

**SURFACE SLURRY SEALING SYSTEMS IN CANADA:
PERFORMANCE AND PRACTICE**

JEAN-MARTIN CROTEAU, P.Eng.
Miller Paving Limited
Markham, Ontario

J. KEITH DAVIDSON, P. Eng.
McAsphalt Engineering Services
Scarborough, Ontario

and

PETER PERRONE
McAsphalt Industries Limited
Scarborough, Ontario

ABSTRACT

Traditional slurry seal systems were first used in Canada in the 1960s while polymer-modified systems were introduced in the early 1990s. Surface slurry sealing systems are placed to restore the surface characteristics of pavement or to preserve a pavement. The systems can be designed to correct rutting, to improve skid resistance, to seal and to protect the pavement surface. Skid Numbers for surface slurry sealing systems can reach the 50s, which, in terms of skid resistance, is exceptionally good. They can be applied on chip seals, on hot mix asphalt pavement or on concrete pavement.

Surface slurry sealing systems are mixtures of cationic emulsified asphalt, mineral aggregates, mineral filler, water and additives, properly proportioned, mixed and spread with a machine over a properly prepared surface. A slurry mixture forms an impervious thin overlay over an existing pavement. The rate of application ranges from approximately 8.0 kg/m² for a non-polymer modified fine graded system to 18 kg/m² for a polymer coarse graded system.

This paper presents an overview of the surface slurry sealing systems technology and a discussion on the state of the practice including design practices, construction procedures and the performance of these surface treatments.

RÉSUMÉ

Les systèmes traditionnels de coulis de scellement ont été utilisés pour la première fois dans les années 1960 alors que les systèmes modifiés au polymère ont été introduits dans les années 1990. Les systèmes de coulis de scellement de surface sont posés pour restaurer les caractéristiques de surface de la chaussée ou pour préserver une chaussée. Les systèmes peuvent être conçus pour corriger l'orniérage, améliorer la résistance à la glissance, sceller et protéger la surface de la chaussée. Les données de glissance d'un coulis de scellement de surface peuvent atteindre les 50, ce qui, en termes de résistance à la glissance, est exceptionnellement bon. Ils peuvent être appliqués sur des enduits superficiels, sur des chaussées en enrobés bitumineux à chaud ou en béton de ciment.

Les systèmes de coulis de scellement de surface sont des mélanges d'émulsion cationique de bitume, de granulats, de filler minéral, d'eau et d'additifs bien proportionnés, malaxés et épandus avec une machine sur une surface correctement préparée. Un mélange de coulis forme un revêtement mince sans vide sur une chaussée existante. Le taux d'application varie d'environ 8,0 kg/m² pour un système à granulométrie fine sans polymère à 18 kg/m² pour un système à granulométrie grossière avec polymère.

Cet exposé présente une vue générale de la technologie des systèmes de coulis de scellement de surface et une discussion sur l'état de la pratique incluant les usages de design, les procédés de construction et la performance de ces traitements de surface.

1. INTRODUCTION

Surface slurry sealing systems have been used in Canada for many years. Traditional non-polymer modified slurry seal systems were used for the first time in the 1960s, while the polymer-modified micro-surfacing systems were introduced in Canada in the early 1990s. It is estimated that approximately 3.5 million square meters of slurry surfacing systems are placed every year in Canada. Surface slurry sealing systems are used to restore the surface characteristics of pavement or as a pavement preservation treatment. The usage of surface slurry systems is increasing in nearly every province in Canada. This paper presents an overview of the surface slurry sealing systems technology and a discussion on the state of the practice including, design practices, construction procedures and the performance of these surface treatments.

1.1 History

The first form of slurry surfacing can be traced back to the late 1920s with a process call “schlämme”. The “schlämme” process was developed in Germany and it consisted of mixing a hot bituminous binder with a very fine aggregate and water. The “schlämme” mixture was prepared in a central plant, maintained under agitation during transportation to avoid sedimentation and placed using brushes and rubber scrapers. After the evaporation of water, the finished product was smooth and waterproof.

The hot bituminous binder was eventually replaced with a slow setting anionic emulsion. The slurry mixture was prepared, transported and placed in the same manner as the “schlämme” process. It was not until the 1960s, with the development of cationic emulsions and continuous flow lay down machines, that a strong interest in using slurry surfacing for road maintenance started. The break of the newly developed cationic emulsions was better controlled and not as dependent on the weather conditions. The traffic readiness of the cationic type slurry seal surfacing was reduced from several hours to one or two hours. The development of continuous flow lay down machines also allowed the placement of slurry surfacing over large areas in a short period of time.

The first polymer-modified slurry sealing system was developed in Germany in the late 1970s. Polymer-modified systems, also called micro-surfacing, are composed of polymer-modified cationic emulsion, crushed aggregates, mineral filler, water and field control additives. The first system was commercialized under the trade name Ralumac and it was imported into North America in the early 1980s. Today several other proprietary and generic systems are available in North America and abroad. The most common uses of micro-surfacing are surface texturing, surface sealing and rut filling of bituminous pavement.

1.2 Definitions

Surface slurry sealing systems include different processes that ought to be differentiated.

Quickset Slurry Seals: Quickset slurry seals are mainly used as sealants on bituminous pavement. The aggregate is relatively fine (less than 6.3 mm) and always 100 % crushed. The emulsion is not modified and always cationic. The fines content ranges between 8 to 12 % and the residual bituminous binder is generally between 9.0 and 10 %. The application rate for a typical bituminous pavement ranges between 6.5 and 7.0 kg/m².

Polymer-modified Quickset Slurry Seals: Polymer-modified quickset slurry seals are also used as sealants on bituminous pavement. They are formulated in the same manner as traditional quickset slurry

seals with the exception that the emulsion is modified with a low loading of polymer, about 1.0 %. This allows the slurry to be applied at a slightly higher rate, which ranges between 7.5 and 9.5 kg/m².

Micro-Surfacing: Micro-surfacing systems are used not only as sealants but also for surface texturing and rut filling of pavement. The maximum size of the aggregate is greater than the maximum size of the aggregate used for slurry seal. The maximum size of the aggregate is between 6.3 and 9.5 mm and it is always 100 % crushed. The emulsion is modified with a heavy polymer loading, between 3.0 and 4.0 %, and the emulsion is always cationic. The fines content ranges between 7 to 10 % and the residual bituminous binder is generally between 8.0 and 9.0 %. The application rate for a typical bituminous pavement ranges between 12.0 and 18.0 kg/m².

Fiber Modified Micro-Surfacing: Fiber modified micro-surfacing systems were developed in Europe and they are not yet commonly used in North America. They were developed to provide a very aggressive macro-texture to the surface of the pavement. The aggregate is often gap graded and the fiber loading helps to prevent segregation. With the exception of the fibers and the gradation of the aggregate, fiber modified micro-surfacing is formulated in the same manner as traditional micro-surfacing.

Contrary to a wide spread perception, the fundamental difference between the slurry seal systems and the micro-surfacing systems is not associated with the type of emulsion used to produce the slurry mixture. It is related to the tightness and strength of the mineral skeleton in the aggregate/bitumen matrix once the water escapes. Micro-surfacing is formulated in such a manner that once the water escapes the mineral particles are interlocked and the mineral skeleton is strong. Hence it is possible to place micro-surfacing material in thick lifts or in multiple layers without risk of deformation. Slurry seal systems are formulated with the objective of creating a bitumen rich mortar. The mineral skeleton is not very strong and there is minimal interlocking of the aggregate particles. Consequently, the thickness at which slurry seal systems can be place is limited because there is a risk of deformation.

2. SLURRY MIXTURE

The formulation of a slurry mixture is carried out in three stages as described below:

- component selection and testing to determine whether they are suitable and meet the materials specification,
- mixture testing to confirm that the two main components, i.e., the emulsion and the mineral aggregate are compatible and to determine the effect of the water, the filler and the field control additives
- performance testing to determine the optimum slurry mixture formulation

2.1 Components Selection and Testing

The first step in the process of establishing a slurry mixture formulation is the selection and testing of the various components which include: aggregate, mineral filler, fibers (if required), added water, emulsion and field control additives.

2.1.1 Aggregate

The aggregate constitutes about 82 to 90 % by weight of the slurry mixture, depending on the aggregate nature and whether the aggregate is used to produce a slurry seal mixture or a micro-surfacing mixture.

The aggregate component tends to constitute a greater portion of a micro-surfacing mixture than of a slurry seal mixture.

The gradation is normally continuous, but there are specialty micro-surfacing mixtures that are gap graded as well. The maximum size aggregate in the slurry mixtures is either 6.3 mm or 9.5 mm. The ISSA (International Slurry Surfacing Association) has standardized these mixtures as Type II and Type III. The consistency and the performance of the mixture are greatly influenced by both the amount of fines (particles less than 75 μm) contained in the mixture and the uniformity in the amount of fines.

Ultimately, it is the aggregate that interacts with the tires of the vehicles. Consequently, the physical properties of the aggregate are extremely important with respect to the slurry mixture performance on the roadway. Minimum physical properties of the aggregate are established in relation to the usage of the slurry mixture. Generally, the minimum requirements for micro-surfacing mixtures are higher than those for quickset slurry seals.

The aggregate is always 100 % crushed and the cubical/angular aggregate is preferable. The presence of flat and elongated particles does not adversely affect the long-term performance of the mixture. However, a mixture that contains a significant amount of flat and elongated aggregate is more difficult to place and the resulting surface texture is not as uniform.

2.1.2 Mineral Filler

Mineral filler - cement or hydrated lime- is always added to the slurry mixture to control the break time of the emulsion. The amount of mineral filler added to a slurry system is usually no more than 1.0 %.

2.1.3 Fibers

The purpose of the fibers is to facilitate the placement of the slurry mixture and to increase the cohesion of the mixture once the water has escaped. The usage of fibers increases the consistency of the slurry mixture even when a gap-graded mixture is used, thereby preventing segregation. Once curing is completed, the fibers form a reinforcement network within the bituminous mixture that greatly contributes to increase the abrasion resistance of the slurry surfacing. Cellulose and mineral fibers have been used, but only with micro-surfacing.

2.1.4 Added Water

The purpose of the added water is to facilitate coating, to adjust the consistency of the slurry mixture and to speed up or slow down the break of the emulsion. The amount of water to be added depends mainly on the weather conditions and the amount of moisture already contained in the aggregate.

2.1.5 Bituminous Binder

Emulsion

The binder is always a cationic emulsion, polymer-modified or of pure bitumen. The residual bitumen ranges from 60 to 65 %. The compatibility of the emulsion with the aggregate is extremely important. The emulsion used to produce a slurry mixture for slurry seal is more versatile than an emulsion used to produce a mixture for micro-surfacing. One quick set cationic slurry seal emulsion may be used with many types of aggregate. However, in the case of a micro-surfacing operation, the traffic readiness is very

important. Therefore, the breaking of the emulsion needs to be controlled with precision and in many cases, this can only be achieved by designing a specific emulsion for a specific aggregate.

Polymer

The addition of polymer in the binder improves the cohesion and the adhesion properties of the residual bitumen. The polymer can be added into the water phase or it can be blended with the bitumen prior to emulsification. The polymer loading varies from 1.0 % of the residual bitumen for a quickset polymer-modified slurry seal system to either 3.0 or 5.0 % in the case of a micro-surfacing emulsion. Natural rubber latex is most often used, but other polymers such as styrene-butadiene rubber (SBR), styrene-butadiene-styrene (SBS) and ethylene-vinyl-acetate (EVA) have also been used.

2.1.6 Field Control Additive

The field control additive is mainly used to retard the break time of the emulsion. The usage of such additive is often necessary in hot weather when the emulsion breaks rapidly and more time is required to properly place the slurry mixture.

2.2 Mixture and Performance Testing

As for any other roadway material, the selection of good quality components is a key element in the performance of the slurry surfacing. However, it is important to point out that the selection of high quality components alone may not be sufficient to ensure that the combination of all the components will provide a satisfactory performance. Good quality components are not always compatible with one another. Mixture testing to ensure compatibility of the primary components is critical to ensure that the slurry mixture system will work adequately.

2.2.1 Quickset Slurry Seal Mixtures

The testing performed to design quickset slurry seals is relatively simple. There are four areas where testing is required: compatibility, workability, cohesion and performance.

Compatibility: The ingredients of a slurry surfacing must be mutually compatible. The slurry must be homogeneous and stable, must be workable for at least two minutes, should have good adhesion and cohesion and once the slurry has been placed, the mixture must be homogeneous. The common compatibility tests used are the cone consistency, the compatibility test and the wet stripping test, which are described in the Design Technical Bulletins published by the International Slurry Surfacing Association (ISSA) [1]. The cone consistency test is used to determine the optimum water content to give a stable, homogeneous and workable mix. The cone test provides a numerical value to consistency. . The wet stripping test is performed on the cohesion test sample, which has been cured at 60°C. The sample is boiled in water for 3 minutes to check the asphalt adhesion to the aggregate. Poor asphalt retention can indicate poor compatibility between aggregate and emulsion.

Workability: The workability test measures the ability of the slurry system to be mixed and to remain workable for a period of time (typically two minutes). The slurry mix must also be smooth and homogeneous.

Cohesion: The cohesion testing machine measures the torque obtained during the development of set and cohesive strength. The test results provide information regarding the setting time (time at which slurry

system can not be remixed into a homogeneous state) and the curing characteristics of the slurry mixture (whether or not the slurry system is a quick-set and quick traffic system). A more detailed explanation will be given later under the micro-surfacing section.

Performance Tests: There are two physical tests which are run on the cured slurry to determine the ability of the system to resist wear and flushing under heavy traffic loads; the Wet Track Abrasion Test (WTAT) and the Loaded Wheel Test (LWT)

The wet track abrasion test measures the amount of aggregate loss due to abrasion. The test establishes the minimum quantity of asphalt emulsion that can be used in that system. The Loaded Wheel Test establishes the maximum quantity of asphalt emulsion that can be used without flushing occurring. The loaded wheel compacts the slurry mat and simulates heavy traffic. By monitoring the surface the designer can avoid severe asphalt flushing.

2.2.2 Micro-Surfacing Mixtures

The testing performed to design an adequate micro-surfacing mixture is divided into four categories of tests: compatibility, workability, cohesion and performance. The compatibility tests [1] provide an assessment on how the two main components of the mixture interact with one another with respect to coating and adhesion. The workability test [1] provide an appreciation on how workable the mixture is for placement on the roadway surface. The cohesion test [1] provide an appreciation on how quickly the mixture builds up cohesion and therefore how quickly a freshly applied micro-surfacing system can be reopened to traffic. Finally, the performance tests [1] provide an appreciation on how the slurry surfacing will behave under traffic.

Compatibility tests: The most common test used to determine the compatibility of the aggregate with the emulsion is the Wet Stripping Test (TB-114). The stripping test is performed on the cohesion test sample, which has been cured at 60°C. The sample is boiled in water for 3 minutes to check the asphalt adhesion to the aggregate. If the coating of the aggregate is greater than 90 % after the test, the binder adhesion to the aggregate is considered satisfactory. The Schulze-Breuer and Ruck test (TB-144) is also another test that is performed to check the bonding between the 0 to 2 mm fraction of the aggregate and the bitumen residue of the emulsion. The test specimens are placed in water for six days, tumbled in the Schulze-Breuer machine for 3,600 cycles at 20 RPM, and then immersed in boiling water for 30 minutes. The mixture's properties with respect to absorption, abrasion loss, integrity and adhesion are evaluated and rated. An acceptable system has to meet a certain rating.

Workability test: The workability test (TB-106) is a simple slump test that allows the determination of the amount of water needed to get a homogenous mixture with an adequate consistency to be placed on the roadway surface using the spreader box of a typical micro-surfacing machine.

Cohesion test: The cohesion test (TB-139) simulates the torque applied to the surface of the micro-surfacing by the rubber of a tire turning on its vertical axis. The test consists of measuring the torque necessary to tear apart a 8.0 mm thick by 60 mm diameter specimen using a 32 mm diameter rubber shoe loaded at 200 kPa. The torque is applied at various time intervals ranging from 20 to 270 minutes after casting.

Micro-surfacing mixtures are defined as quickset and quick traffic systems when the torque value of the cohesion test is greater than 1.2 N.m within 20 to 30 minutes and greater than 1.96 N.m within 60

minutes. The torque value of 1.2 N.m corresponds to a cohesion at which the mixture is set and water-resistant and the torque value of 1.96 N.m corresponds to a cohesion that is sufficient to allow rolling traffic.

The cohesion test is also used to determine the optimum amount of mineral filler to be added to the system. The procedure consists of plotting a curve representing the cohesion of the mixture at various mineral filler contents. The highest point on the curve corresponds to the optimum mineral filler content while the shape of the curve provides an indication of the sensitivity of the system to variation in the amount of mineral filler added.

Performance tests: The main purpose of performance tests is to provide the information necessary to optimize the amount of emulsion to be used in the mix. The first test simulates the surface shearing stresses of vehicle tires while braking or turning on micro-surfacing. The test is called the Wet Track Abrasion Test (TB-100) and it provides the information necessary to determine the lower limit of binder needed in the micro-surfacing mixture to provide adequate abrasion resistance. The second test simulates repeated loading of vehicle tires on a micro-surfacing mixture. The test is called the Loaded Wheel Test (TB-109) and it measures the binder bleeding susceptibility of the micro-surfacing mixture at different binder contents. The test is used to determine the upper limit of binder that can be injected in the mixture.

3. CONSTRUCTION

The mixing and the placement of a quickset slurry seal or micro-surfacing mixture are performed simultaneously using a slurry machine. The slurry machine, the site preparation, the fieldwork and the Quality Control/Quality Assurance are important components of the success of slurry mixture application.

3.1 Equipment

Slurry machines are fitted with the following components:

- storage bins and tanks for aggregate, emulsion, water, mineral filler and field additives,
- a pugmill unit for the mixing of the slurry,
- a spreader box for the placement of the slurry.

There are two types of machine used to mix and place slurry systems: truck mounted machines and self-propelled continuous feed machines (Figure 1 and 2). The truck mounted machines are loaded with water, emulsion and aggregates supplies at a central location while the self-propelled continuous feed machines are capable of receiving materials from special nurse units while continuing to mix and apply the mixture. The truck mounted units are often preferred in an urban setting where room to maneuver is limited while the self-propelled continuous feed machines are used in the rural open space type setting.



Figure 1. Truck Mounted Slurry Machine



Figure 2. Self-propelled Continuous Feed Slurry Machine

3.1.1 Metering devices

The calibration of the metering devices that control the feed of each component is essential to ensure that the desired proportioning of each material is obtained. The proportions of emulsion, aggregate and mineral filler do not vary during the mixing and placement operation while the amounts of water and field additives added to the system are often adjusted to ensure that the consistency of the mixture, breaking/setting time remains constant. It is generally necessary to adjust the water content or to use a field additive when the weather conditions changes.

3.1.2 Mixer

Slurry machines are equipped with either a single shaft auger-like mixer or a multi-bladed twin shaft pugmill. The single shaft mixer is used to mix quickset slurry seal mixtures while the twin shaft pugmill can mix either micro-surfacing mixtures or quickset slurry seal mixtures. The length of the mixer varies between 1.0 and 1.3 m and it is powered with a ≈ 30 hp motor in the case of a single shaft mixer and with a ≈ 90 hp motor in the case of a twin shaft pugmill. The mineral filler is placed into the aggregate stream just before it enters the mixer. Then, as the aggregate enters the mixer, the water and the field additives are blended in. Finally, about one-third of the way up the mixer, the emulsion is injected into the mixer. The mixture is then discharged into the spreader box.

3.1.3 Spreading equipment

The slurry machine tows the spreading box, which rides on skis. The spreading box is fitted with seals on all sides to contain the mixture within the box. The height of the rear seal is adjustable to let the mixture flow through at a controlled rate. There are three different configurations of spreader box used to place slurry mixtures: quickset slurry seal box, micro-surfacing box (Figure 3) and rut box (Figure 4).

The quickset slurry seal box and the micro-surfacing box are similar in design and both are used to place the slurry mixture at a uniform rate. The difference between these two boxes is that the micro-surfacing box is equipped with a twin auger system while the quickset slurry seal box is not. The auger system serves two purposes: to further mix the micro-surfacing mixture and to place the mixture evenly in front of the rear part of the spreader box so that it will be placed evenly on the roadway surface. Quickset slurry seal boxes are not equipped with a twin auger system because the fluidity of the mixture is sufficient to allow the mixture to spread itself evenly at the rear of the box.

The micro-surfacing spreader box can be fitted with a steel strike-off blade at the rear of the box to place a scratch layer, which is usually needed to correct the transverse profile of the roadway surface. Many micro-surfacing spreader boxes are also equipped with a secondary rubber strike-off, which is often needed to improve the surface texture of the final micro-surfacing layer.

The rut box is only used with micro-surfacing. It is used to fill pavement rutting (not hot mix instability rutting) between 15 and 40 mm deep in a single pass. Rut boxes are either 1.5 or 1.8 m in width and each wheel path is treated individually. Rut boxes have two V shape metal strike-offs, one in front of the other, with the point of the V towards the rear of the box. They are equipped with two augers installed in a V shape inside the first V shape strike-off. The rut boxes are designed to push the larger particles of the mixture towards the deeper part of the rut. They are also designed to leave a slight crown in the centre to compensate for compaction by the traffic.

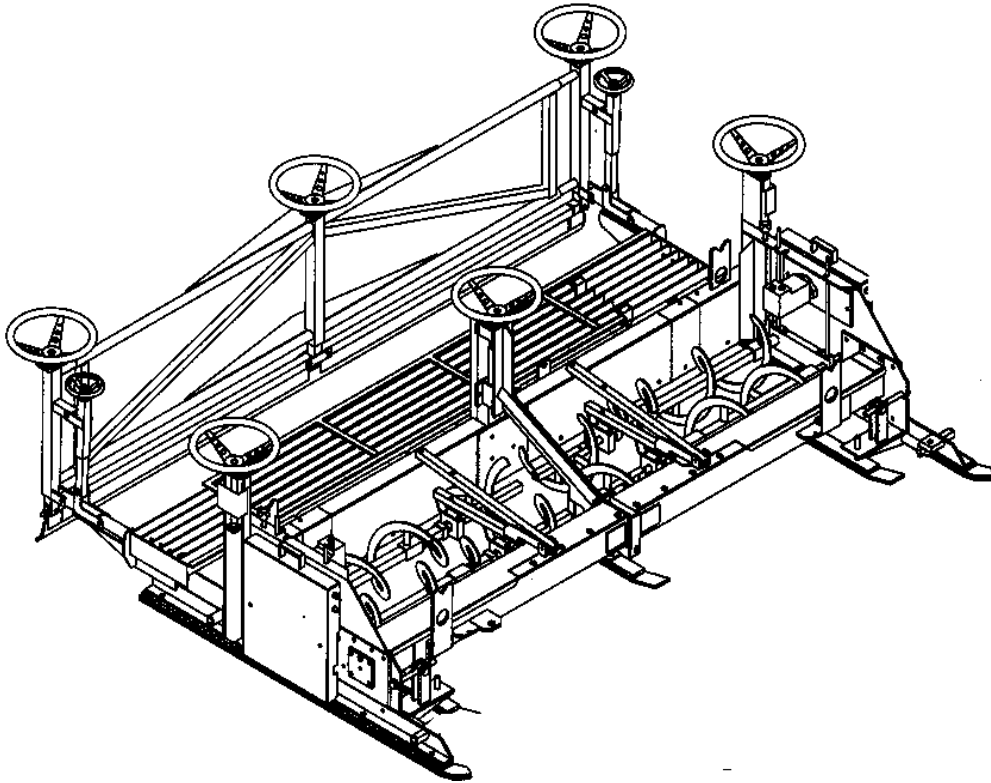


Figure 3. Micro-Surfacing Spreader Box

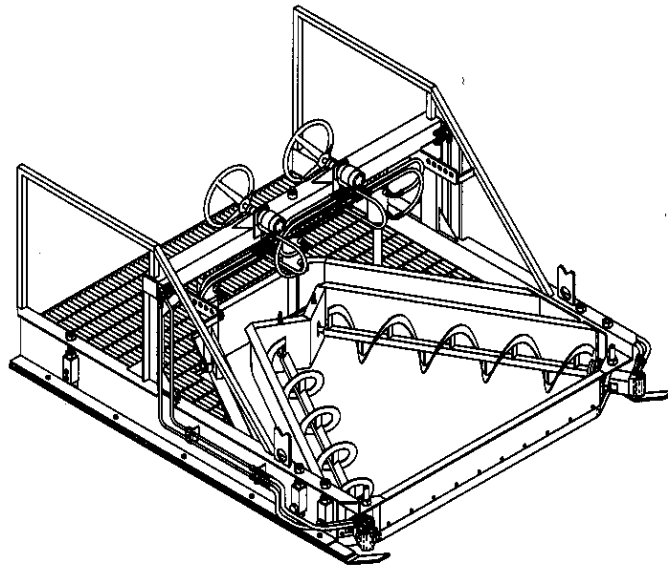


Figure 4. Rut Filling Spreader Box

3.2 Preparation of the Surface

The preparation of the surface of the roadway is very important to ensure the success of a slurry application. Active cracks should be sealed and localized defects should be repaired a few weeks ahead of the slurry application. Thermoplastic bands, arrows, etc. should be scraped off ahead of time as well. Finally, an aggressive sweeping/scraping of the surface is often required to ensure that the surface is free of debris, dust, mud, etc.

Tack coating and/or water fogging is commonly carried out to improve the bonding of the slurry mixture with the roadway surface. When the slurry mixture is placed on a dry and raveled surface, it is a common practice to tack coat the surface prior to the placement of the slurry mixture. The rate of application of tack coat ranges from 0.20 L/m² to 0.40 L/m² of a diluted cationic emulsion (one part emulsion to three parts water). Water fogging of the surface of the roadway facilitates the placement of the slurry mixture by breaking the surface tension between the slurry mixture and the pavement surface.

3.3 Mixing/Placement Operations

3.3.1 Weather Conditions

The handling and placement of a slurry mixture is highly influenced by the weather conditions. The air temperature and the pavement temperature should be above 10°C during placement of the slurry mixture. Slurry mixture should not be placed in rainy conditions, nor should placement occur if the forecast predicts freezing conditions within 24 hours of placement. Very hot and dry weather conditions also influence the placement of a slurry mixture. Under those conditions the mixture tends to break too quickly causing difficulties during placement. A slow breaking emulsion formulation is required under those conditions.

3.3.2 Emulsion Temperature

The emulsion temperature is an important factor with respect to the breaking characteristics of the emulsion. Hot or warm emulsion (above 65°C) tends to break too fast, causing placement difficulties similar to those caused by very hot and dry weather. The best results are obtained when the emulsion temperature is below 40°C.

3.3.3 Mixture Placement

The correct placement of a slurry mixture is obtained when the consistency, the break time and the setting time of the mixture are maintained despite changing conditions such as ambient humidity, wind, shaded areas, temperature, pavement texture, etc. The consistency must be maintained to avoid mixture segregation. Mixtures that are too stiff or too fluid may segregate creating both aggregate rich areas and binder rich areas. The water content must be adjusted in the field to maintain a uniform consistency of the mixture. Field additive is added to the mixing water to retard the break/set of the emulsion in hot weather placement. If the field additive does not lengthen the break/set time of the emulsion sufficiently, an emulsion reformulation is required. On the other hand, when the weather is colder the break/set time may need to be accelerated. The best course of action is to reformulate the emulsion. However, if this is not possible, the option of increasing the amount of mineral filler by an amount generally less than 0.5 % over the mix design recommendation may provide the desired results.

3.3.3 Application Procedure

Quickset slurry seal mixtures are nearly always applied as a single layer system, while micro-surfacing mixtures may be applied either as a single layer system or, more commonly, as a two-layer system. A single micro-surfacing layer may be sufficient when the transverse profile of the existing roadway is good. However, when the surface of the pavement is irregular and/or somewhat rutted (between 5 and 12.5 mm) a two-layer system provides better results. The first layer is applied as a scratch course to improve the transverse profile of the roadway and the second layer provides the final texturing course. In the cases where the ruts are greater than 12.5 mm and up to 40 mm, the rut box spreader is used ahead of time to correct the transverse profile. Again, as a final texturing course, a second layer of micro-surfacing material is applied over the full lane width.

3.3.4 Traffic Time

Both quickset slurry seal and micro-surfacing mixtures are designed to sustain rolling traffic within one hour of placement.

3.4 Quality Control/Quality Assurance

The Quality Control/Quality Assurance activities consist of verifying that the slurry/micro-surfacing mixture is produced in conformity with an approved mix design and that the mixture is placed in accordance with the specification requirements.

3.4.1 Production

The QC/QA activities related to the production consist of verifying that each component of the slurry/micro mixture, aggregate, emulsion, mineral filler, field additive and water are proportioned in conformity with the mix design and that the necessary steps are taken to ensure that the proportioning of these components is maintained. The QC/QA activities also include verification of the homogeneity of the slurry/micro-surfacing mixture.

In order to verify that a slurry/micro-surfacing mixture is produced in conformity with an approved mix-design the following activities are undertaken:

- verification of the equipment and the metering devices to ensure that the slurry machine is in good working order
- calibration of the equipment for proper proportioning of all components
- control of the mixing process to ensure that the mixture is homogenous
- control of the mixture after mixing to verify that the slurry/micro-surfacing mixture is produced in conformity with the mix-design.

3.4.2 Placement

The QC/QA activities concerning the placement of the slurry/micro-surfacing mixture include the verification that the roadway is properly prepared for the placement of the slurry/micro mixture, that the spreading box is calibrated and works properly and that the finished mat is uniform and satisfies the specification requirements.

In order to verify that the slurry/micro-surfacing mixture is placed uniformly the following items are controlled and monitored:

- placement of a tack coat and/or water fogging to ensure a strong bond between the slurry/micro-surfacing mixture and the pavement surface
- rate of application and the speed of slurry machine to avoid possible surface transverse rippling
- use of clean and good rubber strike off to avoid longitudinal streaking
- use of a secondary rubber strike off to reduce or eliminate possible surface transverse rippling
- production, stockpiling, handling and transportation of the aggregate to ensure no contamination by larger particles that may result in tear or drag marks on the mat
- amount of fluid (use of excessive fluid may create excessive inconsistency in the texture of the mat)
- uniform distribution of the mixture within the spreader box to avoid segregation and resulting inconsistency in the mat
- feathering of the longitudinal joints to maintain mat thickness at the joint and to avoid ridges
- use of a string line or other guide to ensure that the edges are straight and neat

4. PROJECT SELECTION

Surface slurry sealing systems are treatments that provide pavement sealing and pavement texturing (Figure 5). It is a thin surface treatment not appropriate to resolve pavement structural deficiencies. Surface slurry sealing systems may be used to restore pavement surface characteristics such as the profile of the cross section of roadway and to provide adequate frictional properties to a polished pavement that may be structurally sound. These systems are well suited as a preventive maintenance treatment to extend the life of sound pavements. Quickset slurry seals and micro-surfacing have been used as temporary treatments on damaged pavements to extend the life of the roadway until funding is available for more extensive rehabilitation work.

4.1 Restoration of Surface Characteristics

Micro-surfacing systems may be used to correct polished roadway surfaces. Pavement frictional characteristics depend on both the macro and micro-texture of the roadway surface. Micro-surfacing mixtures are produced using tough aggregates in terms of hardness and resistance to polishing. The durability of the mixture and the micro-texture of roadway surfaces is maximized. The gradation of micro-surfacing mixtures is also carefully selected to optimize the macro-texture of the pavement surface. Because of the excellent macro and micro-texture characteristics of micro-surfacing, it is selected to restore the frictional properties of many types of roadway surfaces (including polished concrete pavements) in both urban and rural settings

Micro-surfacing systems may be considered to cover light to moderately flushing surfaces. Flushing of HMA (hot mix asphalt) and chip seals is generally caused by different factors such as hot weather, early opening to traffic, and/or excessive binder. The flushing of the surface is somewhat absorbed by a micro-surfacing mixture that is placed in one or two layers with a reduced binder content. On light to moderately flushing areas, leaner micro-surfacing mixtures are effective in mitigating the resurgence of this type of surface defect.



Figure 5. Micro-Surfacing Type II Surface Texture

Micro-surfacing systems may be used to correct the transverse profile of roadway surfaces. Pavement rutting due to sub-grade consolidation in the wheel path over a ten-year period is common. Pavements in that condition are generally structurally sound and the consolidation is stable, but the surface profile is considered defective. Micro-surfacing mixtures are design to be placed in thick lifts or in multiple layers without risk of deformation. Rut filling using a rut box or pavement profiling using a scratch course followed by a surface course are effective means of reinstating the transverse profile of the roadway (Figure 6)

4.2 Preventive Maintenance

Preventive maintenance treatments are low-cost treatments that retard deterioration of the pavement, maintain or improve the functional condition of roadways and extend the pavement's service life when applied on suitable candidates. Preventive maintenance is successful when an appropriate treatment is selected, and the pavement is structurally sound and in relatively good condition. The utilization of preventive maintenance treatments in a pavement management approach that balances the utilization of short and long term treatments can improve the network condition at a significantly lower unit cost than traditional approaches.

Surface slurry sealing systems are surface treatments that provide protection of the pavement surface by delaying the appearance of surface defects caused by both the environment and the associated oxidization of the existing surface. Oxidization of the bituminous surface material leads to surface defects - predominantly raveling, potholes, as well as thermal and age cracking. By sealing the pavement using a



Figure 6. Rut Filling Operation

surface sealing system, the rate at which the existing bituminous surface material oxidizes is greatly reduced. Slurry/micro-surfacing systems are binder rich mixtures (between 8.0 and 10.0 % bitumen), which waterproof and seal existing surfaces, protecting the pavement from the adverse effects of the environment.

5. PERFORMANCE

The performance of surface slurry sealing systems may be evaluated in terms of various aspects of road engineering but predominantly:

- additional frictional properties provided to the existing surface
- surface profile correction
- pavement flushing correction
- protection of the existing pavement from the adverse effects of oxidation.

Other performance criteria such as noise level and uniformity of the surface texture are also important considerations.

5.1 Frictional Characteristics

In many areas in North America the pavement frictional properties are measured using a locked wheel method (ASTM E-274). The locked wheel method simulates emergency braking in wet conditions at the posted speed and the results are reported in terms of Skid Number. The frictional properties of roadways with Skid Numbers equal to or greater than 40 under wet weather driving conditions are considered

adequate. The performance of micro-surfacing treatments with respect to providing improved frictional properties is excellent. Initial Skid Numbers ranging from mid 40s to high 50s are common. Long term Skid Numbers appear to remain high even on high traffic roads.

5.2 Profile Correction

The ability of micro-surfacing to be placed at variable thicknesses makes it well suited to fill ruts or minor surface deformations. Micro-surfacing treatments specifically designed to fill ruts have generally performed well. Consolidation of micro-surfacing rut treatment is considered minimal. Often, further consolidation of the underlying base material of a pavement is the reason why, after a few years of service, the roadways corrected using micro-surfacing exhibit some rutting again.

5.3 Correction of Pavement Flushing

The systematic usage of a micro-surfacing system to correct pavement flushing is not common and the availability of performance information is scarce. Only the State of Texas has reported some results [2] and it appears that micro-surfacing treatments are effective to correct pavement flushing when the flushing is light to moderate.

5.4 Pavement Sealing

Pavement sealing using a slurry/micro-surfacing system is very effective. The service life extension of a pavement treated with slurry/micro-surfacing system ranges between 4 to 8 years, depending on the condition of the existing pavement and the volume of traffic.

5.5 Noise Level

The rolling noise level of slurry/micro-surfacing system is generally associated with the coarseness of the surface texture. As traffic kneads the surface, the coarseness of the surface texture diminishes over time and the noise level decreases as a result. The rolling noise of slurry/micro-surfacing systems is equivalent to HMA surfacing with similar surface texture.

6. CONCLUSIONS

The development of surface slurry surfacing systems has accelerated substantially in the last decade. Applicators have access to sophisticated systems that may be designed to satisfy a wide range application, rural and urban as well as low and high traffic roads. The placement of a traditional quickset slurry seal on low traffic roads extends the life of the pavement for 4 to 8 years. The placement of a fiber modified micro-surfacing system on high traffic roads offers a competitive alternative to traditional methods of restoring surface characteristics of roadways and preserving pavements (Figure 7).

The concept of pavement preservation (as opposed to existing strategies of reactive treatments and reconstruction) is gaining acceptance in North America. The pavement preservation concept advocates the improvement of the overall condition of road networks asset rather than that of a single road at a time. The use of preventive maintenance treatments is an essential part of a pavement preservation strategy. Hence, the use of surface slurry surfacing system to preserve pavements is becoming the preferred choice by many North American road agencies.



Figure 7. Micro-Surfacing after a few months of service

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