants.

SESSION 3: DESIGN

3.1 Introduction (Designing a Job Mix Formula)

The performance of slurry and micro surfacing depends on the quality of the materials and how they interact during and after cure. The mix design procedure looks at the various phases of this process, which include the mixing, breaking and curing, and finally, performance.

3.2 Materials

The use of lesser quality local aggregates is generally based solely on availability and cost. Use of aggregates with a low initial cost may not be cost effective in the long run. The use of higher quality, but more expensive aggregates may be justified by the benefits accrued in extended service life. The cost implications of using the higher grade aggregate in conjunction with the appropriate binder type should be carefully assessed, not on the myopic basis of intial cost, but using life cycle cost analysis.

Pre-screening

Pre-screening involves testing the physical properties of the raw materials. The emulsion type is selected based on job requirements and is checked against the requirements laid out in the specifications, as shown in Table 3-1.

TEST	TYPICAL SPECIFICATION	METHOD
Residue	62% min	AASHTO T 59
Sieve Content	0.3% max	AASHTO T 59
Viscosity @ 25°C, SSF	15-90	AASHTO T 59
Stability (1 day)	1% max	ASTM D244
Storage Stability (5 days)	5% max	ASTM D244
Residue pen @ 25°C	40-90	ASTM D244
R&B SP, °C	57 min	AASHTO T 53
Torsional Recovery	18% min LMCQS-1h)	AASHTO T 59
Polymer Content	2.5% min (LMCQS-1h)	State Test Method

Table 3-1 Emulsion Properties for Polymer Modified Cationic Slurry Quick Set

The aggregate is checked against the agency's specifications and a simple mixing test is performed to assess compatibility with the emulsion. When both of these steps have been completed, the job mix formula can be developed. During the overall process, the materials may be changed at any time until satisfactory results are obtained.

3.3 Job Mix Design

Each slurry system component, including aggregate, emulsion, water, and additives, must meet all specifications and test requirements. A job mix formula is designed for compatibility and performance characteristics under simulated wear conditions.

Sand Equivalent

Refer to AASHTO T 176, Plastic Fines in Graded Aggregates and Soils by Use of Sand Equivalent Test

This test serves as a rapid field-correlation test to show the relative proportions of plastics (clays) and fine dust in granular soils and graded aggregates that pass the 4.75-mm (No. 4) sieve. Higher sand equivalent values indicate cleaner aggregate.

Mixing Proportions

Refer to ISSA Technical Bulletin 113, Test Method for Determining Mix Time for Slurry Surfacing Systems

This test determines the approximate proportions of the slurry mix components. A matrix of mix recipes is prepared and hand mixed. The mixing time is recorded for each mixture. A minimum time is required to ensure that the mixture will be able to mix without breaking in the placement machine. At this stage, phenomena such as foaming and coating are visually assessed and the water and additive contents required to produce a quality mixture can be determined. Figure 3-1 illustrates a good slurry mixture consistency.

Figure 3-1 Good Mixture Consistency

The mixing time must be at least 180 seconds for a slurry seal at 25°C (77°F). The mixing time must be 120 seconds for a micro surface at 25°C (77°F). The process may be repeated at elevated or reduced temperatures to simulate expected field conditions at the time of application. Aggregate coating is the criterion used to select the best mix from candidates with mixing times at least as long as the minimum time required through the range of expected application temperatures.

Cohesion Buildup
Refer to ISSA TB 139, Test Method to Determine Set and Cure Development of Slurry Surfacing Systems by Cohesion Tester

After the emulsion content has been determined, three mixes are made, one at the selected emulsion percentage from above, one at 2% less than the selected emulsion content and one at 2% more than the selected emulsion content. This allows a bracketing of the desired mix proportions. This test may be performed at the expected field temperatures to provide the most accurate estimate of the treatment's characteristics. Table 3-2 lists mix requirements for slurry and micro surfacing.

PROPERTY	TEST	SLURRY SEAL	MICRO SURFACING
Wear Loss (Wet Track Test)	TB 100 (1 hr soak) (6 day soak)	807 g/m^2 max N/A	538 g/m^2 max 807 g/m^2 max
Traffic Time (Wet Cohesion Test)	TB 139 (30 minutes) (60 minutes)	0.12 kg-m min 0.2 kg-m min	0.12 kg-m min 0.2 kg-m min
Adhesion (Wet Strip) Integrity SB	TB 114 TB 144	>90% N/A	>90% 11 Grade Points min
Excess Binder	TB 109	538 g/m2 max	538 g/m^2 max
Lateral Displacement	TB 147		5 % max
Slurry Seal Consistency, mm	TB 106	30 max (slow set only)	N/A
Compatibility	TB 115	Pass	N/A

Table 3-2 Typical ISSA Mix Requirements

Abrasion Resistance (Wet Track Abrasion Test)
Refer to ISSA TB 100, Test Method for Wet Track Abrasion of Slurry Surfacing Systems

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

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

Wet Stripping
Refer to ISSA TB 114, Test Method for Wet Stripping of Cured Slurry Surfacing Mixtures

The purpose of this test is to aid slurry seal designers to select a compatible slurry system with a given aggregate. Emulsion formulations, fillers and additives may be quickly screened by the ability of the system to remain coated under the test condition.

Excess Asphalt
Excess asphalt in bituminous mixtures is tested by use of a loaded wheel tester and sand adhesion. The loaded wheel test is intended to compact fine aggregate bituminous mixtures such as slurry seal by means of a loaded, rubber tired, reciprocating wheel. The test may be used for design purposes to establish maximum limits of asphalt content and enable the mix designer to avoid severe asphalt flushing under heavy traffic loads. Various accessory measurements may also be made during this test to study compaction rates and plastic deformation of mono and multiple layered bituminous mixture specimens.

Wet Cohesion
Refer to ISSA TB 139, Test Method to Determine Set and Cure Development of Slurry Surfacing Systems by Cohesion Tester

This design test measures strength development of the micro surfacing mixture. Samples are cast into molds and tested after 30 and 60 minutes.

Schulze-Breuer
Refer to ISSA TB 144, Test Method for Classification of Aggregate Filler-Bitumen Compatibility by Schulze-Breuer and Ruck Procedures

The design test measures the relative compatibility between the fine component of the aggregate and the emulsion residue.

Upper Binder Limit
Refer to ISSA TB 147, Test Method for Measurement of Stability and Resistance to Compaction, Vertical and Lateral Displacement of Multilayered Fine Aggregate Cold Mixes

The upper binder limit is determined through the use of a deformation measurement. This deformation measurement is obtained by using a Loaded Wheel Tester (LWT). In this test, a loaded wheel is placed on a cured strip of the mixture and the surface is tested by a reciprocating motion that moves the wheel back and forth, simulating the effect of traffic. Once the surface has been tested, hot sand is poured onto the surface and the sample is then retested. When the second round of testing is complete, the amount of sand retained on the sample is measured. This provides a measure of the free asphalt on the surface of the sample.

Optimum Binder
Refer to ISSA TB 109, Test Method for Measurement of Excess Asphalt in Bituminous Mixtures by Use of a Loaded Wheel Tester and Sand Adhesion

The optimum percentage emulsion or binder content is found by plotting the results obtained from the Wet Track Test (TB 100) and the Excess Binder Test. Figure 3-2 illustrates a typical plot of test results. The optimum binder content is close to the intersection of the two plotted lines, but the testing does not account for all the factors influencing the mix. For example, the optimum binder content at the intersection of the plotted results is adjusted for the expected traffic conditions. A rule of thumb is to select the highest binder content that passes both tests for low traffic conditions, and the lowest binder content for heavy traffic conditions. It should be noted that this requires an experienced designer to select the optimum binder content and this must be based on field knowledge and experience. This is a weakness of the current design process.

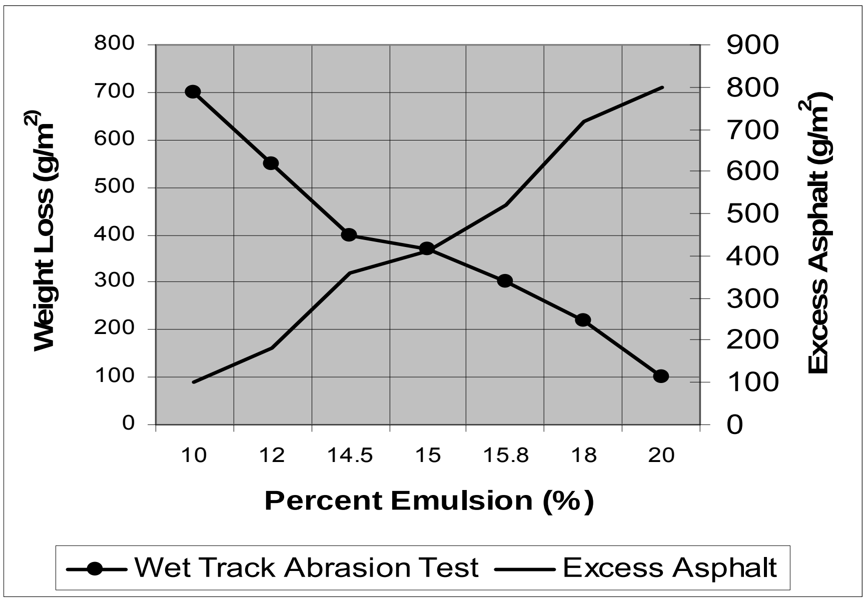


Figure 3-2 Determining Optimum Binder Content

3.4 Final Testing

Once the job mix components have been selected, the mix is tested to determine its properties and ensure compliance with the specifications listed in Table 3-2. If the mix conforms to the specifications, the emulsion content and aggregate grading are reported as the job mix formula.

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

3.5 Final Mix Design

Mix designs must be completed by a competent laboratory with specialized equipment and knowledgeable staff to perform the required tests. Knowing the relationship between material components is critical to the development of a good mix design. Each of the material components must meet all job specifications and test requirements. Individual materials must be qualified through testing before the laboratory will perform further tests to determine the mix compatibility and performance under simulated wear conditions.

The percentage of each individual material required must be identified in the laboratory mix design. A typical mix design letter is shown in Figure 3.3.

Company Letterhead

Date: April 1, 20XX

RE: Type III CQS-1HP Microsurfacing Mix Design

Dear ____________________,

As requested, *Testing Company Name* prepared a job mix formula according to ISSA accepted testing procedures using Type III aggregate from *Company Name*, *Quarry Name*, and the following emulsion CQS-1HP from *Company Name*, *Terminal Name*.

The job mix formula based on the data from the laboratory tests is reported as follows. All values are based on dry aggregate weight.

CQS-1HP:	12.0 ± 1.0 %
Water:	5.0 - 9.0%
Cement:	0.5 - 1.0%
Residual Content of Emulsion:	62.4%
Residual AC Content:	7.4 ± 0.6 %

Test results summarized in this report represent laboratory conditions only. The laboratory tests were performed on materials submitted to this laboratory using accepted procedures. As always, laboratory and field conditions vary significantly due to fluctuations such as temperature and moisture. Care should be taken to adjust material percentages to compensate for any changes.

Sincerely,

John Smith, Chief Chemist

Figure 3-3 Required Slurry System Mix Design

In addition to the mix design letter, the contractor should submit the original laboratory report covering all the specific tests conducted on the materials planned for use on the project. If material sources should change for any reason, placement work must stop and a new mix design would be required.

Field Adjustments for Climatic Variables

It is important to maintain an adequate break (curing) time. As the break is accelerated with rising temperature, it may be necessary to use chemical additives to retard the break when the temperature exceeds 80°F. The contractor must report field changes to the agency.

Field Verification Testing and Sampling

Aggregate and emulsion samples are taken from the stockpile and emulsion tank, respectively. Tests conducted on these samples are for verification rather than control.

3.6 Estimating

Project estimating is an important aspect of project design. Proper estimating avoids cost overruns and project completion delays.

Quantities

Figure 3-4 shows estimated quantities of micro surfacing material to correct rutting.

MICRO SURFACING

Rut-filling Application Estimate Sheet

Average Rut Depth (inch)	Rut-fill (lb/yd^2)
0.50 – 0.75	20 -30
0.75 – 1.00	25 -35
1.00 – 1.25	28 - 38
1.25 – 1.50	32 - 40

To calculate quantities for the pay item Micro Surface, Rut-filling, use these application rates to determine the amount of material required to fill each wheel path (half of the lane). Then add to it the surface course quantity. This total quantity is then the estimated "dry weight" tonnage for Micro Surface, Rut-filling.

Figure 3-4 Micro Surface – Rut Filling

For every inch of micro surfacing mix, add ⅛ inch to ¼ inch as a crown to allow for compaction under traffic.

Production Rates

Figure 3-5 shows typical daily production rates for micro surfacing and slurry seals. For comparative purposes, the figure also shows typical production rates for overband crack filling.

DAILY PRODUCTION RATES

MICRO SURFACING AND SLURRY SEAL
2 mile closure (3.2 kilometer closure)

1. **STANDARD APPLICATIONS:** 30 lb/yd^2 - 2 courses
   a. Truck Mounted Machine (2 trucks) : 1.25 lane-miles/day
   b. Continuous Machine:
      1. 2-lane roadway : 4 lane-miles/day
      2. Multi-lane roadway : 4 lane-miles/day

2. **RUTFILLING -WHEEL TRACKS**
   a. Truck Mounted Machine (2 trucks) : 125-150 tons/day
   b. Continuous Machine:
      1. 2-lane roadway: 250 - 350 tons/day
      2. Multi-lane roadway: 350 - 450 tons/day

3. **RUTFILLING -SURFACE APPLICATION:** 20lb/yd^2 -1 course
   a. Truck Mounted Machine (2 trucks) : 2.0 lane-miles/day
   b. Continuous Machine:
      1. 2-lane roadway: 4.5 lane-miles/day
      2. Multi-lane roadway: 6 lane-miles/day

4. **OVERBAND CRACK FILLING**
   20,000 ft/day -- 5,000 lb/day

Figure 3-5 Daily Production Rates

SESSION 4: EQUIPMENT AND CALIBRATION

4.1 Placement Machines

Slurry seal and micro surfacing placement machines can be used to place either slurry seal or micro surfacing. They exhibit ample horsepower to drive a dual-shaft, multi-paddle pugmill for thorough mixing of materials.

The truck mounted paver is generally used on smaller sized projects and in locations where maneuverability is needed. Truck mounted pavers are manufactured in various sizes with different material capacities. A typical truck mounted paver is shown in Figure 4-1.

A continuous run paver is ideal for large jobs where high production is needed. Continuous run slurry seal and micro surfacing paver reduces the number of construction joints by receiving a constant supply of material while the machine is working, as shown in Figure 4-2.

Figure 4-1 Truck-Mounted Machine

Figure 4-2 Continuous Run Machine

Trailer-mounted, slurry seal and micro surfacing pavers are sometimes used on medium to large sized projects. They can offer good maneuverability when used with short-wheelbase trucks.

4.2 Spreading Equipment

The slurry system equipment industry offers many spreader box designs to address most any application. In general, a slurry seal box is dragged behind the paving machine by chains and may or may not have augers. A micro surfacing spreader box is solidly attached to the paving machine and will have two rows of augers and a texturing strike-off for finishing the surface.

Spreader Boxes

Spreader boxes have five functions:

- Receive and contain the slurry or micro surfacing mix from the slurry machine,

- Evenly distribute the material across the paving width of the box,
- Further agitate the mixtures when necessary,
- Meter the material onto the road surface, and
- Apply the final texture to the road surface.

Figure 4-3 shows a schematic drawing of a typical micro surfacing spreader box. The augers at the rear of the box take the material to the outside of the box, while the front augers bring the excess material back to the center.

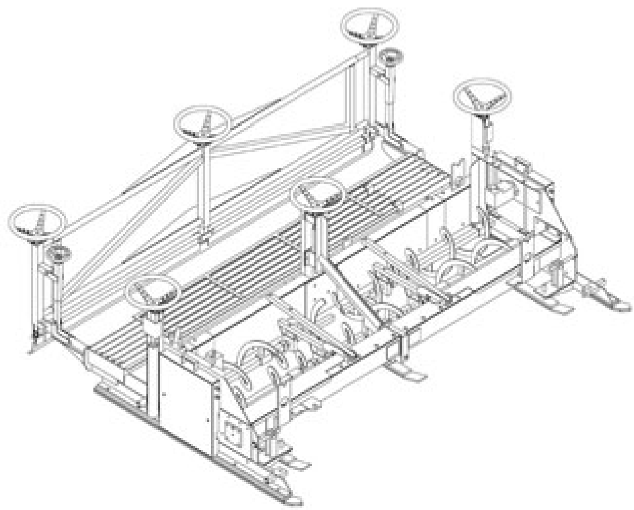


Figure 4-3 Spreader Box Schematic

The augers not only distribute the mix, but also keep it moving to prevent it from breaking inside the box. There is no 'dead space' because the augers cover the entire volume of the box so there is nowhere for the mix to be stationary and start to break. The optimum material level in the spreader box should be approximately half full.

Some spreader boxes are manually adjustable to widths up to 16 feet. A variable width spreader box is hydraulically adjusted by valves located on the spreader box to change the width while paving. In addition, modern spreader boxes can change the pressure of the primary and secondary strike-offs.

There are rubber or urethane strips at the front and rear of the spreader box to contain the mix. Rubber strips are also frequently used on the ends of slurry seal spreader boxes since a slurry seal is very fluid. On micro surfacing boxes, the skis riding on the road surface contain the mix on the ends of the spreader box. The primary strike-off presses downward and meters the material onto the road surface as the box moves forward. The secondary strike-off is optional, but when it is used, its function is to smooth out the final surface by removing ripples, minor drag marks, and apply the final texture.

Rut-filling Box
Special boxes are used for rut filling applications when filling ruts greater than 0.5 inch deep. When filling ruts less than 0.5 inch deep, a steel strike-off box is used for the scratch courses. Rut boxes are available in 5-foot and 6-foot widths.

Figure 4-4 shows a rut-filling box. The micro surfacing material drops into the compartment defined by the containment screed and the front of the rut box. Augers distribute the material along the containment screed walls. The containment wall meters the micro surfacing into the chamber between the shaping screed and the containment screed. As the rut gets deeper, the operator turns the appropriate steering wheel and the center of the shaping screed rises to add the appropriate amount of crown to the center of the rut. Since the shaping screed pivots at the front of the rut box, very little material is deposited along the edges of the rut. The containment screed can also be adjusted up and down as required to ensure adequate amounts of micro surfacing are in front of the shaping screed.

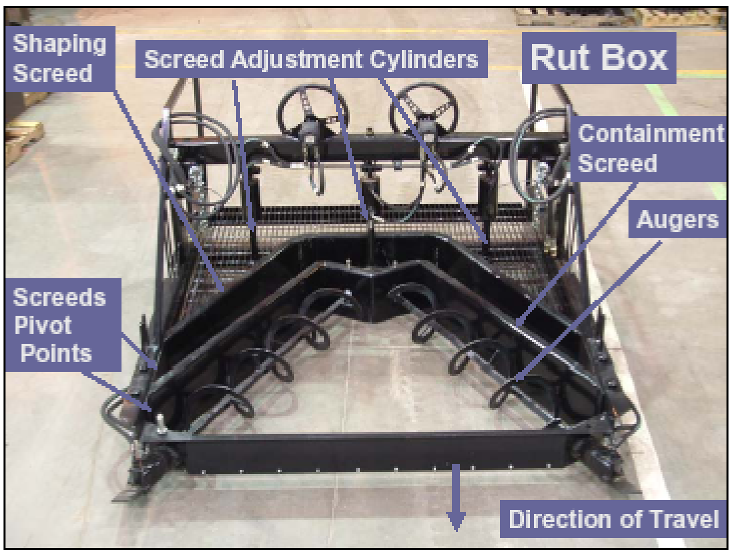


Figure 4-4 Rut-Filling Box

Edge Boxes
Adjustable width edge boxes are used for shoulders and to create clean joints between shoulders and the traveled way.

Strike-Offs
One of the potential problems associated with slurry seal and micro surfacing work is a drag mark. A drag mark occurs when an oversize aggregate particle becomes lodged under the lay down box strike-off plate and, while being pulled along with the placement machine, leaves a furrow in the surface.

A secondary strike-off is a device to correct drag marks, shown in Figure 4-5. It improves the surface texture and surface cosmetics. The secondary strike-off mounts directly behind the lay down box primary strike off and is in contact with the fresh mix. It will remove most surface imperfections without requiring someone to remove them with a hand tool. The secondary strike off does not remove the cause of the drag mark which still must be removed by hand. It does, however correct the imperfections in the surface while the oversized aggregate is removed.

Figure 4-5 Secondary Strike-Off

4.3 Support Equipment

Every successful slurry systems project needs the proper support equipment. As a minimum, the project staging area should have a:

- Front-end Loader,
- Tanker for emulsified asphalt,
- Tanker for additive,
- Tanker for water (unless a potable water supply is available), and
- Portable scalping screen

The staging area is a location where the aggregate is screened, weighed, and loaded onto trucks for delivery to the placement machine(s). A good practice is to screen the aggregate to remove any oversize particles and contaminates before it is loaded onto trucks. This should be done even though the selected aggregate is crushed screened material.

Mobile Support Units

The mobile support unit brings aggregate, asphalt emulsion, and water to a full-size continuous run (slurry seal / micro surfacing) paver. These units assure a continuous flow of materials for increased production rates and more consistent texture quality. A mobile support unit has a storage tank on each side of the trailer for delivering asphalt emulsion and water to the continuous placement machine and a conveyor system for delivering the aggregate, without lifting the trailer bed.

On longer projects, it is advisable to use several mobile support units to ensure the materials flow on a continual basis to the continuous run placement machine to maintain production. Figure 4-6 shows mobile support units.

Figure 4-6 Mobile Support Units

Sweepers

The main sweeping task on a slurry systems project is to clean the existing road surface of dust and foreign materials prior to placement. Three different types of sweeping equipment are typically used in slurry systems construction: rotary (kick) brooms, pick-up sweepers, and vacuum brooms.

Mobile pick-up brooms and vacuum sweepers are similar in that they both "remove" the dust and debris from the roadway. Both sweepers have hoppers to store the removed material. It is the manner in which they remove the dust and debris that distinguishes them from each other.

4.4 Calibration

Since laboratories perform tests on mix designs with precise ratios, these ratios also need to be reproduced in the field. This is achieved using precise controls and a calibration process. In this way, the contractor can determine exactly the ratios of material going into the mix, to recreate the mix design that was tested in the laboratory. The end result is better quality control of the mix being applied on the project.

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

Relation of Mix Design to Calibration
Calibration is a process in which the actual output of the machine is measured by weight for aggregate, emulsion and fines. These actual outputs are correlated to the revolutions of the aggregate belt because the laboratory specifies all material ratios by weight to the amount of aggregate. The required correlation is achieved with the use of counters.

After being calibrated, the paver can be set to deliver precise ratios of emulsion to aggregate, and fines to aggregate, as specified in the mix design from the laboratory. By doing this, the contractor and agency know what they can expect from the mix being applied, because of the laboratory tests that have been performed on a mix with the same ratios. Calibration also assists payment calculations by providing a precise record of the amount of materials that were applied on the project.

The mix design formulated by the laboratory specifies the amount of emulsion as a percentage (by weight) of the amount of aggregate. It also specifies the amount of fines as a percentage (by weight) of the amount of aggregate. For example, a 10% mix design for emulsion requires that for every 10 units of weight of aggregate delivered to the pugmill, one (1) unit weight of asphalt emulsion must also be delivered to the pugmill. If a mix design calls for 1.5% fines, for every 10 units of weight of aggregate delivered to the pugmill, 0.15 units of weight of fines (cement or lime) must also be delivered to the pugmill.

Counters
The feed rates are tracked with counters, which are also called totalizers. The function of a counter is to count the revolutions of a shaft, pulley, or sprocket. In some applications, the counter counts fractions of a revolution. For example, a counter could register three counts per revolution of a shaft. In another application with a different counter design, a counter may register 30 counts for each revolution. The number of counts registered per revolution is not necessarily of concern to the operator in performing a calibration, because the equipment manufacturer takes this into account when designing the placement machine.

Counters operate independently of how fast a shaft, pulley, or sprocket may be turning. If a counter registers two counts per revolution, and the shaft turns 100 times in one minute, the counter will register 200 counts. If the same shaft were to turn 100 times in three minutes, the counter will still register 200 counts.

Machine Operation
Aggregate is delivered by a conveyor belt into the pugmill. For a given gate setting, the amount of aggregate delivered is constant for each revolution of the conveyor belt.

Figure 4-7 is a cross section of the aggregate hopper for which the head pulley (at the right) has a counter with two triggers. In this configuration, the counter would register two counts per revolution of the head pulley. This diagram also shows the emulsion pump.

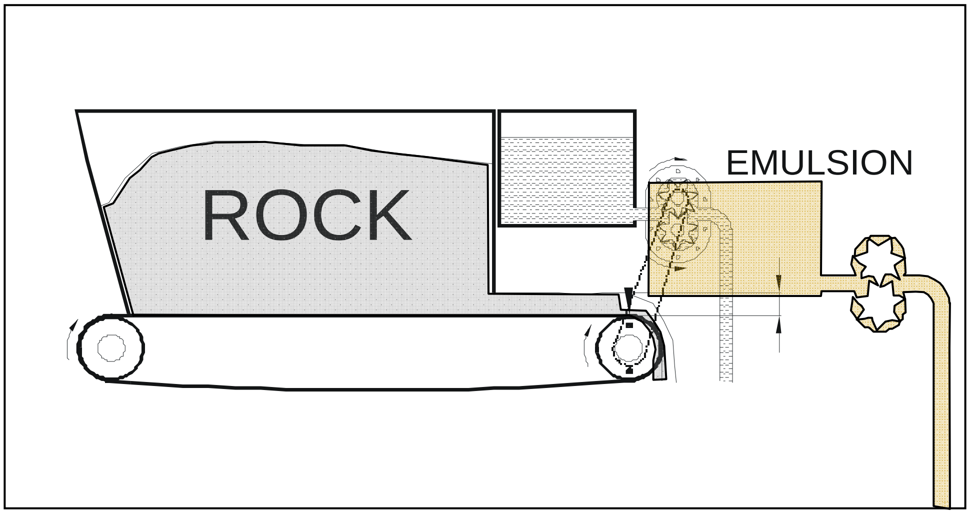


Figure 4-7 Machine Operation – Aggregate Hopper

The common configuration for slurry system machines is for the emulsion pump and the aggregate belt to be driven by a common shaft, known as a jack shaft or clutch shaft as shown in Figure 4-8. The linkages force the belt and pump to rotate at a fixed ratio (usually not 1:1), thereby ensuring a repeatable and fixed emulsion / aggregate ratio.

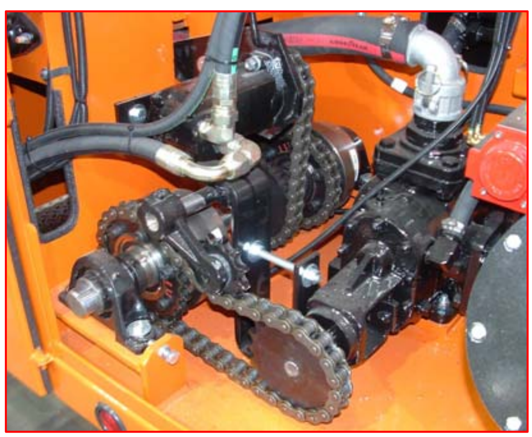


Figure 4-8 Belt to Pump Linkages

Figure 4-9 illustrates an example where the gate is set at 4 inches and the belt turned for 10 counts, resulting in the delivery of 100 pounds of rock.

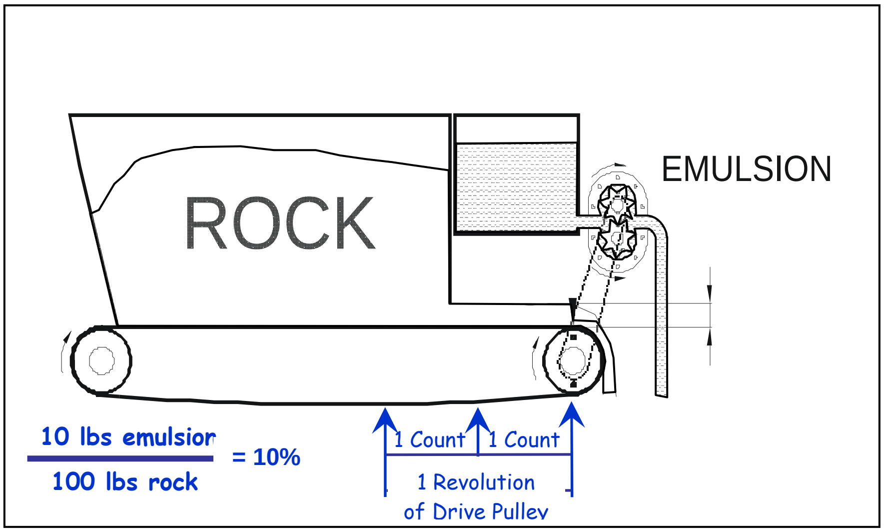


Figure 4-9 Machine Operation – Calibration Example

During the same 10 counts, (it is quite common to measure the emulsion delivery on the aggregate belt counter) the emulsion pump delivered 10 pounds of emulsion, which resulted in a 10% mix design for emulsion to aggregate.

4.5 Field Calibration Procedure

A. After the mix design is received from an approved laboratory, the calibration process begins by using the following sequence:

- If possible calibrate the emulsion pump on the rock belt counter.
- Use a container capable of holding 600 to 700 gallons, such as a tanker or mobile support unit (*called second container*).
- Before pumping from the paving machine into the tanker or mobile support unit, obtain the empty weight of the second container. Fill the hose before taking the first weight. Pump from the paving machine into the second container for a minimum of 50 counts of the rock belt. Divide the net weight pumped by the number of counts to obtain weight per count.
- Run three tests and average the results. If there is a large variance between the three results, rerun the emulsion calibration until the variance is less than 5%.
- Do not pump the emulsion back and forth between the paving machine and the second container as air will become entrained into the emulsion, leading to incorrect results.

Place results on the Emulsion Calibration Worksheet, Table 4-1.

EMULSION CALIBRATION
Minimum 50 counts of the Rock Belt counter per Sample

Emulsion	A	B	C	D	E_1
	Full Weight - LBS	Empty Weight - LBS	Net Weight - LBS (A-B)	No. of Counts	Lbs per Count (C÷D)
Sample 1					
Sample 2					
Sample 3					

Average Lbs/count of Emulsion ____________

Table 4-1 Emulsion Calibration Worksheet

B. The second step involves calibrating the cement or mineral fines.

- Use a small pan to obtain a cement or mineral fines sample from the machine, calibrating with the cement counter.
- Weigh the pan prior to collecting the sample from the machine. (Scale range: 0-30 lbs.)
- Collect three samples for a minimum of 10 counts of the cement counter and determine the weight per count for each test sample. Determine the average weight per count for the three test runs.

Place results on the Fines Calibration Worksheet, Table 4-2.

CEMENT / MINERAL FINES CALIBRATION
Minimum 10 counts of the Fines Feeder counter per Sample

Cement / Fines	A	B	C	D	E_1
	Full Weight - LBS	Empty Weight - LBS	Net Weight - LBS (A-B)	No. of Counts	Lbs per Count (C÷D)
Sample 1					
Sample 2					
Sample 3					

Average Lbs/count of Fines ____________

Table 4-2 Fines Calibration Worksheet

C. The third step involves calibrating the aggregate output.

- Test the moisture of the aggregate.
- Calculate the moisture factor. Moisture factor is the percent (in decimal format) of moisture in the aggregate + 1.00.

> Example:
> Moisture is 5%, therefore the moisture factor is:
> 0.05 + 1.00 = 1.05 Moisture factor

- Select three different gate openings as per Graph 4-1.
- Run at least 2 tons of material per gate setting recording the net weight conveyed and the number of counts of the rock belt for three test samples, each a minimum of 50 counts.
- Determine the average dry weight per count as per the rock calibration worksheet and plot the results to the graph. If a plotted straight line is not acquired on the graph, re-run the tests.

Place each result on the 3 Aggregate Calibration Worksheets, Table 4-3.

AGGREGATE CALIBRATION WORK SHEET

Minimum 50 counts of the Rock Belt counter per Sample (3 Samples Per Gate Setting)

% Moisture in Aggregate in Decimal ___________ + 1.00 = Moisture Factor

Gate Setting	A	B	C	D	E_1
	Full Weight - LBS	Empty Weight - LBS	Net Weight - LBS (A-B)	No. of Counts	Lbs per Count (C÷D)
3”					
3”					
3”					

Average Aggregate (E_1) ________ ÷ Moisture Factor = Dry Aggregate (lbs/count)

Gate Setting	A	B	C	D	E_2
	Full Weight - LBS	Empty Weight - LBS	Net Weight - LBS (A-B)	No. of Counts	Lbs per Count (C÷D)
4”					
4”					
4”					

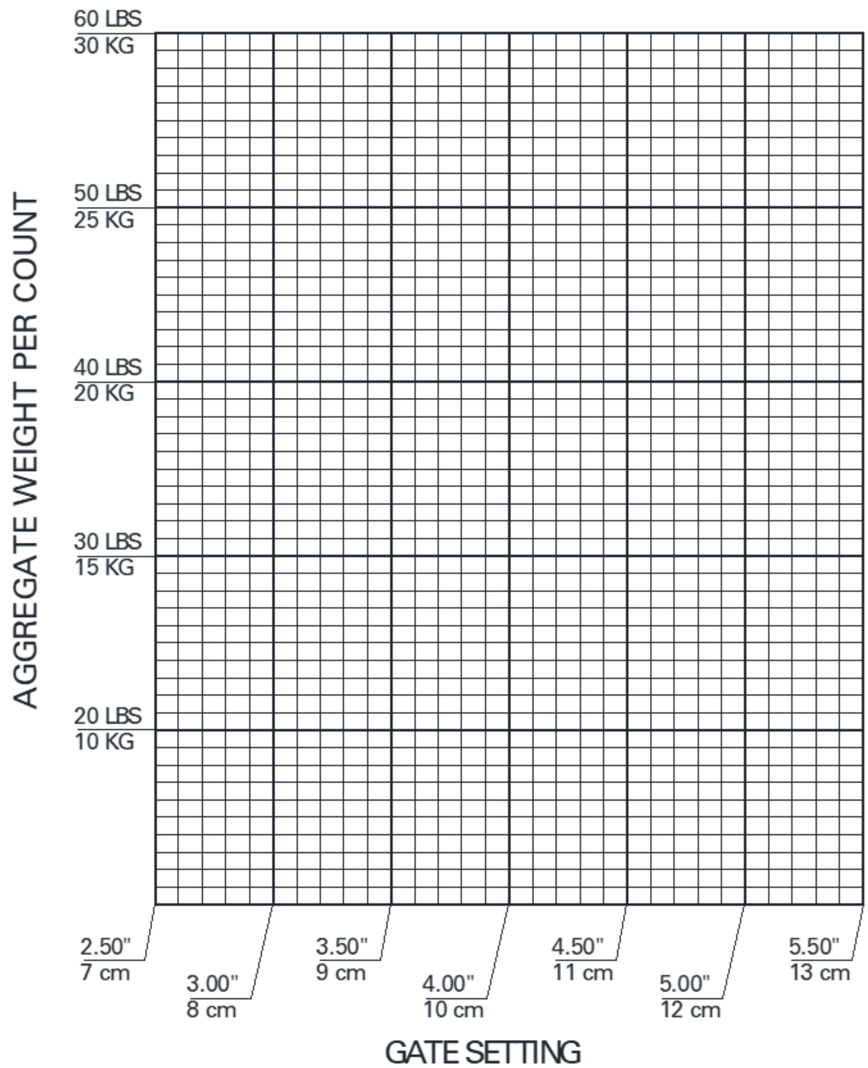
Average Aggregate (E_2) _______ ÷ Moisture Factor = Dry Aggregate (lbs/count)

Gate Setting	A	B	C	D	E_3
	Full Weight - LBS	Empty Weight - LBS	Net Weight - LBS (A-B)	No. of Counts	Lbs per Count (C÷D)
5”					
5”					
5”					

Average Aggregate (E_3) _______ ÷ Moisture Factor = Dry Aggregate (lbs/count)

Table 4-3 Aggregate Calibration Worksheets

Plot the values of Dry Aggregate (lbs/count) for each gate setting on the following graph and draw a line through the three points.



Graph 4-1 Selecting Aggregate Gate Setting

D. The final step involves setting the gate opening for the aggregate. This is done from the mix design for the emulsion, and the pounds per count of emulsion determined in Step 1 above. The pounds per count of aggregate can be computed from either the % emulsion in the mix design, or % residual asphalt from the mix design. The worksheet below summarizes what was calculated above, and determines the gate opening.

- Emulsion weight per count of Aggregate belt (Table 4-1) EM W/C ___________________
- Choose the proper calibration procedure (below) based on your mix design.

- **CALIBRATION BY PERCENT EMULSION**

Find the required Dry Aggregate weight per count (DA W/C) based on % Emulsion.

- The following percentages are entered in decimal form. (I.E. 12% = 0.12)

EM W/C __________ ÷ _________% Emulsion required = ___________ DA W/C

Example: 5.0 ÷ 0.12 = 41.67 DA W/C

- **CALIBRATION BY PERCENT RESIDUAL ASPHALT**

Find the Dry Aggregate weight per count (DA W/C) based on % Residual Asphalt.

EM W/C __________ x R.A. EM _________ ÷ % R.A. Reqd. _________= ___________ DA W/C

Example: 5.0 x 0.65 ÷ 0.078 = 41.67 DA W/C

Table 4-4 Dry Aggregate Weight/Count Calculation

- To find the corresponding aggregate gate opening from the graph (Graph 4-1), locate the DA W/C calculated in Table 4-4 on the left side of the graph. Follow this value horizontally to the right until it intersects the line drawn through the three points. At the point of intersection, follow this value vertically, down to the bottom scale to determine the gate opening for the paver. Set the gate to this measurement.

4.6 Calibration Summary

A mix design is proportioned by weight while the placement machines deliver materials by volume. Due to the differing nature of the measurements, it is essential that calibration be completed using the actual job materials. <u>No machine should be allowed to work on a job without a proper calibration</u>.

SESSION 5: CONSTRUCTION

5.1 Introduction

Each phase of construction can impact the overall quality and service life of the slurry system. Factors of importance include weather conditions, surface preparation, and traffic control. Thorough attention to detail is critical during the construction process to ensure a successful final product.

5.2 Project Pre-planning

A project's success depends on the effort expended in pre-planning. Addressing the equipment and manpower needs is an important first step in the planning process. Sufficient time should be spent finding an appropriate staging area as close as possible to the job site.

Safety must be of paramount importance. Roadway work zones are hazardous both for motorists who drive through the complex array of signs, barrels, and lane changes and for workers. The operation of work zones needs to be carefully planned well in advance of the application.

Equipment

The equipment must be thoroughly maintained and checked to ensure it can operate without breakdown or malfunction. In cases where equipment breaks down or malfunctions unexpectedly, it should be repaired as soon as possible and operate without further problems for the remainder of the project.

Manpower

The number of workers needed on a project depends on the scale of the work and the desired production rate. Suggested needs for small projects and large scale projects with continuous placement operations are shown in Table 5-1.

Labor Category	Application	
	Residential	Mainline Continuous
Supervisor	1	1
Placement Trucks / Drivers	2	-
Machine Operator	1	-
Placement Machine Driver	-	1
Placement Machine Support	-	1
Placement Machine Operator	-	1
Ground Men	2	2
Support Truck Drivers	-	4
Load Site Operator	-	1
Tack Truck Driver	-	1
Traffic Control / Cleanup	4	6
Totals	**10**	**18**

Table 5-1 Typical Manpower Requirements

Staging Area

The stockpile site and staging area should contain the following elements:

- A clean and well-drained pad for aggregate stockpile,
- Space for an emulsion tanker and additive tanker,
- Space for truck loading and maneuvering, and
- A potable water supply.

5.3 Surface Preparation and Traffic Control

The main objective of surface preparation is to provide a clean and sound surface on which the slurry seal or micro surfacing is applied. The first step of surface preparation is to restore the pavement's structural integrity and functional performance characteristics through crack sealing and patching.

Isolated Failures and Cracks

Crack sealing repairs should be made at least 3 weeks prior to the placement of slurry seal or micro surfacing. Longer lead times for crack repairs are more desirable.

A repair will be necessary when the pavement has failed in localized areas where the underlying support materials have disintegrated, become infiltrated with fine-grained materials, or otherwise lost their load-carrying capacity. Unlike typical patching, base repair requires the removal and replacement of the underlying base/sub-base materials. The main steps associated with base repairs are:

- Mark and cut the failure boundaries,
- Remove the affected pavement and base/sub-base layers,
- Place and compact in lifts of new granular base/sub base materials,
- Apply a tack coat along the edges of the repair area, and
- Place and compact the new asphalt surface.

Existing Structures

Utility inlets should be covered with heavy paper, plastic sheet, or roofing felt adhered to the surface of the inlet. The covering is removed once the slurry seal / micro surfacing has sufficiently cured. In addition to protecting the inlets, all starts, stops, and handwork on turnouts should be covered to ensure sharp, uniform joints and edges. Figure 5-1 shows a protected manhole cover and removal of the covering after material placement.

Figure 5-1 Protected Manhole Cover & Removal

Removal of Pavement Markings

Thermoplastic pavement markings must also be removed prior to placing a slurry seal or micro surfacing, or at least, be abraded to produce a rough surface. Paint markings require no special preparation, unless build-up of multiple paint layers is extremely heavy.

All raised pavement markers must be removed prior to construction.

Traffic Control Plans

The signs, devices and traffic controllers (flaggers) used must match the traffic control plan. The work zone must conform to the agency's requirements. All workers must have all required safety equipment and clothing.

Cleaning the Pavement Surface Prior to Construction

Immediately before the slurry seal or micro surfacing is applied, the road must be swept clean of all dust and debris. Sweeping is done with a mechanical sweeper or vacuum. If a mechanical sweeper is used, two or three sweeping passes are typically needed. If hard-to-remove materials (such as organic matter or animal remains) are present, high power pressure washing is necessary. If the road is not thoroughly cleaned free from all types of contaminants, the slurry seal or micro surfacing will de-bond (delaminate) over the contaminated areas.

5.4 Weather

The ideal day for constructing a slurry seal project should be sunny, warm, with low humidity and a light breeze. However, few days exhibit ideal conditions, and instead, contractors are restricted to working within the minimum and maximum weather conditions. Thus, a contractor must closely examine the current and forecasted weather prior to constructing any slurry system.

The basic prerequisite for success is that the emulsion must be able to properly break and cure. As a result, humidity, wind conditions, and temperature (both surface and air) are important and need to be considered. Modifications to additives should be made according to the changing environment during application. In any case, application of a slurry seal is not suitable for night work.

This is due to the lower evaporation rate at night, which results in longer breaking and curing times. However, micro surfacing can be placed at night because it relies on a chemical break.

Ambient Temperature
Micro surfacing shall not be applied if either the pavement temperature or the 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. The breaking time for both slurry seal / micro surfacing is affected by temperature. Work should not be started if cold temperatures are anticipated within 24 hours of construction. Humidity should be 60% or less and a slight breeze is advantageous.

Rain
Work should not be started if rain is imminent. Micro surfacing may resist rain-induced damage after as little as one hour but typically requires at least three times to cure to a fully waterproof state.

5.5 Test Strip

A highly recommended practice is to place a test strip on or near the project site. The test strip should be constructed under similar placement conditions, such as same time of day, temperature, and humidity that is expected for the duration of the project.

The test strip should be a minimum of 300 feet in length with the job mix proportions, materials, and equipment to be used on the project. Do not start full production after constructing the test strip until the test strip has been evaluated and accepted by the agency. If the test strip is unacceptable, repeat the test strip process until an acceptable test strip is produced.

5.6 Tack Coat

Normally a tack coat is not required unless the surface to be covered is extremely dry, raveled, or is concrete or brick. However, tack coats are typically applied on high traffic volume pavements to prevent potential delamination, and on pavements with a higher level of surface oxidation.

The material used for the tack coat must meet the requirements of AASHTO Standard Specification M 140 for Emulsified Asphalt, M 208-01 (2014) for Cationic Emulsified Asphalt, or M 316-14 for Polymer-Modified Emulsified Asphalt. Typically, tack coats are slow-setting emulsions, chosen because they are sufficiently stable and result in a fast break when applied as very thin films. The intent is to ensure a good bond between pavement layers by minimizing any dust on the existing surface and wetting existing oxidized surfaces, without adding excess binder to the surface treatment.

A tack coat consists of one part emulsified asphalt and one part water, applied with a distributor at a rate of 0.05 to 0.10 gallons per square yard, depending on the surface texture. The tack coat should be allowed to cure sufficiently before applying the micro surfacing treatment.

5.7 Application of Mixture

The pavement surface should be wetted immediately ahead of the spreader box. The purpose is to leave the surface damp and reduce the surface tension for better bonding to the existing pavement.   Care must be exercised to not pool water on the surface.

Note: Most mixing machines are equipped with a water pressure system and spray bar with nozzles to provide a water spray to dampen the surface.

Scratch Coat with Micro Surfacing

A scratch coat is used to level pavements having minor transverse irregularities that are narrower than the width of the spreader box, or on pavements with longitudinal ruts less than 0.5 inch deep. When applying a scratch coat, a steel strike-off is substituted for the primary strike-off in the standard micro surfacing drag box. The steel strike-off drags over the high spots of the pavement, filling in the irregularities. Scratch coats should always be covered with a full-width micro surfacing. The scratch coat principle is shown in Figure 5-2.

Figure 5-2   Scratch Coat Principles and Treatment

Full-width Placement (All Slurry Systems)

When applying a full width seal, a standard spreader box is used. The edge of each pass should align with the longitudinal joints or paint lines on the roadway. The longitudinal and transverse joints should be uniform and neat in appearance with no material build-up or uncovered areas. Longitudinal joints should be constructed on lane lines, edge lines, or shoulder lines, and should not overlap more than 3 inches.

The longitudinal edge lines should not vary by more than ± 2 inches in 100 feet.

Rut-Filling with Micro Surfacing

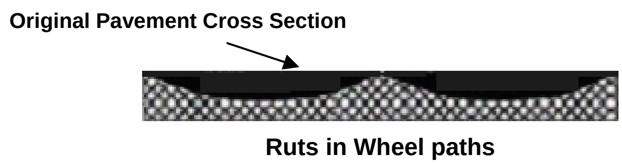
Use a rut box to fill ruts and depressions equal to or greater than 0.5 inch. The rut box channels the mix into the ruts and leaves a crowned finish to compensate for later compaction due to trafficking. The rut filled areas need to experience traffic for at least 24 hours before the final surface course is placed. Use a Type

III gradation for rut filling. Where ruts exceed 1 inch, multiple passes with the rut box are necessary.

Generally, after filling the ruts, a full-width micro surfacing is placed over the lane, but this is not essential. Figure 5-3 illustrates the principle behind rut filling. Rut filling 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.

Re-profiling Wheel Ruts

For each inch of applied micro surface rut fill mix add 1/8” to 1/4” crown to compensate for return traffic compaction.



Ruts ½” & Over Must Use the Rut Box

Figure 5-3 Rut Filling Principle

5.8 Workmanship

Workmanship and quality, which are often used interchangeably, are linked to specific and measureable qualities of the final product. Areas of particular importance include the following:

Longitudinal Joints

High quality longitudinal joints should be straight on tangent sections and uniformly follow the traffic lane on curved sections. They may be constructed as an overlap or butt joint. If overlapped they must correspond to the lane lines and should not exceed 3 inches in width or be more than 0.25 inch vertically.

Transverse Joints

Transverse joints are inevitable when working with truck-mounted placement machines (batch systems). Every time a truck is emptied, a transverse joint is required. Transitions at these joints must be smooth to avoid creating bumps in the surface. The joints must be butted to avoid these bumps and handwork should be kept to a minimum. The main difficulty in obtaining a smooth joint occurs as the placement machine starts up at the joint. Starting transverse joints on roofing felt can eliminate these problems.

Transverse joints should be constructed as butt-type joints. The traverse joint is considered acceptable if there is no more than 0.25 inch vertical separation between the pavement surface and a 10 foot straightedge placed perpendicular to the joint.

Edge Lines

The edge of the spreader box should produce a very straight and clean edge line corresponding to the original edge of the pavement travel way. Normally, the existing paint line (fog line) at the edge of the travel way 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 should be used as a guiding edge for alignment.

Texture

A well designed slurry system mixture will yield a consistent texture throughout the project. Achieving uniform texture underscores the importance of calibration prior to each project. Failure to calibrate often yields mixtures with low cement content or too high a water content. This leads to a black and flush looking surface with poor texture. Other problems caused from a failure to properly calibrate may lead to what is known as “false slurry” where the emulsion breaks onto the fine material. In such instances, delamination (debonding) may occur, resulting in premature failure. These types of mixes can be recognized as non-uniform and appear to set very slowly.

A finished surface should be free of excessive surface defects, ripples, or drag marks. Any single drag mark exceeding 0.5 inch in width and 6 inches in length is unsatisfactory.

Often, ripples are a result of excess speed causing the box to vibrate or jump leaving transverse ripple lines. Drag marks are caused by excessive buildup of material in the spreader box, strike-off, or the drag. Cleaning the spreader box and changing the strike-off and drag will correct the problem.

Smoothness / Ride Quality

Slurry mixtures follow the existing road surface profile and thus do not have the ability to significantly change the pavement’s smoothness. Micro surfacing has the ability to correct minor surface irregularities, thus improving the ride quality to a minor extent. Until the micro surfacing fully cures, rolling traffic will tend to improve the ride quality.

Handwork

Those areas that are not accessible to the spreader box will require handwork. The cardinal rule for handwork is “less is best”. The more the slurry system mixture is worked, the more segregation takes place. When handwork is necessary, care should be taken to wet the existing pavement surface first and to spread the mixture so the finished surface is uniform. Water in the mixture reduces pavement surface tension and helps the squeegee move the product. A mixture that has set during handwork should be removed.

5.9 Unique Requirements

Special situations arise that require particular attention to factors that could adversely affect the final product. To compensate for these special situations the following practices should be followed:

Rolling

Rolling is used for some airport projects where loose aggregate may cause foreign object damage, particularly where jet engines operate. It is also a common practice on parking lots that may not receive the desired traffic to set the material.

It is common practice to use a 10-12 ton pneumatic-tired roller on airport projects and parking lots. Covering the area with two complete passes should be done as soon as the mixture has set up enough to support the roller and not pick up material on the tires..

Sanding

Sanding may be used to reduce the time that cross streets or intersections are closed. Sanding is the application of a fine layer of dry, washed sand that is broadcast over the slurry surface. Sanding may also be used on wet spots, but should not be considered until the slurry seal / micro surfacing can withstand walking traffic.

Sweeping

On heavily trafficked roads or where early opening has led to aggregate loss, sweeping is essential. A suction broom is the best type of sweeper to use. Sweeping should be done just prior to opening to traffic and at periods determined by the level of aggregate loss.

The slurry seal and micro surfacing must develop sufficient cohesion to resist abrasion due to traffic. Early minor stone shedding is normal, but should never exceed 3%. If a mixture is reopened to traffic too early, it will ravel off quickly, particularly in high stress areas. It is important that the mixture develop adequate cohesion before it is opened. A general rule of thumb for slurry seals is that it can be opened when it has turned black. A general rule of thumb for a micro surfacing is that it can carry traffic when it is expelling clear water.

5.10 Yield Checks

Yield checks are made by comparing the area covered with the quantity placed. It is recommended that a minimum of four (4) yield checks be made per day. Spot checks for individual loads or several loads can be made at any time to ensure that the proper thickness of material is being placed.

5.11 Temporary Pavement Markings

Temporary pavement markings should be installed after the slurry system cures. Do not place permanent pavement markings for 10-14 days for water borne pavement markings or per manufacturer's recommendations for other types. If such markings are applied too soon, they will become discolored due to bleeding of the underlying material. In the interim, temporary pavement markings should be used with the expectation that they will be replaced with permanent markings following curing.

SESSION 6: QUALITY ASSURANCE

6.1 Introduction

Quality assurance includes everything in the process that is necessary to make the product perform in the way it was intended. Quality assurance consists of taking the proper steps at the right time to ensure that a project is being implemented in the right way. When a process does not work satisfactorily, corrective actions need to be applied. Such corrective actions should be known and planned before starting the project.

A quality assurance program that complies with the Code of Federal Regulations Title 23, Section 637 (23 CFR 637) is required for any federal-aid highway construction project.

Quality assurance incorporates three critical aspects: quality control by the contractor, quality acceptance by the agency, and independent assurance. In addition, the AASHTO Implementation Manual for Quality Assurance outlines the use of qualified laboratories, qualified personnel, and a framework for conflict resolution.

6.2 Contractor Quality Control

Quality control means making sure things are done according to the plans, specifications, and permit requirements. These steps are critically important for a successful project and should be adhered to from project conception and design to project construction.

The Contractor is responsible for all process control sampling and testing. This also includes providing inspection, and exercising management control to ensure that all project work conforms to the contract requirements. In addition, the Contractor is responsible for maintaining complete testing and inspection records and making them available to the agency.

Ideally, quality control is achieved by developing a company culture which encourages quality and is embraced by everyone in the organization. At minimum, the contractor must develop a quality control plan to define and document the following processes:

1. ***Quality Control Testing*** – List the materials to be tested, tests to be conducted, the location of sampling, and the frequency of testing. Establish a detailed testing schedule based on production and a means to ensure its accomplishment.

2. ***Inspection/Control Procedures*** – Address each of the following subjects in each phase of construction.

a. ***Preparatory phase***.
   i. Establish a procedure to ensure that materials comply with contract requirements and all submittals, including certifications that are delivered to the owner.
   ii. Identify a procedure to ensure that equipment is capable of complying with the contract requirements.

b. ***Start-up phase*****.**
   i. Institute a procedure for reviewing contract requirements with personnel who will perform the work.
   ii. Establish standards of workmanship.

c. ***Production phase*****.**
   i. Create inspection procedures for use during construction to identify and correct deficiencies and a feedback loop to prevent repeated deficiencies.

d. ***Description of records*****.**
   i. List the project records to be maintained.

e. ***Personnel qualifications*****.**
   i. Document the names, certifying authority, and relevant experience of all personnel directly responsible for inspection and testing.

f. ***Subcontractors.***
   i. If a subcontractor is to perform work on the project, detail how the subcontractor will interface with the contractor.

A company's documented Quality Control Plan generally should comprise three to six pages with an additional two to four pages of detailed information about the pavement preservation treatment and pre- or post-treatments, if appropriate. Pre-treatments may include vegetation removal, crack filling, tacking, etc. Post-treatments may include fog sealing, blotting, applying a de-tack solution, etc.

6.3 Quality Acceptance by the Agency

For a quality assurance program to meet the requirements of 23 CFR 637, construction inspection must be performed as part of the acceptance program.   *(Section 637.203 identifies construction inspection as a component of the state's acceptance program.)* Therefore, the agency is responsible for the acceptance function on its construction projects regardless of the contracting mechanism used. The agency's verification of sampling, testing, and inspection provides a quality assessment completely independent of the contractor's quality control process.

Quality acceptance includes inspecting the materials upon delivery and placement and inspecting the workmanship and quality of the finished product. This includes performing acceptance sampling, testing, and measurement activities to ensure the product's quality.

All incoming materials need documentary evidence that they conform to specified quality and contractual requirements before they are used on the project. The documentation is necessary to verify that the materials have met specific requirements.

6.4 Independent Assurance

Only tests that are used in the acceptance decision need to be covered by an Independent Assurance (IA) program. The IA program may comprise several actions such as: periodic observation of the test procedure, regular calibration of the test equipment, and the periodic testing of personnel proficiency. Both written and practical examinations may be used to determine the qualifications of those personnel performing the test.

Different laboratories could be responsible for performing the IA tests for state DOT and contractor personnel. The state could use the project approach for contractor personnel and the system approach for state personnel.

6.5 Qualified Laboratories

Agencies that chose not to use the contractor’s results in an acceptance decision must have an accredited central laboratory. State DOTs comply with the AASHTO Accreditation Program (AAP). AAP is a voluntary program that is available to all testing laboratories including government, commercial, university, and research facilities. The AASHTO Materials Reference Laboratory (AMRL) provides administrative coordination and technical support for AAP.

AMRL-accredited laboratories demonstrate that their testing services are of the highest quality and conform to specific national and international standards. An AMRL-accredited laboratory has been subjected to rigorous on-site, third party assessments and has demonstrated that the laboratory’s technical staff and the testing apparatus associated with each test achieved the highest standards. Each assessment includes a thorough review of the laboratory’s quality management system, including records of technician training, equipment calibration, and checks.

6.6 Qualified Personnel

The FHWA has a long history of encouraging qualification of all highway construction technicians, including construction inspection personnel. An example of FHWA's support of qualification programs for technicians is the AASHTO TSP•2 Oversight Panel’s recent commitment to advance pavement preservation certification.

6.7 Slurry Systems Quality Assurance Program

Implementing a quality assurance program is critical to the success of a slurry seal or micro surfacing project. Any step skipped in the process, significantly increases the risk of failure or a reduced service life of the slurry system.

Contractor Quality Control Plan – should include the following procedures:

A. Slurry System Aggregate

I. Stockpile - sample and test the aggregate a minimum of once per day of production of the crushing operation with a sample consisting of three test portions tested in accordance with AASHTO T 27 and T 11 *(Sieve Analysis of Fine and Coarse Aggregates)*.
II. Construction - verify the application rate of aggregate using the paver's calibration records.

B. Emulsified Asphalt

I. Only emulsified asphalt from certified or approved sources is allowed for use. Include the supplier's name, plant location, emulsion grade, and batch number on all reports.

II. Provide material certification and quality control test results for each batch of emulsified asphalt used on the project.

III. Verify the application rate of the emulsified asphalt using the paver's calibration records.

C. Daily Documentation

I. Aggregate used, tons (dry)
II. Emulsified asphalt used in slurry system, tons
III. Emulsified asphalt used for tack coat, tons (if specified)
IV. Mineral filler used, pounds
V. Water used in mixture, gallons
VI. Additive used in mixture, gallons
VII. Surface area completed, square yards
VIII. Surface area application rate, dry pounds of aggregate per yd^2
IX. Percentage of emulsified asphalt based on dry aggregate

Quality Acceptance by the Agency – should include taking random samples and performing acceptance tests.

A. Slurry System Aggregate

I. Stockpile - take sample once per day. Samples will be stored and tested for gradation at the discretion of the agency. The contractor may be allowed to request split samples from the agency.

II. Price Reduction – may be levied for gradations failing to comply with project specifications.

B. Emulsified Asphalt

I. Tankers – take a sample from every tanker supplying emulsified asphalt to the project.

II. Testing – emulsions must comply with AASHTO Standard Specification M 140-14 for Emulsified Asphalt, or
M 208-01 (2014) for Cationic Emulsified Asphalt, or
M 316-14 for Polymer-Modified Emulsified Asphalt.