**PROJECT 06-01 (PHASE II)**

# GUIDE FOR PREVENTION AND MITIGATION OF NON-LOAD-ASSOCIATED DISTRESS

Submitted to:

Airfield Asphalt Pavement
Technology Program
(AAPTP)
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May 15, 2010

AMEC Project No. 0911900948

## ACKNOWLEDGEMENT OF SPONSORSHIP

This report has been prepared under the Airport Asphalt Pavement Technology Program (AAPTP). Funding is provided by the Federal Aviation Administration (FAA) under Cooperative Agreement No. 04-G-038. Dr. Satish is the Manager of the Pavement Test Facility at the William J. Hughes Technical Center. Dr. David Brill is the Contracting Officer's Technical Representative and a Program Manager in the FAA Technology Research and Development Branch at the William J. Hughes Technical Center. Mr. Monte Symons served as the Project Director for this project.

The AAPTP and the FAA thank the Project Technical Panel members who willingly gave of their expertise and time for the development of this report. They were responsible for the oversight and the technical direction. The names of the individuals on the panel are as follows:

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## DISCLAIMER

# EXECUTIVE SUMMARY

Hot-mix asphalt (HMA) pavements in the United States represent a considerable investment in the infrastructure of airfields, and it is in the interests of the Federal Aviation Administration as well as airport managers and engineers to maintain those airfield pavements in good condition and extend their service lives. A pavement maintenance/monitoring plan helps preserve that investment and is also a prerequisite for federal funding under the Federal Aviation Act of 1994.

HMA pavements are subject to two kinds of wear: those due to loads (such as the weight of airplanes and maintenance vehicles) and those from non-load-associated sources, such as aging and climate. A wide range of climatic conditions can cause non-load-associated distresses, such as thermal (block) cracking, longitudinal and transverse cracking, and surface deterioration (raveling and weathering), and many products and procedures are available as preventative or corrective measures to address those types of distresses.

Choice of the appropriate pavement technology, product, and procedure is important, as is cost-effectiveness, since many HMA pavements are found at small, lightly trafficked airfields with limited funds for repair and maintenance. Until now, however, no comprehensive guide has existed to provide information about the methods and materials available, how to apply them, their cost-effectiveness, and their relative advantages and disadvantages. The *Guide for Prevention and Mitigation of Non-Load-Associated Distress* provides that necessary guidance.

This guide describes the various types of non-load-associated distresses and their causes and discusses how to accurately gauge the condition of a pavement using ASTM's Pavement Condition Index and determine the most appropriate time for pavement rehabilitation by using the "trigger point" ("critical value") system. Various types of materials—asphalt cement, asphalt emulsion, asphalt cutback, coal tar and aggregates—are used to construct HMA pavements, and all are described along with their relative susceptibility to non-load-associated distress.

Diverse pavement preservation techniques can be used to extend the serviceability of HMA pavements, such as spray-applied sealing systems, chip seals, slurry seals, cape seals and microsurfacing. Each technique is described in detail and discussed in terms of its function, materials and relevant specifications, advantages and disadvantages, life expectancy, and proper application/construction, including quality assurance and troubleshooting.

By creating this guide, the Federal Aviation Administration hopes to provide a practical manual that will help the nation's airfield personnel better maintain and preserve their HMA pavements and provide better results for lower costs. This guide is intended to be used with its companion report, Techniques For Prevention And Remediation Of Non-Load-Associated Distresses On Hma Airport Pavements. The information and recommendations in this report are based on a review of the published literature and discussions with industry representatives, federal and state aeronautics administrators and airfield engineers.

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# CHAPTER 1.0 INTRODUCTION

## 1.1 PROBLEM STATEMENT

Hot-mix asphalt (HMA) pavements in the United States represent a considerable investment in the infrastructure of airfields. Many of those airfield pavements are found at small, lightly trafficked airfields that have limited funds for the repair and pavement maintenance to protect their investment. These airfields exhibit a wide variety of distresses, most of which are unrelated to traffic loading. Rather, these distresses are caused by age-related hardening of the asphalt binder, which results in block cracking or raveling of the surface, or by extreme fluctuations in the temperature of the HMA surface, which results in thermal cracking.

Many products and procedures exist to deter, reduce, repair or prevent these type of distresses and to extend the usable life of an HMA pavement. Until now, however, airfield managers and engineers in the United States have had no comprehensive guide to the methods and materials available, how to apply them, their cost-effectiveness and their relative advantages and disadvantages. The *Guide for Prevention and Mitigation of Non-Load-Associated Distress* provides that necessary guidance.

## 1.2 OBJECTIVES

Airport Asphalt Pavement Technology Program (AAPTP) Project No. 06-01 represents the second phase of AAPTP Project No. 05-07, Techniques for Prevention and Remediation of Non-Load Associated Distresses on HMA Airport Pavements, which was a study into common non-load-associated problems affecting HMA airfield pavements and the products and procedures that could be used to combat those problems. Project No. 06-01 consists of two independent activities:

- Preparation of this guide
- A laboratory and field study to develop a test procedure that can predict when action is needed to prevent non-load-associated distress

This report, *Guide for Prevention and Mitigation of Non-Load-Associated Distress,* presents information about measures that the engineers and administrators of the nation’s airfields can take to mitigate or prevent non-load-associated distress in HMA pavements and to provide a detailed discussion of the materials and techniques involved. By providing this guide, the Federal Aviation Administration hopes to encourage the quality construction of HMA pavements and the application of the appropriate pavement preservation techniques at the appropriate time in the existence of airfield pavement systems.

The information and recommendations in this report are based on a review of the published literature and discussions with industry representatives, federal and state aeronautics administrators, and airfield engineers.

## 1.3 NON-LOAD-ASSOCIATED DISTRESS

Non-load-associated distresses include block cracking, longitudinal and transverse cracking, and raveling and weathering. They are described in detail below.

### 1.3.1 Block Cracking

Block cracks are interconnected cracks that divide the pavement into approximately rectangular pieces. The blocks may range in size from approximately 1 foot by 1 foot to 10 feet by 10 feet. The primary cause of block cracking is a volume change within the HMA caused by daily temperature cycling, which results in daily stress/strain cycling. Block cracking usually indicates that the asphalt binder has hardened significantly. Block cracking normally occurs over a large portion of pavement area, but sometimes will occur only in nontraffic areas.

### 1.3.2 Longitudinal and Transverse Cracking

Longitudinal cracks are parallel to the pavement's center line or "laydown" direction. They may be caused by the following:

- A poorly constructed paving lane joint
- Shrinkage of the HMA pavement due to low temperatures or hardening of the asphalt binder
- A reflection crack caused by cracks beneath the surface course, including joints and cracks in Portland cement concrete slabs

Transverse cracks may extend across the pavement at approximately right angles to the pavement's center line or direction of laydown. They may be caused by pavement shrinkage or reflection cracks. Transverse cracks are not usually associated with loads.

Longitudinal cracking may also result from traffic loading. This cracking occurs in the wheel path and can deteriorate very rapidly if moisture is allowed to pass through the cracks into the pavement's underlying layers.

### 1.3.3 Raveling and Weathering

Raveling and weathering are the wearing away of the pavement surface caused by the dislodgement of aggregate particles and loss of asphalt binder. Such damage may indicate that the asphalt binder has become brittle due to environmental effects. It also can result from poor construction techniques, such as inadequate compaction.

# CHAPTER 2.0 MITIGATION OF NON-LOAD-ASSOCIATED DISTRESS

## 2.1 INTRODUCTION

Chapter 107(E) of the Federal Aviation Act of 1994 requires that after January 1, 1995, a grant for the construction, reconstruction or replacement of an airport pavement may be approved only if the sponsor has provided assurances or certifications that they have implemented an effective pavement maintenance/management program. The sponsor must establish and maintain a pavement management program that details the procedures that will be taken to assure that proper maintenance is performed. The Federal Aviation Administration (FAA) does not specify the details of the pavement management program, only that the program should be simple and straightforward.

The software many state aeronautics departments use to document airfield pavement conditions is MicroPAVER, often referred to simply as “PAVER.” PAVER’s database is used to document the following information:

- The location, dimensions and pavement types of all runways, taxiways and aprons.
- The year of construction and most recent major rehabilitation
- The results of periodic pavement condition surveys

PAVER further provides state aeronautics departments with easy access to crucial data so they can more effectively monitor and manage their airport pavements.

The procedure to document the condition of an airfield is described in ASTM D5340, Standard Method for Airport Condition Index Surveys. This procedure is used to develop the data required to calculate the Pavement Condition Index (PCI) for each feature on an airfield. The PCI is used to document the condition of a particular pavement feature using a numerical index ranging from 0 for a failed pavement to 100 for a pavement in perfect condition (see Figure 2.1). Calculation of PCI is based on the results of a visual condition survey that identifies distress type, severity and density. The PCI number reflects the structural integrity and surface condition of the pavement; it does not provide any information about the structural capacity of a particular airfield feature.

| | |
|---|---|
| 100 | Good |
| 85 | Satisfactory |
| 70 | Fair |
| 55 | Poor |
| 40 | Very Poor |
| 25 | Serious |
| 10 | Failed |
| 0 | |

***Figure 2.1 Pavement Condition Rating Scale***

Figure 2.2 provides a conceptual depiction of a PCI deterioration curve. These PCI values can be used to monitor the condition of a pavement surface. If they are plotted against time, the result is a deterioration curve. The shape of the curve and the speed at which a pavement deteriorates is a function of the environment and the loadings that are applied. This system can also be used by an airport to document and monitor the condition of the road system on the airport.

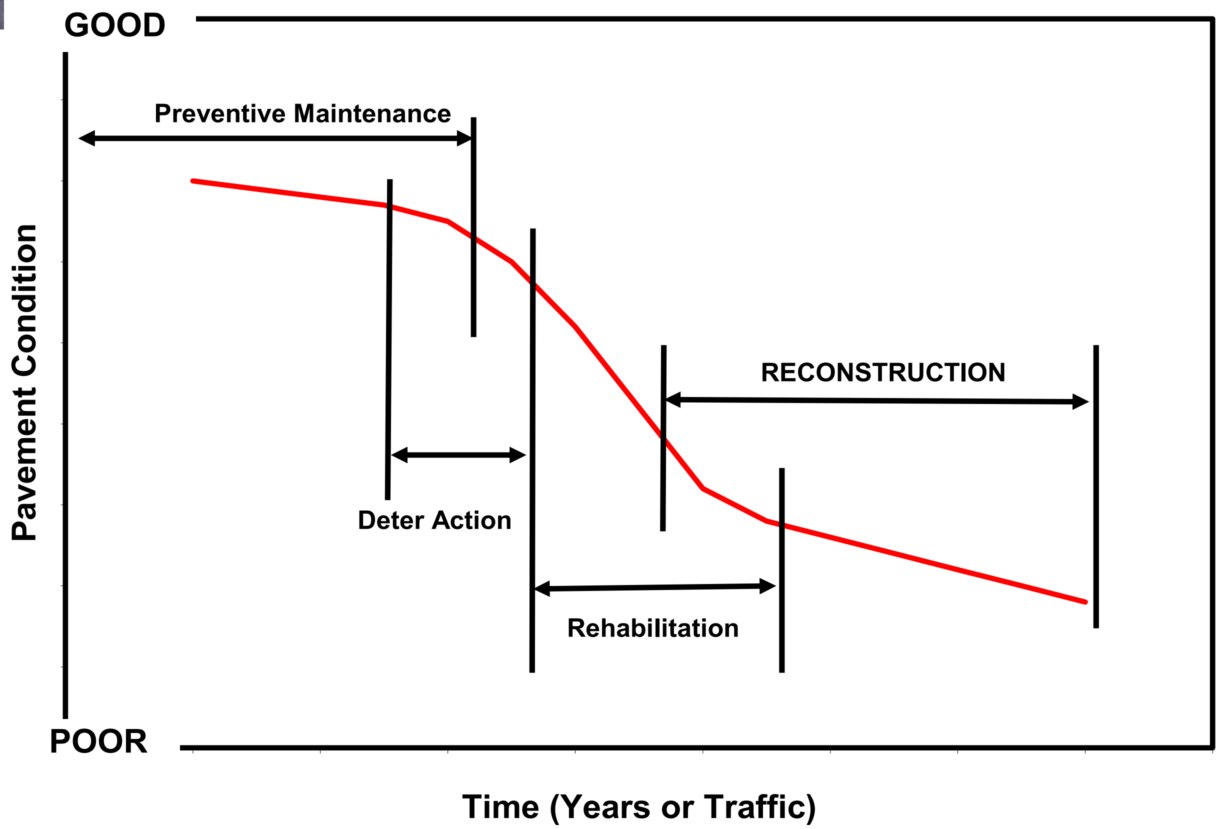


***Figure 2.2 PCI Deterioration Curve***

Preventing potential pavement problems takes less time and money than taking corrective actions. More and more airports are constructing new pavements with higher-quality materials. These include Superpave performance-graded asphalts as well as mix designs developed to address climate-specific problems such as thermal cracking and other distresses. FAA Engineering Brief No. 59a provides guidance and an interim specification, P-401(SP), for Superpave mixtures. This interim specification can be used on all runway, taxiway and apron pavements. Improved asphalt binders with polymers and other additives have been found to decrease raveling and increase durability in the most difficult climates.

As stated above, implementation of an effective pavement management system is required for any project to replace or reconstruct airfield pavements. The most cost-effective programs include both preventive and corrective actions. FAA Advisory Circular No. 150, Guidelines and Procedures for Maintenance of Airport Pavements, gives specific guidelines and procedures for maintaining airport pavements and establishing an effective maintenance program. The circular includes specific types of distress, their probable causes, inspection guidelines and recommended methods of repair. The FAA does not prescribe the exact format of a local program, allowing each agency or airport to customize its system to suit local needs, conditions and resources. The techniques, therefore, vary significantly.

## 2.2 SELECTION OF PROCEDURE TO MITIGATE NON-LOAD-ASSOCIATED DISTRESS

Many factors need to be considered when selecting an appropriate approach for the prevention and mitigation of non-load-associated distresses. These include pavement age, condition, climate, traffic type, and whether the pavement section is a taxiway or runway subjected to high-speed aircraft movement or an apron with turning movements that may scuff the surface.

Figure 2.2 presented the traditional approach to pavement management, which emphasizes the response to deterioration. The pavement preservation concept views the problem in terms of continuous prevention and rehabilitation, as illustrated in Figure 2.3. Pavement preservation has been defined as a cost-effective set of planned practices that extend pavement life and improve safety and function while saving public tax dollars. Pavement preservation consists of three components:

- Preventive maintenance
- Minor rehabilitation (nonstructural)
- Routine maintenance

The goal of a pavement preservation program is to reduce aging, extend service life, and in some cases restore the function of the existing pavement. Note that the deterioration curve shapes in Figure 2.3 can vary. Different pavements will have different deterioration curves depending on the environment and traffic.

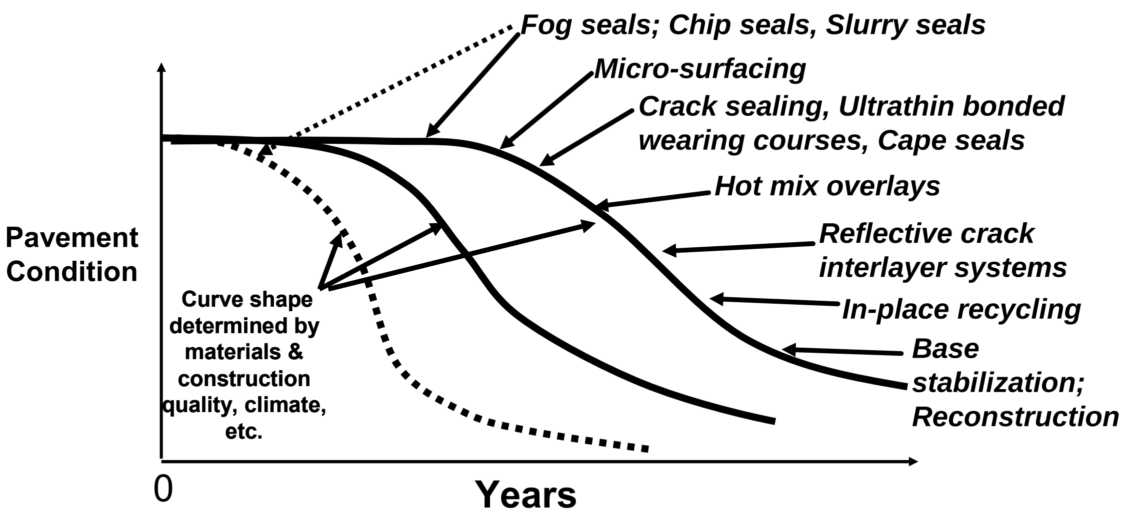


***Figure 2.3 Pavement Preservation - Optimal Timing of Pavement Treatments***

Figure 2.4 illustrates how a planned sequence of treatments can extend pavement service life. The solid lines represent surface treatments such as fog or slurry seals, while the dotted lines indicates more robust treatments, such as a hot-mix asphalt (HMA) overlay.

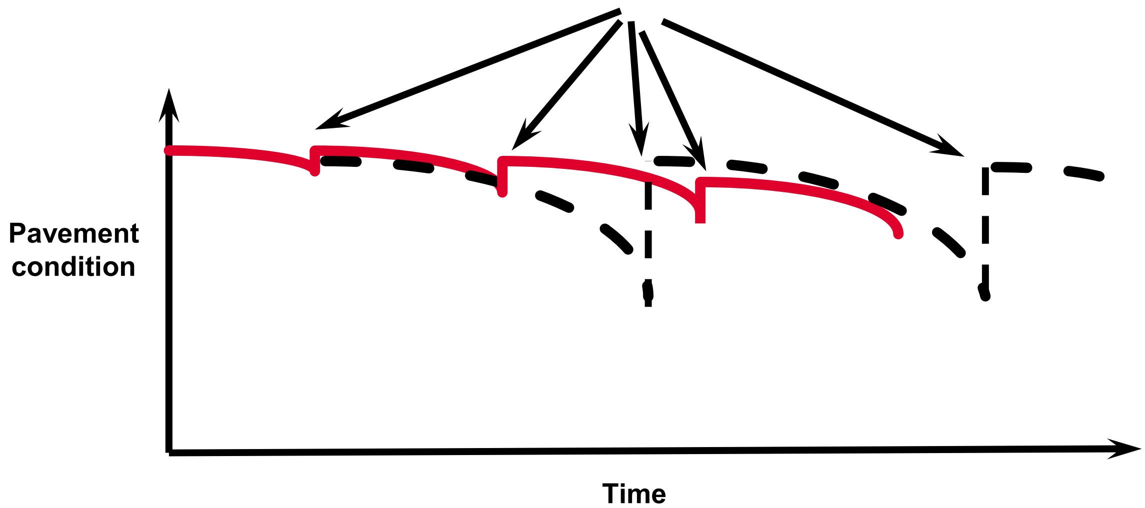


***Figure 2.4 Pavement Preservation Strategies to Prolong Pavement Life***

The steps in the selection of the proper preservation strategy include the following:

- Assessing the existing condition – For airfield pavements, this is generally done using the Paver Procedure developed by the U.S. Army Corps of Engineers. Some state aviation agencies use other procedures. Many have been developed locally. The key is to use some type of systematic process to assess and document the condition of the features in the airfield pavement system. The pavement structure should also be evaluated. This can be done using sample pits and standard laboratory testing, or it can be done using the falling-weight deflectometer described in the FAA Advisory Circular No. 150/5370-11a, Use of Nondestructive Testing Devices in the Evaluation of Airport Pavement.
- Identifying and ranking feasible treatment strategies – This step includes an assessment of the functional and structural ability of the pavement to meet future needs of the airfield, as well as feasible treatments. While a number of methods are available in the marketplace, the feasibility depends upon the local availability of quality materials and workmanship, relative cost-effectiveness and timing, and available funds.

The best approach to reducing non-load-associated distresses in HMA pavements is to create and fund a strong pavement preservation program based on traditional and newly developed applications. This includes common preventive maintenance activities such as crack sealing and surface treatments (fog seals and slurry surfacing seals). The objective is to retard the deterioration and prolong the life of the pavement by applying these preventive maintenance treatments before damage is visible. If the pavement structure is sound, but surface cracking has progressed beyond a state where conventional preventive maintenance tools can be effective, the pavement may be a candidate for an overlay or, if the distress is severe enough, complete reconstruction.

Conducting preventive maintenance activities on a sound pavement in good condition is usually the most cost-effective alternative. House painting is a good analogy for preventive maintenance. As with painting a house, the effectiveness of pavement preservation tools are directly related to the condition of the surface at the time of application. Table 2.1 gives expected life extensions of various treatments, showing that treatment application at the right time (PCI level) results in a longer-lasting pavement.

***Table 2.1 Effectiveness of Treatments Based on PCI***

| | Estimated Life (years) | | |
|---|---|---|---|
| **Surface Treatment** | **Good Condition (PCI = 80)** | **Fair Condition (PCI = 60)** | **Poor Condition (PCI = 40)** |
| Spray-Applied Seal | 3 to 5 | 1 to 3 | 1 to 2 |
| Chip Seal | 7 to 10 | 3 to 5 | 1 to 3 |
| Slurry Seal | 7 to 10 | 3 to 5 | 1 to 3 |
| Microsurfacing | 8 to 12 | 5 to 7 | 2 to 4 |

An inappropriate repair (either method or timing) can accelerate the rate of deterioration of the pavement. One useful tool applicable to all asphalt preservation activities is the Pocket Guide to Asphalt Pavement Preservation, which is co-published by the Federal Highway Administration and FP$^2$, Inc. (formerly the Foundation for Pavement Preservation). Printed copies are available from the National Center for Pavement Preservation (NCPP), or it may be downloaded from the NCPP website at http://www.pavementpreservation.org/toolbox/links/PPGuide.pdf. The pamphlet includes a pavement rating form along with a table that shows the distress types and levels that are appropriately remediated by each type of treatment and summaries of the treatment types. The NCPP website (www.pavementpreservation.org) and the American Association of State Highway and Transportation Officials website (www.tsp2.org) offer a wealth of additional information on all aspects of pavement preservation.

The major cause of asphalt embrittlement in HMA pavements is oxidation. Therefore, one goal of pavement preservation is to delay aging by restricting the supply of oxygen to the pavement, which is accomplished by reducing the surface permeability. Another important goal of preservation is to protect the pavement from moisture damage, which can also be delayed by reducing surface permeability. This can be done with varying degrees of success by applying spray-applied seals, chip seals, microsurfacing, slurry seals or other applications that apply asphalt emulsion to the surface in sufficient quantities to prevent intrusion of air and water. Heavier emulsion applications may be needed when surface permeability is high. Unsealed cracks serve as pathways for moving air and water into underlying layers, so cracked, permeable pavements may not be candidates for preventive seals, unless the cracks are sealed before treatment. Since some oxygen will always be available to the asphalt, sealing strategies are most effective if applied early, before binder properties age to critical cracking conditions. The objective is to apply the surface seal prior to the point where the curve begins to bend downward.

## 2.3 TIMING OF TREATMENTS

The timing of treatments depends on the condition of the pavement, the expected service life and the cost of the treatment. The goal is to place “the right treatment at the right time.” One approach to determining treatment timing is the use of the “trigger point” or “critical value” concept proposed by Bekheet, et al. It can be used to develop pavement strategies that would impact the overall performance of a pavement system. They suggested that by regularly monitoring and documenting these indices, the optimum time for application can be identified. Their concept is presented in Figure 2.5.

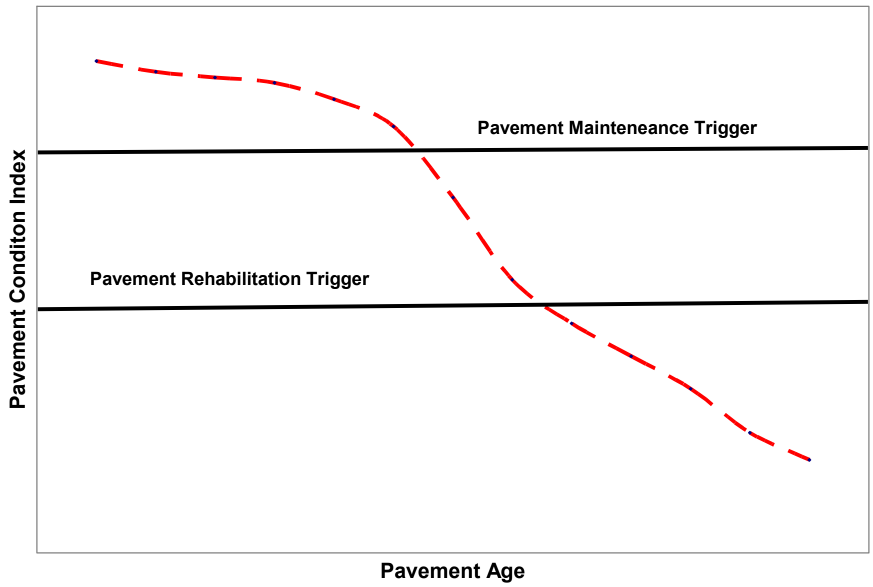


***Figure 2.5 Concept of Trigger Points for a Preventive Maintenance Strategy***

When rehabilitation is accomplished at the trigger point, the deterioration curve is moved up and a new deterioration curve is defined. In some cases, this is a major alteration in the curve. Bekheet and his colleagues developed the following table based on their experience. Table 2.2 provides an estimation of the life expectancy that can be achieved by the use of different treatment types.

***Table 2.2 Estimation of the Impacts of Different Treatment Types on the Life of an HMA Pavement***

| Strategy | Impact on Pavement Performance |
|---|---|
| Route and Seal | Extension of Service Life by 2 or 3 Years |
| Mill and Patch (20%) | Improvement of PCI Condition by 5 to 7 PCI Condition points |
| Microsurfacing | Improvement of PCI Condition by 10 to 12 PCI Condition Points |
| Mill and Pave | Modeled Using Performance Data |

The following two curves (developed during Phase I of this study) (Figures 2.6 and 2.7) are examples of how this concept could work. The two curves were developed using pavement condition data from Arizona. The first curve, in Figure 2.6, shows the effect of using a slurry seal on the pavement. The pavement's service life without the slurry seal would have been 20 years. With the addition of the slurry seal (top line), its service life has been extended to 24 years. In this example, the slurry seal was placed when the pavement was about eight years old. It shows that if another slurry seal had been placed on this pavement, the service life of the pavement might have been extended further.

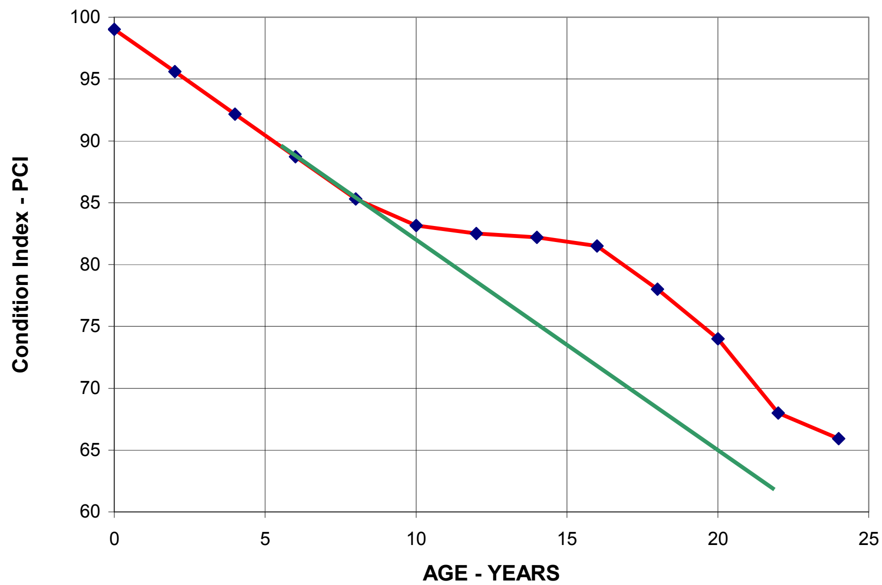


***Figure 2.6 Slurry Seal Example***

Figure 2.7 looks at the effect of letting the pavement continue to deteriorate until it needs major rehabilitation. In this case, it is also a pavement from Arizona where the condition dropped to a PCI of 60 and then was overlaid with a new layer of HMA.

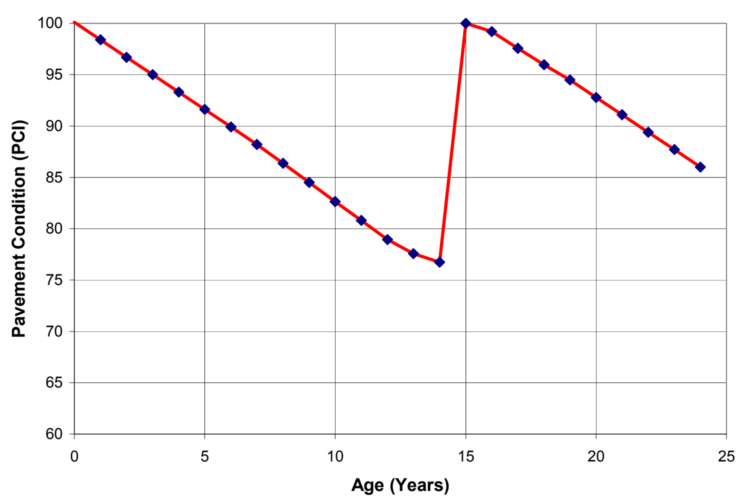


***Figure 2.7 Overlay Example***

A number of states have successfully used this concept to manage their pavement systems. Table 2.3 provides the critical values used by the Washington Department of Transportation (DOT) for HMA surfaces.

***Table 2.3 Critical PCI Values Used by the Washington DOT***

| Load Classification (lb.) | PCI Values | | |
|---|---|---|---|
| | Runway | Taxiway | Apron |
| Less than 60,000 | 65 | 60 | 60 |
| Greater than 60,000 | 70 | 65 | 60 |

Note: lb. = pound(s)

The following work types were established jointly by the FAA and the Washington DOT:

- Spray-applied seals for pavements with PCI values ranging from 85 to 95 if the pavement age is greater than five years. The application interval is four to five years.
- Slurry seals when airport pavements have PCI values ranging from 75 to 84 with an application interval of five years.
- Overlay when pavements have PCI values that are greater than 40, but less than their critical PCI values.
- Reconstruction when PCI values are less than 40.

Table 2.4 provides the criteria used by the State of Arizona.

***Table 2.4 Arizona DOT Criteria***

| PCI Value | Action Taken |
|---|---|
| 85 to 100 | No Action |
| 70 to 80 | Slurry Seal |
| 55 to 70 | Place an Overlay |
| Less than 55 | Replace |

The state of Oregon has divided its airports into five categories:

- Category 1 – commercial
- Category 2 – business
- Categories 3, 4 and 5 – general aviation

The Oregon DOT has established the critical PCI values shown in Table 2.5 for each category shown in the following table. These are the values at which the pavement section needs to be replaced.

***Table 2.5 Critical PCI Values Used by the Oregon DOT***

| Category | Runways | Taxiways | Aprons |
|---|---|---|---|
| 1 and 2 | 65 | 60 | 50 |
| 3 and 4 | 60 | 55 | 50 |
| 5 | 55 | 50 | 45 |

During the Phase I study for Airport Asphalt Pavement Technology Program Project No. 05-07, the interviews and telephone conversations with aviation personnel indicated that the decision for when and what various techniques are used is in part based on local preference and the experience of the engineer or aviation director. Analysis of PAVER pavement management data, however, showed that trigger points or critical values were being employed, whether subjectively or intentionally, to indicate when various mitigation techniques should be used. The following list presents the trigger points and deterioration rates for commonly used mitigation procedures. The deterioration values should be used with care; the data used to develop them are limited and may not reflect the construction quality of the treatment or other maintenance that was done but that was not reported.

Typical PCI Trigger Points

- Spray-applied seals
    - PCI at time of treatment – 75 to 90
    - Deterioration rate – 1.45 PCI points per year
- Slurry seals
    - PCI at time of treatment - 75 to 85
    - Deterioration rate – 1.91 PCI points per year
- Overlays or reconstruction
    - PCI at time of treatment - 60 to 65
    - Deterioration rate – 1.41 PCI points per year

## 2.4 CONCLUSION

The most important step in mitigating the effects of non-load-associated distress is developing a preservation plan that becomes effective soon after construction. This plan should include periodically monitoring the pavement condition both formally, using a pavement management procedure such as PAVER, or informally through periodic visual inspections. Trigger points for specific mitigation techniques should then be developed for each state or agency and for each individual airport.

# CHAPTER 3.0 MATERIALS

## 3.1 INTRODUCTION

A hot-mix asphalt (HMA) pavement is a layered system that consists of a layer of HMA placed on top of a series of other structural layers (see Figure 3.1). There are two failure modes for an HMA pavement, structural and non-load associated.

The structural design of an HMA pavement consists of building a pavement system that distributes the wheel load (from either an aircraft or truck) over the weaker layers in the pavement. The philosophy of the structural design of a HMA pavement is as follows:

- To provide sufficient total pavement thickness above any layer (base, sub-base, and subgrade) to prevent permanent deformation in that layer; and
- To provide enough thickness in each of the layers in the pavement system (HMA layer, base and sub-base) to limit the fatigue cracking of the HMA layer.

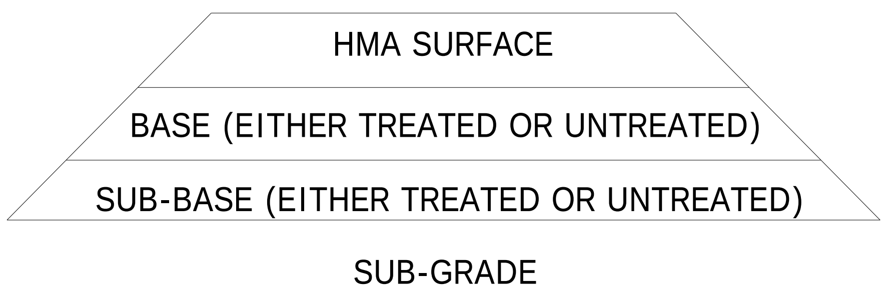


***Figure 3.1 HMA Pavement Structure***

The specific types of materials used, their thicknesses, and their relative positions in the pavement system will have a significant influence on the structural response of the pavement. Table 3.1 presents the function of each of the pavement layers.

***Table 3.1 Structural Function of the Layers of an HMA Pavement***

| Layer | Function |
|---|---|
| Surface | • Provides structural capacity<br>• Provides a smooth riding surface<br>• Provides a barrier against moisture intrusion from the surface<br>• Provides frictional resistance |
| Base | • Adds significant structural capacity<br>• Helps to distribute the load<br>• If it is a permeable base, keeps the pavement system strong |
| Sub-base | • Adds structural capacity |
| Subgrade | • Ultimately carries traffic loadings |

When an HMA pavement structure fails due to loading, it can take primarily two forms: alligator cracking or rutting. Alligator cracking develops when there is a fatigue failure in the HMA layer or a stabilized layer in the pavement system. Rutting occurs when the HMA layer does not have sufficient shear strength to withstand the loading being applied to it or when the subgrade or other layers in the lower part of the pavement do not have sufficient strength to withstand the loading applied to the pavement system.

The other failure mechanism for HMA pavement surfaces is not associated with load. Non-load-associated distresses are caused by the oxidation and hardening of the asphalt binder in the surface. When the binder hardens, the HMA layer can no longer withstand the temperature cycling that occurs in the pavement system. The result is block cracking and raveling.

This section discusses various types of paving materials and their susceptibility to non-load-associated distress. For information about the construction of HMA airfield pavements, refer to Airport Asphalt Pavement Technology Program Project No. 05-01, *Airfield Asphalt Pavement Construction Best Practices Manual.*

## 3.2 ASPHALT

### 3.2.1 Asphalt Cement

Asphalt cement is produced by refining crude oil. It is a thermoplastic material that varies in consistency depending upon its source and its processing method. It is a semisolid at ambient air temperatures. It is liquefied for mixing or spraying by increasing its temperature to about 250 to 325 degrees Fahrenheit (ºF) so that it will readily coat aggregate and permit placing and compaction of the asphalt mixture in a pavement structure. Upon cooling, the asphalt cement returns to its semisolid state and securely holds the aggregate particles in place. Asphalt cement is specified using the Superpave performance-graded (PG) asphalt specification, American Association of State Highway and Transportation Officials M 320.

The testing used for the PG asphalt specification simulates the critical stages in the life of asphalt cement — from transportation, storage and handling to mix production and construction. Ultimately it simulates the effects of aging of the asphalt cement. The PG binder is designated as a PG xx-yy. The PG stands for “performance graded” and the “xx” represents the high-temperature properties of the asphalt cement. The higher this value is, the stiffer the asphalt cement will be; generally this results in an asphalt cement that is more resistant to rutting or permanent deformation of the asphalt layers. For example, a PG 76-yy will generally provide better rutting resistance than a PG 64-yy. The 22, or “yy” value in the example, represents the low-temperature properties. As this number is reduced, the low temperature properties of the asphalt cement are improved. For instance, a PG xx-34 will have better low-temperature properties than a PG xx-22. These grades vary depending on climate — in Alabama, for example, a typical asphalt cement would be a PG 64-22; in North Dakota, it would be PG 58-34 ;and in Arizona, it would be PG 70-10.

Many times, modified asphalts are used. Modified asphalt binders may be produced in a number of ways with includes polymer and/or chemical modification. Polymer modification is the most prevalent. Polymers are elastomeric compounds (similar to rubber) that can cause two different reactions when blended into asphalt cement. In one case, the polymer forms discrete particles in the asphalt binder, functioning primarily as a thickener, which increases the viscosity or stiffness of the asphalt binder.  This stiffening effect will have no significant effect on the low-temperature properties.  The result is an increase in the high-temperature grade (for example, from a PG 64-yy to a PG 76-yy). In the second case, the polymer forms a continuous network in the asphalt binder, creating a homogeneous blend. The result can be an improvement in the high- and low-temperature properties of the asphalt binder. Polymer-modified asphalt binders have been shown to extend the service life of an asphalt pavement. They can provide better rutting resistance, fatigue endurance and durability (resistance to non-load-associated cracking).

The chemistry of the crude oil source contributes to asphalt aging. The reaction of aromatic molecules in the asphalt binder with oxygen results in age-related embrittlement (hardening) of the asphalt binder. Some asphalt crude sources are more susceptible to age-related hardening than others. The implementation of the Superpave asphalt specifications was in part designed to address those problems. If the proper Superpave grade is chosen for an HMA pavement, the non-load-associated distress can be reduced.

Asphalt binder aging, with the resulting loss in elasticity (ductility), is most severe at the pavement surface where temperatures are greatest during the summer. Thus, the top surface of the pavement will age faster. During the winter, cracks will initiate at the brittle surface where cooling occurs most rapidly, temperature swings are greatest, and pavements record their lowest temperatures. Because softer binders have lower initial cold temperature stiffness, one easy solution might be to specify a lower low-temperature PG for surface mixes — for example, specifying a PG 64-28 instead of a PG 64-22.

### 3.2.2 Asphalt Emulsions

Asphalt emulsions are suspensions of either asphalt cement globules in water, or water suspended in asphalt. Chemical emulsifying agents are incorporated to maintain the stability of the suspension by creating self-repelling electrical charges on the surface of each asphalt-water interface until the appropriate time for "breaking" is reached. An emulsion breaks, or “sets,” through one of two mechanisms. The simplest mechanism is water evaporation, a relatively slow process that leaves the emulsion residue tender and sensitive to traffic for many hours. To make emulsion use more consistent with user demands that roads remain open to traffic, many emulsions are formulated to chemically destabilize soon after application, either by reacting with the aggregate, or through the addition of break control agents. Chemical break allows the tiny asphalt droplets to coalesce quickly into a continuous asphalt film, squeezing out water so traffic may be returned in one hour or less. Emulsions can also break prematurely, either in the tank or on an aggregate surface before the emulsion has been uniformly dispersed and placed. For example, emulsions will break prematurely when frozen, or when mixed with excessive amounts of dust, clay or other very fine materials. See figure 3.2 for a graphical explanation of the curing process for asphalt emulsions.

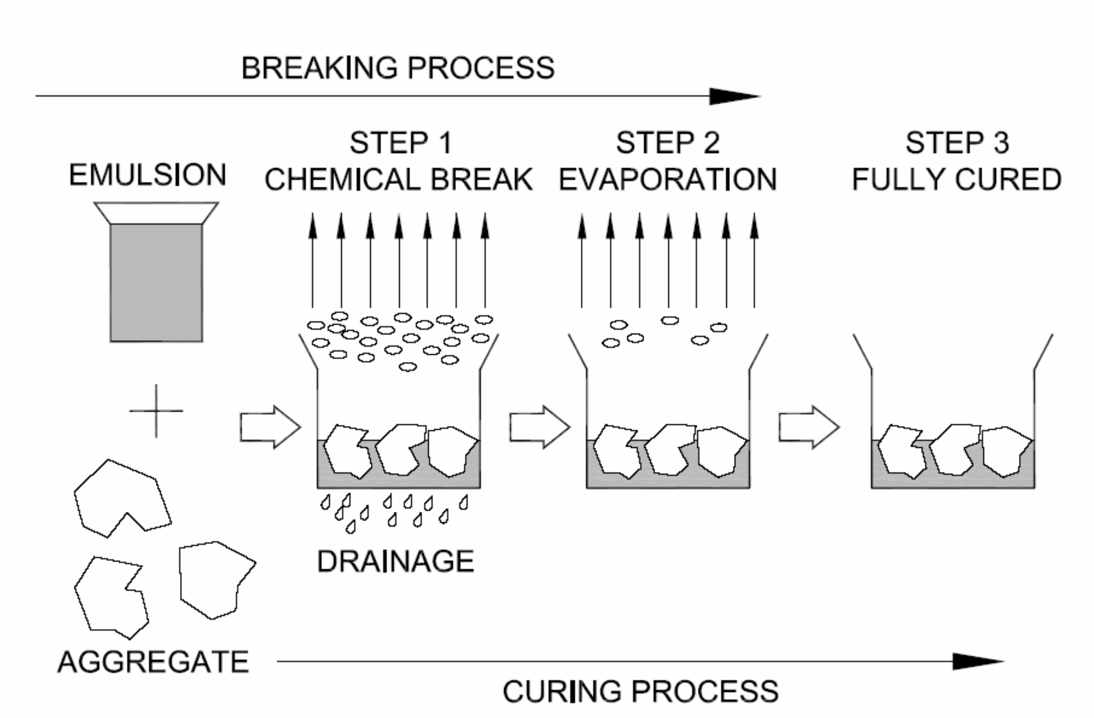


**Figure 3.2 Asphalt Emulsion Break and Cure Stages**

Since breaking characteristics are critical to different applications, emulsions are classified as slow-, medium-, or rapid-setting (Table 3.2). The surface charge on the droplets can be introduced by using a broad range of surface-active chemicals, or emulsifiers. Amine emulsifiers make cationic emulsions by creating a positive ionic charge. Fatty acids and associated chemicals make anionic emulsions by leaving a negative charge on the surface of each asphalt droplet. To be most effective, the chemistry of the emulsifier should be matched with the aggregate surface chemistry to assure proper curing and ultimate asphalt-aggregate adhesion. Although a bit oversimplified, it is useful to remember that like charges repel and opposite charges attract, so a good residual asphalt coating can often be achieved by selecting an emulsion having the opposite charge relative to the aggregate surface.

***Table 3.2 Emulsified Asphalt Grades***

| Emulsion Type | Anionic | Cationic |
|---|---|---|
| Rapid Setting (RS) | RS-1<br>RS-2<br>HFRS-2 | CRS-1<br>CRS-2 |
| Medium Setting (MS) | MS-1<br>MS-2<br>MS-2h<br>HFMS-1<br>HFMS-2<br>HFMS-2h<br>HFMS-2s | CMS-2<br>CMS-2h |
| Slow Setting (SS) | SS-1<br>SS-1h | CSS-1<br>CSS-1h |
| Quick Setting (QS) | QS-1h | CQS-1h |

An asphalt emulsion cures through a combination of chemical break and evaporation of the water in the emulsion. See Figure 3.2 for a graphical depiction of the curing or breaking process.

### 3.2.3 Asphalt Cutbacks

Asphalt cement can also be liquefied by diluting (or cutting back) the asphalt cement in naphtha, kerosene or oil. Combinations of these materials create cutback asphalts. They are designated as rapid curing, medium curing or slow curing. Cutback asphalts are used at or near ambient air temperatures, but do not attain full strength as a binder until the diluent has evaporated. Cutback asphalt was widely used as a material for prime coats and surface treatments where lengthy working time was required. More recently, the use of cutback asphalt has been restricted in some areas of the United States because of the hydrocarbon vapors released to the atmosphere during the curing process.

Petroleum solvents used for dissolving asphalt cement are variously called distillate, diluent or cutter stock. If the solvent used in making the cutback asphalt is highly volatile, it will quickly escape by evaporation. Solvents (such as oils) of lower volatility evaporate more slowly. Based on the relative speed of evaporation, cutback asphalts are divided into three types:

- Rapid-curing (RC) – Asphalt cement is combined with a light diluent of high volatility, such as a gasoline or naphtha. Grades include RC-70, RC-250, RC-800, and RC-3000.
- Medium-curing (MC) – Asphalt cement is combined with a medium diluent of intermediate volatility such as kerosene. Grades include MC-30, MC-70, MC-250, MC-800, and MC-3000.
- Slow-curing (SC) – Asphalt cement is combined with oils of low volatility. Grades include SC-70, SC-250, SC-800, and SC-3000.

SC cutback asphalts may also be referred to as road oils. This term originated when asphalt residual oil or even straight-run crude oil from the well was applied to give roads a low-cost, all-weather surface.

The degree of liquidity of a cutback asphalt depends on the percent of solvent that is mixed with the asphalt cement. To a minor degree, the liquidity of the cutback may be affected by the hardness of the base asphalt from which the cutback is made. The more viscous grades of cutback asphalt are indicated by higher numbers in the grade designation and may require a small amount of heating to make them fluid enough for construction operations.

## 3.3 COAL TAR

Coal tar is a byproduct of the coking process used for steel production. Its molecular structure is much more aromatic than that of asphalt, and it contains significant quantities of polynuclear aromatic compounds in the benzo-a-pyrene family. The known carcinogenic/mutagenic behavior of this latter compound has led to a significant reduction in the use of coal tar for paving applications, particularly hot-applied systems where vapor concentrations can exceed environmental compliance standards. Both asphalt and coal tar are classified as bituminous materials. At one time, coal tar was used like asphalt cement as a binder in paving mixtures. This was discontinued in the 1970s when its health effects became known. Coal tar is still used in pavement sealants for airfields and parking lots. These sealants are typically clay-stabilized emulsions similar to the asphalt emulsions discussed above. In some cases, they may be mixed with an elastomeric polymer to improve flexibility. They may also be mixed with a rejuvenator. The primary benefit of their use is to improve the resistance of the HMA surface to spilled petroleum products, such as aviation fuel or lubricating oil.

## 3.4 AGGREGATES

Depending upon the application, asphalt-aggregate mixtures have varying aggregate requirements for gradation, particle shape, soundness, abrasion resistance, unit weight, plastic fines and polish value. The aggregate component used in asphalt mixtures is selected by optimizing quality and economy. The aggregate used for the treatments, discussed in Chapter 4, can significantly affect the performance of that treatment.

### 3.4.1 Grading or Particle Size Distribution

The grading or gradation of an aggregate defines the distribution of the various particle sizes. Gradation is typically determined by both washed-sieve analysis and dry-sieve analysis. Once separated, the mass of material retained on each sieve is measured and compared to the total sample weight. The aggregate gradation is ultimately expressed as the accumulative percent passing each sieve size. The individual grading requirements for surface treatments is presented in Chapter 4.

### 3.4.2 Surface Texture

Although smooth-surface-textured aggregate can be used satisfactorily for some construction applications, rough-surface-textured aggregate is usually preferred. The strength of an HMA mixture and of an unbound aggregate base is increased when rough aggregates are used. Also, rough-surface-textured aggregates are needed in surface course mixtures or pavement preservation techniques to help maintain provide high friction levels between rubber tires and the pavement surface. When the rough surface texture of an aggregate is removed through wear by tires, the friction is decreased.

### 3.4.3 Absorption

Asphalt absorption is the amount of asphalt binder that is absorbed into the HMA mixture during the mix production and placement process and as the pavement ages. The amount of asphalt that is absorbed into an aggregate can affect the durability of an HMA mixture. If an absorptive aggregate is used in pavement preservation procedures, additional asphalt will be required. Smaller, more volatile asphalt molecules are preferentially absorbed into the tiny pores of the aggregate, leaving the remaining binder more brittle and the pavement more prone to cracking. Water absorption is an indicator of asphalt absorption. If an aggregate has more than 2 to 2½ percent water absorption, it is considered to be absorptive. High water absorption also indicates that the aggregate may be difficult to dry. This retained moisture may restrict effective coating. Asphalt absorption is generally about one-half of the water absorption. To reduce the potential for non-load-associated cracking, hard, non-absorptive aggregates should be used in the HMA mix and surface treatments.

### 3.4.4 Deleterious Substances

Deleterious substances are those substances present in an aggregate that are harmful to the desired properties of aggregate-binder systems. Harmful substances occasionally found in aggregate include (1) structurally soft and/or weak particles, (2) clay and other types of surface coatings, (3) organic materials, (4) aggregate particles such as chert which exhibit disruptive expansion, and (5) aggregate particles which react chemically. Soft aggregate, expansive aggregate, and chemically reactive aggregate disintegrate rapidly when exposed to severe climatic situations, which can result in failure of an aggregate-binder system. Coatings and organic material adversely affect adhesion between aggregate and binder and also result in a mixture that does not perform as intended. Deleterious substances should be minimized.

# CHAPTER 4.0 SURFACE TREATMENTS

## 4.1 INTRODUCTION

This chapter provides information and guidance on the use of surface treatments for the mediation of non-load-associated cracking. It discusses four surface treatment techniques and crack sealing, which should be a part of the construction process for the surface treatments discussed. The four procedures discussed are as follows:

1. Spray-applied seals – This is the spray application of an emulsified asphalt or emulsified tar to a hot-mix asphalt (HMA) pavement surface.
2. Slurry surfacing systems – These use a mixture of fine aggregate and either asphalt emulsion or emulsified coal tar that are mixed into a slurry and spread on the pavement surface.
3. Chip seals – These consist of a spray application of asphalt or asphalt emulsion that is followed by an application of aggregate and rolled with a pneumatic roller.
4. Cape seals – This is a chip seal that is followed by a slurry seal.

Project selection and design, material selection and placement, traffic control and local environmental conditions at time of construction all play important roles in the success of any preservation action. The following issues are known to result in poor performance of surface treatments:

- Improper project selection –the wrong treatment for the wrong pavement
- Improper pavement preparation – dirty surfaces, insufficient treatment of open cracks
- Inattention to climatic conditions – imminent rain, pavement too hot or too cold, work too late in the season for the treatment to properly cure
- Insufficient traffic control – open to traffic too early, no pilot car, speeds too high before emulsion fully cures
- Poor construction practices – plugged distributor nozzles, improper bar height and pressure, inadequate aggregate distribution or coating
- Inadequate materials – dirty aggregate, incompatibility of emulsion and aggregate, insufficient inspection and testing leading to lack of control during construction

The Federal Highway Administration (FHWA) has developed a series of checklists to help guide state and local maintenance and inspection staff in the use of innovative pavement preventive maintenance processes. Those checklists are available from the FHWA division office in each state, or they can be downloaded from the FHWA Web page at www.fhwa.dot.gov/preservation.

## 4.2 CRACK SEALING

This will address the crack sealing of longitudinal or block cracking, which are generally caused by age-induced deterioration of the HMA pavement surface and/or the opening of longitudinal construction joints.

### 4.2.1 Introduction

Description

The purpose of crack sealing is to prevent water or incompressible materials (such as sand) from entering the pavement structure through cracks in the surface. This should be a proactive activity. Cracks should be sealed as they develop, and kept sealed. Generally, crack sealing is the first step in placing a surface treatment on an HMA pavement surface. Crack sealing materials are designed to adhere to the walls of the crack and to stretch with the movement of the crack over a range of climatic conditions. Crack sealers are usually asphalt rubber or asphalt binders modified with elastomeric polymers or other materials. The crack sealers are normally heated and applied at high temperatures. Cold-pour crack fillers are made by the addition of fillers to heavily polymer-modified asphalt emulsions. They are designed for easy application to fill and seal cracks in the pavement. When cured, the polymer-modified asphalt residue seals out water and incompressible materials. Crack fillers are generally **not** used on airfield pavements.

Function

The function of crack sealing is to prevent the intrusion of water into the underlying layers of the pavement structure (which weakens the pavement) and to prevent the intrusion of incompressible materials from entering the crack, which causes deterioration as the pavement expands and contracts with temperature changes.

### 4.2.2 Advantages/Disadvantages

Crack sealers retard deterioration and have been found to be a cost-effective pavement preservation treatment. When used before the placement of a surface treatment or an HMA overlay, they help prevent reflective cracking (the reflection of cracks in underlying layers through the HMA overlay). But if they are not applied correctly, the crack materials may bleed through new surfaces or create bumps.

### 4.2.3 Life Expectancy

The life expectancy of a crack sealant is two to five years (the time before the crack reopens).

### 4.2.4 Materials

Federal Aviation Administration (FAA) Specification P-605, Joint Sealing Filler, states that a sealant for HMA pavements must meet the requirements of ASTM D6690, Joint and Crack Sealants, Hot-Applied, for Concrete and Asphalt Pavements. This sealant material is manufactured by mixing a rubber material or rubberlike polymer with asphalt cement. In the field, those materials are melted in a hot-sealant machine like the one shown in Figure 4.1. The rubber materials can be new rubber, high-quality reclaimed rubber or rubber buffings from tire-retreading operations. These materials are elastomeric, which means that the sealant will stretch easily without breaking. These sealants also recover over time to close to their original dimensions.

***Figure 4.1 Hot-Sealant Machine***

FAA Specification P-605 allows the use of a backup material or bond breaker in the bottom of the joint to be filled. This is used to control the depth of the sealant, to achieve the desired shape factor, and to support the sealant against indentation and sag. Backup materials and bond breakers:

- Should be compatible with the sealant
- Should not adhere to the sealant
- Should be compressible without extruding the sealant
- Should recover to maintain contact with the joint faces when the joint is open

Backup materials must consist of flexible, compressible, and non-moisture-absorptive material. Materials such as closed-cell polychoroprene, polyurethane, polystryrene or polyethylene rods are typically used.

Jute, paper or other moisture-absorbing materials are not to be used for the backing material. The backing material should be made of rubber, butyl rubber, or another approved material that will not react with the joint sealer and will not form a gas when the hot joint sealer is applied.

### 4.2.5 Construction Procedures

Many times in HMA pavements the cracks will have irregular dimensions and wander across the pavement. This makes it difficult to properly prepare the crack for sealing. If the crack is not properly prepared, however, the sealant will not function satisfactorily. The procedure for sealing cracks in HMA pavements includes sealer removal (when resealing), routing, crack cleaning and drying, and sealant placement, which are discussed in this section. A discussion of the repair of wide cracks is also included.

## Surface Preparation

### *Removing Sealant and Routing Cracks*

To reseal a crack that has been previously sealed, the old crack sealant must be removed with hand tools before the crack is routed. The crack should be cleaned using a vertical spindle router or rotary impact router equipped with carbide bits (see Figure 4.2). The router is designed to form a sealant reservoir while it maneuvers along the irregular direction of the crack. Routing is also required when the edges of the crack are raveled or contain loose aggregate. This is done to provide a sound HMA surface to which the sealer can adhere.

***Figure 4.2 Router Being Used to Clean a Crack***

General guidelines for routing cracks are based on the width of the crack from Air Force Pamphlet 88-6, Standard Practice for Sealing Joints and Cracks in Rigid and Flexible Pavements:

- Hairline cracks (less than ¼ inch) should not be routed (see Figure 4.3).
- Small cracks of ¼ to ¾ inch (see Figure 4.4) should be widened to a nominal width of ⅛ inch greater than the average width of the existing crack. Widening the cracks will help eliminate the potential for raveling of the HMA pavement along the edges of the crack and will provide a sealant reservoir that has vertical faces. The depth of the routed crack should be approximately ¾ inch.

- Medium cracks of ¾ inch to 2 inches (see Figure 4.5) do not need routing, but some repair may be required.
- Large cracks (greater than 2 inches) or multiple cracks (see Figure 4.6) require crack repair instead of routing.

***Figure 4.3 Hairline Crack***


***Figure 4.4 Small Crack***

***Figure 4.5 Medium Crack***

***Figure 4.6 Multiple Cracks***

The following are advantages of routing cracks:

- Opens small cracks to allow greater penetration of the sealant
- Results in a reservoir for the sealant
- Provides for uniform edges for better adhesion

The following are disadvantages of routing cracks:

- Is very labor intensive, which increases the cost of sealing
- Can be difficult to follow a meandering crack
- May damage older or thin HMA pavements

*Cleaning and Drying Cracks*

After the cracks have been routed, they should be cleaned with compressed air (see Figure 4.7). This is an essential step in crack sealing, since most failures result from the loss of adhesion of the crack sealer. To effectively clean the crack, high-pressure air blasting should be used, employing compressors to produce a jet stream of air to remove dust, debris and/or loose pavement fragments. The cracks should be cleaned to a depth of at least twice the crack width. The airflow should be free of oil and moisture, and the compressed air should have a minimum pressure of 100 pounds per square inch and a minimum blast flow of 150 pounds per square inch.

Operators should make at least two passes of high-pressure air blasting along each crack or crack segment. The first pass dislodges loose and partially loose dirt and debris from the crack channel; the wand should be held no less than 2 inches away from the crack. The second pass completely removes all the dislodged crack particles from the roadway and shoulder. In this pass, the wand can be held further away from the pavement surface to make use of a larger blast area.

**_Figure 4.7 Using Air to Clean Out a Crack_**

This method is effective in cleaning the crack, but it is not effective for drying it. For crack sealing, the crack must be moisture free. This may require using a hot air lance (see Figure 4.8) to dry the crack immediately prior to crack sealing. Heat lances should provide a continuous stream of hot, high-pressure air with no flame at the exit nozzle.

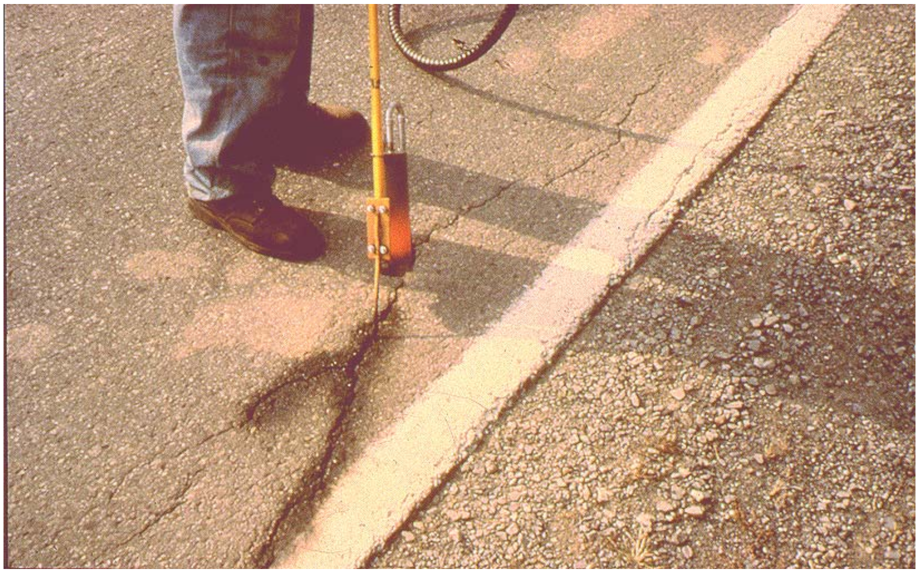

***Figure 4.8 Using a Hot Air Lance to Dry a Crack***

Placement of Sealant

The best placement conditions for most materials are dry pavement and an air temperature that is at least 40° Fahrenheit (40°F) and rising. However, the use of a heat lance may permit many hot-applied materials to be placed in cold or damp conditions. The best time of the year to place sealants is in the spring or the fall. During the winter months, the crack will be the widest due to low-temperature shrinkage. Therefore, if crack filling is done during the winter, the crack will be overfilled and the result will be a bump or sealant smeared over the top of the pavement during the summer months. If the crack is sealed during the heat of the summer when the width of the crack is the smallest, there will be a tendency to underfill the crack. Then when the pavement cools, the crack sealant will pull away from the sides as the temperatures drop. The result will be water intrusion into the crack in the spring and deicing materials in the winter.

The application temperature for sealant will generally range from 370°F to 390°F. The effects of overheating or extended heating will depend on the specific material. Some materials exhibit a thickened, gel-like consistency, while others thin out or soften considerably. In either case, the old material should be discarded, and new material should be prepared.

The placement of the sealant is can be accomplished with either a pour pot or a wand. The placement of the sealant with a pour pot (see Figure 4.9) is **not** recommended due to safety concerns and inability to control the temperature. It is recommended that sealant be placed using a wand and kettle (see Figure 4.10). Various sizes of dish-shaped attachments are available that can be connected to the end of the application wand for one-step application and finishing. Industrial rubber squeegees, like the one shown in Figure 4.11, can be used behind the material applicator to provide the desired shape.

***Figure 4.9 Use of Pour Pot to Seal Cracks***


***Figure 4.10 Sealing Cracks with Wand and Kettle***

***Figure 4.11 Placement of Sealant***

The following are the four basic configurations for crack sealing:

1. Flush filling – Flush filling consists of blowing out the crack with an air compressor and filling it with sealant (see Figure 4.12). The crack sealant is inserted into the pavement and then struck off level (flush) with the pavement surface. The advantage of this method is speed and cost. The disadvantage is that little crack sealant is placed in the crack, so the sealant tends to fail early. Another problem is that the cracks are not routed, so loose and/or oxidized material may cling to the sides of the crack, creating a zone of weakness.
2. Overband filling – This consists of blowing out the crack with an air compressor and placing an excess amount of crack sealant so the band of sealant caps the crack as well as fills it (see Figure 4.13). The advantage of this method over flush filling is that it provides a little more durability than flush filling. The disadvantage is that the sealant cap can be scraped away during snow plow operations.
3. Rout and fill – This method consists of routing the crack as discussed above and then filling the routed crack with a slightly depressed sealant (⅛ inch below) the surface (see Figure 4.14). The advantage of this method is that the sealant is placed on a clean surface, resulting in better bonding with no sealant on the pavement surface. The disadvantage is the time required and the cost.
4. Rout and overband – This method is the same as No. 2, above, except that the sealant is placed in a routed crack.

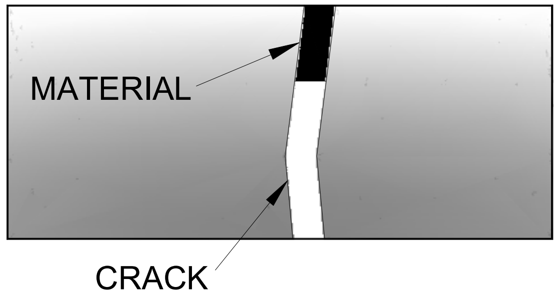


***Figure 4.12 Flush Filling***

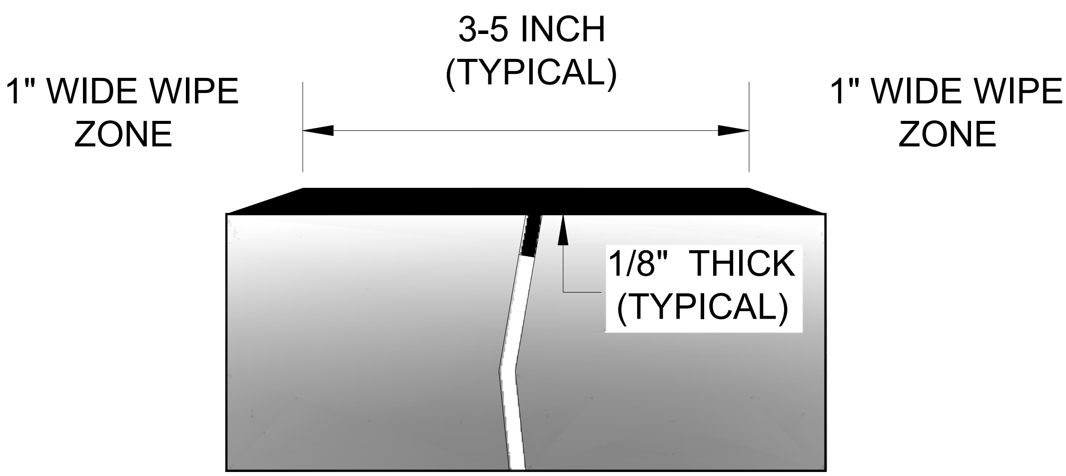


***Figure 4.13 Overband Filling***

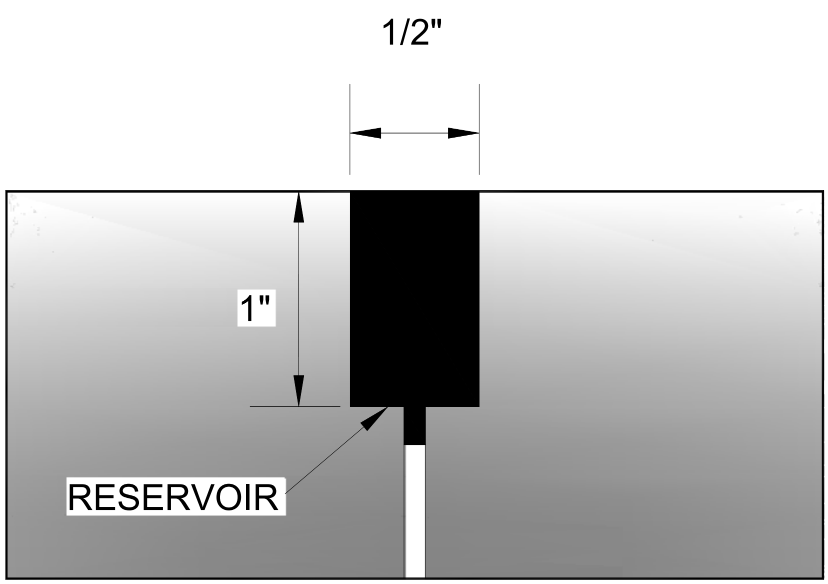


***Figure 4.14 Route and Fill***

The New Mexico Department of Transportation (DOT) conducted a survey of other DOT highway departments with regard to the life expectancy of the above four techniques. Their survey found the following:

- Flush filling lasts one to two years before cracking returns.
- Overband filling lasts two to three years before cracking returns.
- Rout and fill lasts three to four years before cracking returns. Failures are usually a combination of crack edge failures and sealant cracking.
- Rout and overfill generally lasts five years.

When rubber-modified asphalt materials must be blotted to prevent tracking, toilet paper, talcum powder, and clean dry blotter dust are often used. These blotters should be applied immediately after finishing so that they can stick to the material and serve as temporary covers. Care must be taken not to over apply dust and powder materials. If dry blotter sand is used it should be sweep up after the sealant has had time to cure to prevent possible foreign object damage (FOD) problems.

Repair of Wide Cracks

When a crack is wider than 2 inches or there is secondary cracking along the sides of the crack, it may be necessary to use full-depth or partial-depth cracking repair.

When sealing a crack that is wider than 2 inches or has secondary cracking, it is suggested that the surface be milled from 1½ inches for cracks in good condition to full depth for pavement with severe deterioration. When choosing the configuration of the area to be milled, make sure the trench is wide enough to ensure good compaction. It is difficult to achieve good compaction in a deep and narrow trench. The most common mill width used for this purpose is 14½ inches.

After removal of the pavement the area removed should be filled with high-quality HMA. Prior to placement of the HMA, the edges and the sides of the trench should be tack coated with an asphalt emulsion. This procedure requires more labor than other techniques and as a result tends to be very time consuming and costly. However, if the cracks are in extremely poor condition, mill and fill may be the only viable crack treatment. The key to the success of this procedure is proper placement and compaction of the HMA. If compaction is not achieved, the surface may ravel and cause an FOD problem.

### 4.2.6 Quality Assurance

The keys to a quality crack-sealing process are the following:

- Insuring that the crack to be sealed is clean and dry
- Consistently maintaining the correct application temperature
- Maintaining sufficient supply of heated material in the kettle
- Properly dispensing right amount of material into crack

The inspector should ensure that cracks are properly cleaned, that the material is placed in accordance to the supplier's recommended temperatures and that the material is placed only in the crack (if overbanding is not allowed) and at proper width (if overbanding is allowed).

### 4.2.7 Troubleshooting

The troubleshooting guide presented in Table 4.1 presents some common problems associated with crack filling and the suggested solution.

***Table 4.1 Troubleshooting Guide***

| Problem | Solution |
|---|---|
| Tracking | • Reduce the amount of sealant being applied<br>• Use some type of blotter |
| Choice of Sealer | • Ensure that the cracks are clean and dry<br>• Increase the temper of application<br>• Allow a longer cure time before trafficking |
| Bumps | • Check the squeegee and ensure that it is leaving the correct flush finish<br>• Squeegee shortly after sealant application<br>• Change the roller on the squeegee |

## 4.3 SPRAY-APPLIED SEALS

### 4.3.1 Introduction

<u>Description</u>

A spray-applied seal is a light, even application of a diluted asphalt emulsion or diluted coal tar emulsion to an HMA pavement surface.

<u>Function</u>

A spray-applied seal will seal and enrich an HMA pavement surface and seal low-severity cracks. Traditionally these treatments, often called fog or flush seals, are applied to pavements to arrest pitting and raveling, to decrease permeability, to rejuvenate the properties of the existing asphalt binder, and to reduce aggregate loss from chip seals. They may also be applied to blacken a surface to improve appearance, visibility, or contrast between travel lanes and shoulders. Figure 4.15 shows a spray-applied seal on a United States Army airfield in the southeastern United States.

***Figure 4.15 Spray-Applied Seal on an Army Airfield***

### 4.3.2 Advantages/Disadvantages

When spray-applied sealers are used as a preventive maintenance treatment, they can reduce the rate at which surface properties change with aging. This can be done by reducing the surface permeability to limit oxygen infiltration or by applying rejuvenators that blend with an aged asphalt to restore binder relaxation properties that have diminished due to oxidation. In either case, the expected life of spray-applied sealers is generally shorter than that of other surface treatments. However, it is important to note that a properly applied spray seal will reduce permeability by flowing into and blocking some surface pores and fine cracks. Although the surface appearance after one or two years might indicate the seal has worn off, the asphalt in the surface pores should remain, and thus the beneficial reduction in permeability should continue intact for a significantly longer period of time

If applied too heavily or to a nonporous surface, a spray-applied sealer may leave the pavement slippery and unsafe. Therefore, these materials must be applied with caution, especially on taxiways and runways. A recent study found that friction is generally lowered by the seal, but returns over time. Sanding can mitigate friction loss, but the correct timing for the sand application will depend upon the residue properties and curing rate of the applied sealant. For critical areas, a short field test section is recommended to confirm that the sealer will absorb into the pavement and that acceptable friction numbers can be met before traffic is released.

### 4.3.3 Life Expectancy

The life expectancy of spray-applied seal will vary with the product used and the condition of the pavement on which the seal is being placed. The following gives some general guidelines based on the Pavement Condition Index (PCI) and pavement condition:

- PCI 80 – good condition – reapply in three to five years
- PCI 60 – fair condition – reapply in one to three years
- PCI 40 – poor condition – reapply in one to two years

Generally for pavement surfaces with a PCI of 60 or below, it is probably not cost effective to use a spray-applied seal.

### 4.3.4 Materials

Many products are used for sealing HMA pavement surfaces. Sealant selection is based on the preference of the agency involved and the desired result. Appendix B contains the FAA specifications for a number of these products. Spray-applied sealers fall in several general classifications, as listed below. Due to the continuously changing nature of the market, no specific brand names are provided.

1. Asphalt sealers – Products such as a slow setting (SS/CSS) emulsions can be diluted and spay applied on the surface. They are commonly used to “seal” the pavement surface or to “bind” or “lock” cover material or fines to reduce surface raveling. If sand is used to improve friction, it is usually applied before the emulsion cures. Newer materials containing polymers and other additives are currently being promoted and marketed.

2. Asphalt rejuvenators – Products in this family are typically slow-set emulsions of rejuvenator oils, which may be blended with asphalt. Polymers or other additives may be included in the blend. The rejuvenator is only effective if it can penetrate from ¼ inch to ½ inch and restore the relaxation properties (ductility) of the oxidized asphalt near the pavement surface. The pavement surface must therefore be permeable, and the applied emulsion must have a very low surface tension and low viscosity so it can carry the oil into and through fine pores in the mixture.

   A properly rejuvenated surface will be less prone to crack and ravel. Rejuvenating sealers are most beneficial in situations where the surface has an open texture and the existing binder is brittle from age. If rejuvenator emulsions do not infiltrate into the surface, an oily surface reside will leave the pavement very slippery. Although highly effective if used properly, a number of highway agencies have placed moratoriums on their use because misapplication led to serious traffic accidents. If sand is used to improve friction, it should be applied after the sealant has had sufficient time to infiltrate the HMA mixture. Applying sand too early results in oily fines left loose on the surface, since the rejuvenator residue is usually too soft to act as a binder. Improper timing of sand application can leave the pavement slicker than if no sand had been applied.

   Be aware that a variety of rejuvenating seals are marketed and used throughout the United States, and performance varies markedly. The applicable FAA specification is P-632, Bituminous Pavement Rejuvenation.

3. Gilsonite sealer binders – Gilsonite is a natural, unrefined asphalt ore that is mined in Utah. It is rich in resins that can help replenish the pavement’s surface where oxidation first starts. Gilsonite is 45 percent resin, and is naturally very high in anti-oxidants, polar compounds, and antistrip chemicals. It has a high affinity, or attraction, to all kinds of aggregates. Under the correct conditions, Gilsonite-based

emulsions can be used effectively on any type of HMA pavement. They are applied by using a standard asphalt distributor. Typical application rates are between 0.10 and 0.15 gallons per square yard.

4. Coal-tar-emulsion sealers – Coal tar is among the byproducts created when coal is carbonized to make coke or gasified to make coal gas. These byproducts can be emulsified to make pavement sealers that will penetrate into the pavement surface, providing multiple benefits by reducing permeability, restoring aged asphalt properties and providing a fuel resistance surface.

   Coal tar sealers are primarily used on parking lots, driveways and airfield pavements where oil leaks or fuel spills are most likely to damage a pavement. Sand is often mixed with the sealer emulsion just prior to application in order to maintain adequate friction resistance. Materials may be either sprayed or squeegeed onto the pavement. The FAA specification for these materials is contained in FAA Specification P-631 and FAA Engineering Bulletin 44B,

### 4.3.5 Construction

Surface Preparation

Before applying any spray-applied sealer, the HMA pavement surface must be flushed with water or cleaned with a road sweeper or power broom to remove the dust, dirt and debris on the surface. The pavement surface must be clean and dry before applying the spray-applied sealer. Flushing with water should be completed at least 24 hours prior to the application.

Weather

Spray-applied seals should not be placed when the atmospheric temperature is below 50$^{o}$F and the pavement temperature is below 60$^{o}$F. Seals placed in cold weather may not infiltrate the surface or set up as expected, and traffic may displace the material before curing is complete. If the seal is applied when the air temperature is above 90$^{o}$F, the emulsion may “skin over” or flash set. This may prevent infiltration or result in the materials not being uniformly spread across the pavement surface. Windy days may also be problematic; the emulsion will not be applied uniformly and may cause damage by blowing onto nearby buildings, passing vehicles or parked aircraft.

If an unexpected rain occurs before the emulsion cures, the oil droplets may wash out of the pores of the pavement. The result will be an extremely slippery surface or, worse, the emulsion could find its way into a local lake or stream. If the surface is still slick after it has dried it When it may be necessary to apply a sand blotter to correct the skid resistance. If the spray applied seal has washed off the surface it may be desirable to reapply the sealer. If this is done it must be done with great caution to avoid the application of excessive sealer (the first application may have sealed some of the pores in the surface).

Application Rates

Spray-applied seal emulsions will contain approximately 40 percent water, which is somewhat higher than most other paving-grade emulsions. Standard practice is to further dilute the product so it spreads uniformly during application and infiltrates the pavement more quickly. This dilution can be done at the supplier's plant or in the field. A dilution rate of 50 percent using a 1:1 dilution ratio (equal parts of water and emulsion) is recommended. The amount of emulsion to be applied depends on the condition of the HMA pavement surface being treated. Application rates recommended by the Asphalt Institute are shown in Table 4.2.

***Table 4.2 Recommended Application Rates***

| Original Emulsion (%) | Dilution Ratio | Tight Surface* (gallons per square yard) | Open Surface* (gallons per square yard) |
|---|---|---|---|
| 50 | 1:1 | 0.03 to 0.11 | 0.09 to 0.22 |

Notes: *A tight surface is of low absorbance and relatively smooth; an open surface is relatively porous and absorptive with open voids.

To estimate the application rate for a particular project, pour 1 quart of the diluted emulsion (usually a 1:1 rate) over 1 square yard. If the emulsion is not absorbed into the surface after two to three minutes, decrease the application rate and apply to a new 1-square-yard area until the application rate is determined. If the surface looks as if it could absorb more emulsion, apply another test section with a higher rate. If a large apron or long taxiway is being treated. it may be necessary to use this procedure at several locations, particularly if surface characteristics appear to vary along the project.

If the pavement is impermeable, the sealer will remain on the surface, leaving an oil-rich layer that will track and reduce friction. For most products applied to a dense HMA pavement, the skid resistance during the first four hours after application is typically cut by half. If angular sands are spread on the newly applied sealer so that no loose sand remains, friction numbers soon after application can improve to about 80 to 90 percent of original values. If sand is used, brooming should take place as soon as practical after the emulsion is fully cured. Supplier guidelines for some of sealers do not require sanding, particularly when residues are hard or are modified with polymers.

The secret to proper sealer application procedures is **CAUTION**. It is better to apply two or more low-rate applications of the sealer to achieve the proper rate of application than to make only one pass and have it be too heavy. The project engineer must be wary of areas that might contain free oil, grease, petroleum, or asphalt when applying the sealer. The engineer must also take care not to apply the sealer to a densely graded pavement or to a surface that has been treated in a manner that will prevent penetration by the sealer. When in doubt, apply small trial sections at the desired rate and check infiltration and friction. If equipment to measure friction is not available, a rapid acceleration/deceleration with a pickup truck can provide a reasonable comparison of skid resistance between treated and untreated sections. If the surface remains slick, consider lowering the application, applying sand or even cancelling the project.

Placement of Sealer

The asphalt distributor is critical to the placement of the spray-applied sealer. The distributor consists of a truck-mounted insulated tank with a system of spray bars and nozzles at the back of the tank to apply a uniform application of asphalt. During application of the spray-applied seal, the emulsion must be properly heated, the spray bar should be properly set and the spray pressure should be established in accordance with the distributor manufacture's recommends for the viscosity of the material being applied. The spray nozzles should be set at the proper angle and should be checked to ensure that they are not plugged.

The asphalt distributor consists of a truck-mounted or trailer-mounted insulated tank ranging in capacity from 800 to 5,500 gallons. Most distributors are equipped with a heating system that will maintain the sealer at the proper spray temperature.

The distributor has a power-driven pump capable of handling products ranging from light, cold applications of emulsified asphalt to heavy asphalt cements heated to spraying viscosity temperatures. At the back end of the tank is a system of spray bars with nozzles through which asphalt is forced under pressure to the surface of the road. These spray bars cover widths from 6 to 30 feet in one pass, depending on their width and the pump's capacity.

Although the methods of maintaining pressure may vary, all distributors use gear-type pumps to deliver asphalt to the spray bar. On some distributors, the pressure is governed by a variable pump speed. On others it is governed by a constant pump speed and a pressure relief valve.

The spray-applied seal should be spread uniformly across the pavement, and there should be no streaking (Figure 4.16). The starting and stopping of the distributor should be made on building paper.

***Figure 4.16 Streaking of Spray-Applied Seal***

A sand blotter may be required to ensure skid resistance on the HMA surface. If required, it should be placed at the rate of approximately 2 pounds per square yard. A broom should be used to remove the excess sand or, for an airfield, a vacuum sweeper.

The correct pump speed or pressure is that which neither atomizes the asphalt nor distorts the spray fan. A low pressure may result in streaking from a nonuniform discharge of material from the individual nozzles. In addition to atomizing the asphalt, a high pressure may distort the spray fan. To determine the discharge in volume per minute for each nozzle size, refer to manufacturers' supply charts and data for proper pump speed or pressure.

A tachometer used as an aid in maintaining uniform spreader speed has proven to be highly successful. Newer distributors have interlocks between the asphalt pump and the forward speed of the distributor. As the distributor changes speed, the pump speed is adjusted to compensate, thus maintaining a constant application rate.

The spray bar is one of the more important parts of the distributor because it is through the spray bar and nozzle that the proper quantity of asphalt is forced under pressure onto the road surface. To achieve good results, the correct size of nozzles must be selected for the type and grade of asphalt and the application rate. Before use, nozzles should be checked for damage and proper setting.

The angle of the long axis of the nozzle openings (Figure 4.17) must be adjusted so that the spray fans do not interfere with one another. The nozzle angle varies according to the make of the distributor but is typically between 0.26 and 0.52 radians (15 and 30 degrees). It is important that all nozzles be set at the proper angle within to ensure a proper spray pattern (Figure 4.18)

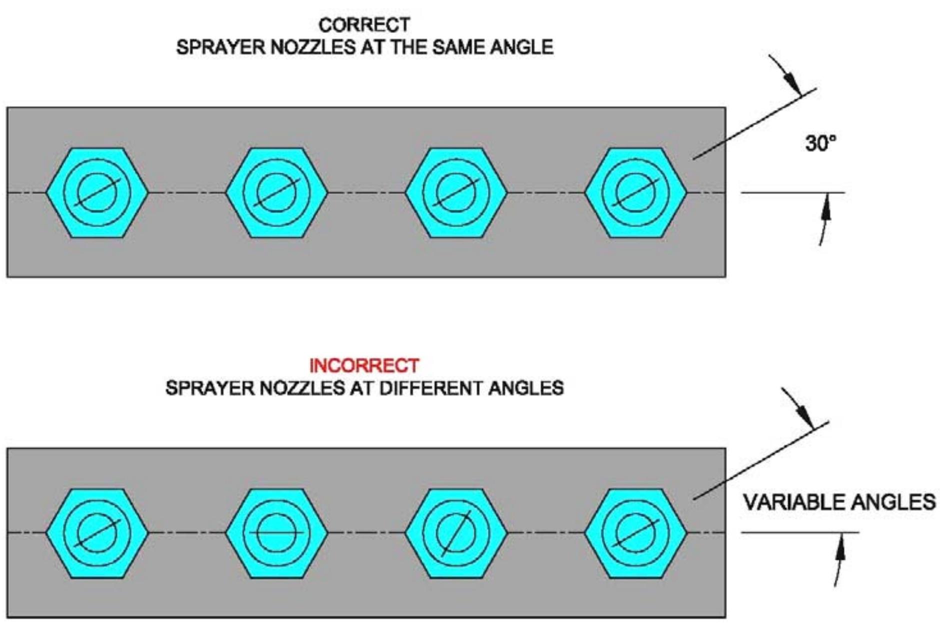


***Figure 4.17 Nozzle Alignment***

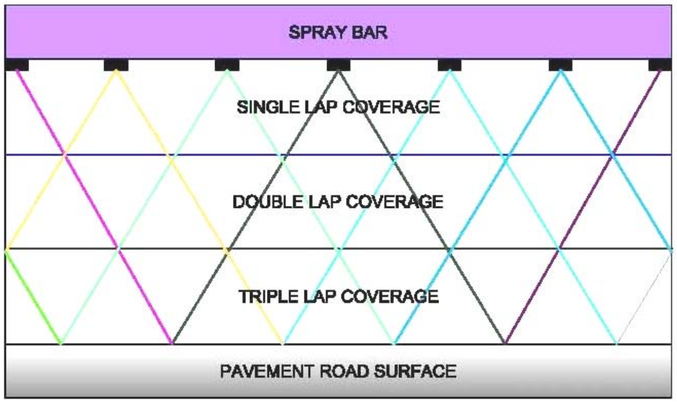


***Figure 4.18 Proper Spray Pattern***

### 4.3.6 Quality Assurance

The control of the product placement and workmanship is critical to the performance and life of a spray-applied seal. The asphalt distributor should be checked to ensure that the nozzles are properly allied and are free of clogs. Most modern distributors are equipped with technology to tie the application rate to the speed of the vehicle. When starting the placement of the spray-applied seal, it is suggested that the rate of application be checked as follows:

- Place a pan, nonwoven geotextile, or felt pad on the road surface. Prior to placing it on the roadway determine the weight of the pan, geotextile or pad. (Figure 4.19).
- Make sure that the distributor applies the spray-applied seal at the determined rate over the pan or geotextile.
- Record the weight of the pan and the spray-applied seal, the geotextile or felt pad and the spray-applied seal.
- Subtract the two weights to determine the weight of the emulsion applied.

***Figure 4.19 Felt Pad Used to Verify Application Rate***

During production, the distribution of the spray-applied sealer should be periodically checked by doing the following:

- Determining the number of gallons in the distributor
- Measuring a known distance for a test section
- Applying the spray-applied sealer to the test section
- Determining the number of gallons in the distributor
- Determining the number of gallons used by subtracting the final volume from the initial volume
- Dividing the number of gallons applied by the number of square yards covered by the spray-applied sealer to determine the application rate in gallons per square yard
- Comparing the results of these calculations to those from the computer-controlled application system on the truck, making adjustments as needed

### 4.3.7 Troubleshooting

The troubleshooting guide (from the FHWA and the California Department of Transportation) presented in Table 4.3 presents some of the common problems and their potential causes and typical solution.

***Table 4.3 Troubleshooting Guide – Spray-Applied Seals***

| Problem | Typical Cause(s) | Typical Solution |
|---|---|---|
| Spattering of the Sealer | • Emulsion has been diluted too much<br>• Spray bar is not at proper height<br>• Spray pressure is too high | • Adjust the emulsion dilution rate<br>• Make necessary adjustments to the spray bar height and pressure |
| Streaking or Drill Marks Appearing in the Emulsion | • Emulsion is too cold<br>• Viscosity of the emulsion is too high<br>• All nozzles are not at the same angle<br>• Spray bar is not at proper height<br>• Spray bar pressure is too high<br>• Nozzle is plugged | • Review emulsion temperature requirements<br>• Verify that the selected emulsion is appropriate for site condition<br>• Check the spray bar height and pressure and the nozzle angles and make necessary adjustments<br>• Check nozzles for obstructions and clear any that are found to be plugged |
| Flushing or Bleeding of the Emulsion | • Emulsion application is too high | • Review the selected application rate and adjust as necessary |

## 4.4 SLURRY SURFACING SYSTEMS

### 4.4.1 Introduction

Description

Slurry surfacing procedures use mixtures of well-graded fine aggregate, mineral filler (if needed), emulsified asphalt and water. They are mixed and applied to a pavement with a single piece of equipment, the slurry surfacing machine. As the surfacing machine moves forward, the slurry components are mixed and dropped into a spreader box that places the slurry on the pavement surface. As the slurry cures, asphalt droplets coalesce to bond with the aggregate. See Figure 4.20 for a diagram of a slurry surfacing machine.

The following are a few of the several types of slurry surfacing options:

- Slurry seal
- Polymer-modified slurry seal
- Microsurfacing
- Evolving technology
    - Rubber-emulsion aggregate slurry (Flexseal)
    - Coal tar slurry (Grip-Flex)

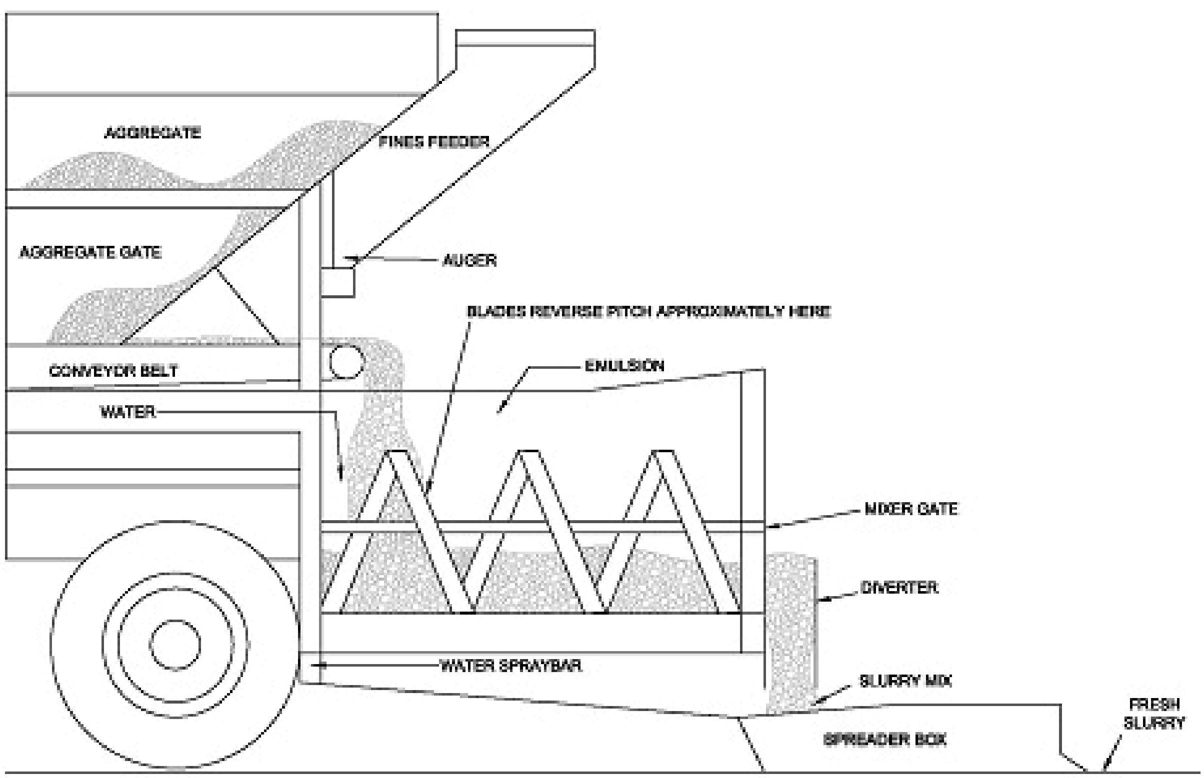


***Figure 4.20 Diagram of Slurry Surfacing Machine***

A slurry seal is very thin, typically one aggregate thick (approximately ¼ inch). International Slurry Surfacing Association (ISSA) slurry specifications list three seal types, based upon maximum aggregate size. A standard slurry emulsion is slow setting and does not contain polymer. Typically, four to eight hours of curing time are needed before the road can be reopened to traffic. When polymers are added to these SS/CSS emulsions, the product falls under polymer-modified slurry specifications, which require enhanced performance in the wet track abrasion test. However, cure time to traffic reopening is still relatively long.

Microsurfacing creates a very thin surface that is placed much like slurry, but specialized emulsifiers and break control agents enable it to cure much more quickly. A high polymer content makes the mix much stronger, so microsurfacing can be laid on high-volume asphalt pavements and over Portland cement concrete, including rut-filling applications. Microsurfacing material must be modified with significantly more polymer than modified slurry, and break control reduces sensitivity to weather and enables traffic to return in as little as one hour after construction. Rubber-emulsion aggregate slurry contains crumb rubber and clay stabilizers so it can be premixed at central plants and placed using special distributors equipped with a spreader box. Coal tar slurry is very similar to a slurry seal, except that the binder is a coal tar derivative that would be expected to have improved fuel resistance.

Function

Slurry surfacing systems are used for both the preventive and corrective maintenance of HMA pavement surfaces. Since a slurry surfacing system is very thin, it does not increase the pavement's structural strength. Any pavement that is structurally weak in localized areas should be repaired before applying the slurry seal. All ruts, humps, low pavement edges, crown deficiencies, waves or other surface irregularities that diminish the riding quality should be corrected before placing the slurry seal. Microsurfacing is different in that the high polymer content in the asphalt emulsion enhances mixture strength. In addition to conventional thin applications, Microsurfacing machines can be equipped with special spreader boxes to fill wheel-path ruts.

Timely application of any slurry system can help reduce surface distress caused by oxidation of the asphalt and embrittlement of the paving mixture. Figure 4.21 shows a slurry seal machine placing material. Slurry seals are one of the oldest surface treatments and are commonly used on airfields. Some airports will not use slurry seals on apron areas due to the possibility of raveling caused by turning aircraft, which may cause FOD problems. Some airports have found that microsurfacing can be used for airfield applications by making one important change to conventional highway practice: To reduce raveling-induced FOD, lightly compacted the microsurfacing material with a rubber-tired roller before the emulsion is fully cured so that any loose surface aggregates are pushed down into the HMA surface.

***Figure 4.21 Slurry Seal Operation***

A slurry seal or microsurfacing is used for the following:

- Seal sound pavements
- Restore the surface texture in a pavement by providing a skid-resistant surface
- Reduce the permeability of the surface
- Correct raveling
- To fill ruts in an HMA pavement (microsurfacing)

A slurry seal or microsurfacing should not be used to do the following:

- Correct a surface profile
- Fill potholes
- Alleviate cracking (Any existing cracking will reflect through the slurry seal within a year.)

### 4.4.2 Advantages/Disadvantages

Slurry seals and microsurfacing can seal small surface cracks, stop raveling and loss of matrix, make open surfaces impermeable to air and water and improve skid resistance and pavement appearance. Slurry seals and microsurfacing protect the existing pavement structure from ultraviolet damage, oxidation, mechanical wear and exposure to some chemicals. Microsurfacing has the advantage that it can be placed in thicker lifts (layers) and be used to correct minor surface-profile irregularities and for rut filling.

Slurry seals cure more slowly than microsurfacing material and cannot be used to fill depressions. They can also remain tender for several weeks after placement, leaving marks or damage from turning vehicles. This can result in an FOD problem and require diligent sweeping operations during the early life of the slurry seal. Underlying cracks tend to reflect through the slurry seal in two to three years because the surface is very thin.

### 4.4.3 Life Expectancy

The life expectancy of a slurry surfacing system depends on the condition of the HMA pavement prior to the placement of the slurry seal. The following is an estimate of the service life of a slurry surfacing system based on the PCI at the time of placement:

- PCI = 80, good condition – 7 to 10 years
- PCI = 60, fair condition – 5 to 7 years
- PCI = 40, poor condition – 2 to 5 years

### 4.4.4 Materials

Slurry surfacing consists of:

- Binder – asphalt or coal tar emulsion
- Water
- Aggregate
- Additives

<u>Binder</u>

Emulsified asphalt used in the slurry seal mix may be SS-l, SS-1h, CS-1 or CSS-1h. Quick-setting (QS) asphalt emulsion used when early opening to traffic is necessary. The asphalt emulsion used for slurry seals can be a polymer-modified material. (Refer to Section 3.2.2 for a discussion of the different asphalt types.) For microsurfacing, polymer-modified QS emulsions are used, such as PMQS-1h. For coal tar slurry, the binder is a thermoplastic emulsion of coal tar made with a plastic resin and emulsified coal-tar pitch.

<u>Water</u>

The water used for slurry surfacing must be clean, potable water free of harmful soluble salts and chemicals.

<u>Aggregates</u>

The aggregate used in slurry seals and microsurfacing must be clean, angular, durable, well graded and uniform. An individual aggregate or a blend of aggregates to be used in a slurry mix should meet these limits:

- Sand equivalent value, ASTM D2419 (American Association of State Highway and Transportation Officials [AASHTO] T 176):
    - Slurry seal - 45 minimum
    - Microsurfacing – 65 minimum
    - Coal-tar-emulsion slurry seal – no specification
- For slurry seals and microsurfacing a Los Angeles abrasion loss, ASTM C131 (AASHTO T 96) Grading C or D, 35 maximum is required; for a coal-tar-emulsion slurry seal a 25 maximum is required.
- Sodium sulfate loss should not exceed 12 percent, and the magnesium sulfate loss should not exceed 20 percent.
- The amount of smooth-textured sand with less than 1.25 percent water absorption is limited to not more than 50 percent of the total combined aggregate.

FAA Specification P-626 provides for four gradation bands (Table 4.4):

- Type I is used for maximum crack penetration. Also, it makes an excellent pretreatment for hot-mix overlay or chip seal. It is usually used in low-density traffic areas such as light aircraft airfields, parking areas or shoulders where the primary objective is sealing.
- Type II is the most widely used gradation. It is used to seal; to correct moderate raveling, oxidation, and loss of matrix; and to improve skid resistance. It is used for moderate traffic, depending upon the quality of aggregates available and the design.
- Type III is used to correct surface conditions, as the first course in multicourse applications for heavier traffic, and to improve skid resistance.
- Type 1A is used when a coarser gradation is desired than what is provided by Type 1.

Generally the industry has used only Type II and III gradations for microsurfacing.

Sometimes, a small amount of liquid or powdered additive is incorporated into the asphalt emulsion to control the setting time of the slurry mixture. This additive starts the setting process in anionic QS emulsions. It retards setting in cationic quickset emulsions. Water used in the slurry should be potable and compatible with the mix.

***Table 4.4 Slurry Mixture Gradations***

| Type of Slurry | Type I | Type II | Type III | Type IA |
|---|---|---|---|---|
| **Sieve Size** | **Percent Passing (by weight)** | | | |
| ⅜ inch (9.5 mm) | 100 | 100 | 100 | 100 |
| No. 4 (4.75 mm) | 100 | 90 to 100 | 70 to 90 | 98 to 100 |
| No. 8 (2.36 mm) | 90 to 100 | 65 to 90 | 45 to 70 | 85 to 95 |
| No. 16 (1.18 mm) | 65 to 90 | 45 to 70 | 28 to 50 | 50 to 75 |
| No. 30 (600 µm) | 40 to 65 | 30 to 50 | 19 to 34 | 30 to 50 |
| No. 50 (300 µm) | 25 to 42 | 18 to 30 | 12 to 25 | 18 to 35 |
| No. 100 (150 µm) | 15 to 30 | 10 to 21 | 7 to 18 | 10 to 21 |

| Type of Slurry | | Type I | Type II | Type III | Type IA |
|---|---|---|---|---|---|
| Sieve Size | | Percent Passing (by weight) | | | |
| No. 200 (75 µm) | | 10 to 20 | 5 to 15 | 5 to 15 | 5 to 10 |
| Residual Asphalt Content (% weight of dry aggregate) | | 10 to 16 | 7.5 to 13.5 | 6.5 to 12 | 9 to 13.5 |
| Application Rate | $lb/yd^2$ | 8 to 12 | 12 to 20 | 18 to 30 | 10 - 16 |
| | $kg/m^2$ | 4.3 to 6.5 | 6.5 to 10.9 | 9.8 to 16.3 | 5.4 - 8.6 |

Notes % = percent, lb = pound, µm = micrometer(s), mm = millimeter(s), $yd^2$ = square yard, kg = kilogram(s), $m^2$ = square meter

FAA Specification EB-35 (Table 4.5) provides the following gradation for the coal tar slurry seal.

***Table 4.5 Coal Tar Slurry Seal Gradation***

| Sieve Size | Percent Passing (by weight) |
|---|---|
| ⅜ in. (9.5 mm) | 100 |
| No. 4 (4.75 mm) | 100 |
| No. 8 (2.36 mm) | 80 to 90 |
| No. 16 (1.18 mm) | 55 to 77 |
| No. 30 (600 µm) | 35 to 60 |
| No. 50 (300 µm) | 24 to 45 |
| No. 100 (150 µm) | 15 to 25 |
| No. 200 (75 µm) | 5 to 20 |
| Residual Asphalt Content (% weight of dry aggregate) | 10 to 16 |
| Application Rate lb/sq yd | 7 to 8 |

Notes: % = percent, lb = pound, µm = micrometer(s), mm = millimeter(s), $yd^2$ = square yard, kg = kilogram(s), $m^2$ = square meter

Additives

Many types of additives are used in slurry seal mixtures to help control break and setting times. The most common additives are Portland cement, hydrated lime, and aluminum sulfate. Any additives used should be included in the mix design report obtained from the laboratory. The equipment placing the slurry should have the means to control the addition of the additive into the slurry surfacing mix.

Portland cement allows the mixing time to be extended and helps to create a creamy consistency that makes the slurry seal easy to spread. Cement is a fine material and absorbs the water from the emulsified asphalt. This causes the slurry seal to break faster after placement. Hydrated lime functions like cement and causes the slurry seal to set up faster after placement. Aluminum sulfate is used as a retardant and increases the setting time of the slurry seal on the roadway.

### 4.4.5 Comparison of Slurry Surfacing Systems

Table 4.6 provides a comparison of the three slurry surfacing procedures.

***Table 4.6 Comparison of Slurry Surfacing Systems***

| Materials/ Placement | Microsurfacing | Slurry Seal | Coal Tar Emulsion |
|---|---|---|---|
| Asphalt Binder | Always uses a polymer-modified QS emulsion. | Generally an asphalt emulsion that is not polymer modified. But polymer-modified emulsions have been used. | Uses a thermoplastic coal tar emulsion made of plastic resin and emulsified coal-tar pitch. |
| Aggregate Quality/Gradation | Stricter specification used for sand equivalent; use only Type II and Type III. | Can use Type I, II or III or 1A. | Uses gradations and aggregate specifications developed for it. |
| Additives (Break) | Uses a chemical break, which is largely independent of weather conditions. | Breaking and curing are largely dependent on weather conditions. | Breaking and curing are largely dependent on weather conditions. |
| Equipment (Mix Stiffness) | For a stiffer mix, use augers in the spreader box and secondary strike off. | For a softer mix, use a drag box for placement. | Use a standard slurry seal machine to place the material. |
| Applications | Applications are the same as for slurry seal rut filling. Use for correction of minor surface-profile irregularities. | Use to correct raveling, seal oxidized pavements and restore skid resistance. | Provides a fuel-resistant surface. |

### 4.4.6 Mix Design

When building a project using a slurry surfacing system, the first step is to have a qualified laboratory develop the mix design. No project should be built until the mix design has been approved by the engineer. The mix design should be done by a laboratory with experience in the development of slurry surfacing designs. The purpose of the mix design procedure is) to determine:

- Will the components mix together and form a free-flowing slurry?
- Will the emulsion break in a controlled manner on the aggregate, coat the aggregate and result in good forms on the aggregate?

- Will the emulsion build up cohesion to a level that will resist abrasion by traffic?
- Will the slurry seal surfacing resist traffic-induced stresses?

The second step in the development of the mix design is to verify that the aggregates meet the specifications, specifically those items listed in Section 4.4.4 and listed in Tables 4.4 and 4.5 above. The third and final step is to determine the amount of residual asphalt binder in the asphalt emulsion. This is determined by placing a known quantity of asphalt emulsion in an oven and drying it to a consistent weight.

The following sections describe the mix design procedures for each of the three slurry surfacing systems

Mix Design - Slurry Seal

FAA Specification P626 does not require a specific mix design procedure but recommends that the designer follow ISSA Publication A105, Recommended Performance Guidelines for Emulsified Asphalt Slurry Seal Surfaces and ISSA Technical Bulletin No. 111, Outline Guide Design Procedure for Slurry Seal. Both of these publications are published by the ISSA,. They contain information to aid designers of slurry mixes. ASTM D3910 also contains a detailed procedure for the development of a slurry seal mix design. The ISSA and ASTM guidelines are very similar. This section discusses the ISSA procedure.

ISSA recommends the quality tests shown in Table 4.7.

***Table 4.7 ISSA Quality Tests for a Slurry Seal***

| ISSA Test Procedure | Description | Specification |
|---|---|---|
| TB 115 | Slurry Seal Consistency | No tacky surface and no asphalt or aggregate migration |
| TB 139 | Wet Cohesion: 30 minutes minimum (set)<br>Wet Cohesion: 60 minutes minimum | 12 kg-cm Minimum<br>20 kg-cm Minimum |
| TB 109 | Excess Asphalt by LWT Sand Abrasion | 50 g/ft$^2$ Minimum<br>538 g/ft$^2$ Maximum |
| TB 114 | Wet Stripping | Pass (90 percent minimum) |
| TB 100 | Wet Track Abrasion Loss, One-Hour Soak | 75 g/ft$^2$ maximum |
| TB 113 | Mix Time (should be performed at the highest temperatures expected during construction) | Controllable to 180 Seconds Minimum |

Notes: g/ft$^2$ = grams per square foot, kg-cm = kilograms of force applied when a torque wrench is moved 1 centimeter, LWT = loaded wheel tester

During the mix design process, mixes will be manufactured at three levels of emulsion content. Each mix is tested to evaluate consistency and resistance to wear. Figure 4.22 shows the slurry in a consistency test (ISSA Test Procedure TB 115). This test is used to determine the optimum mix proportions (proper ratio of aggregate, filler, water and emulsion) as related to the consistency for pavement surface placement. Several mixes are made using dried aggregate and various combinations of mineral filler, asphalt emulsion and water.

***Figure 4.22 Consistency Test***

Figure 4.23 shows the wet track abrasion device used to evaluate the slurry's resistance to wear. This test measures the wearing qualities of slurry seal under wet abrasion. The test specimens are disk shaped, 0.25 inches thick and 11 inches in diameter. After the initial set of the mix, the specimen is dried to a constant weight in an oven. The cured slurry is placed in a water bath for a period of time (one hour for slurry seals and one hour and six days for microsurfacing mixes). The slurry is then abraded under water with a rubber hose for five minutes. The abraded specimen is washed free of the debris, dried in the oven and weighed. The test measures the loss in weight of the specimen as expressed in grams per square meter (or square foot) and is reported as the wet track abrasion loss.


**Figure 4.23 Wet Track Abrasion Test Machine**

An example of a slurry-seal mix design report is presented on the following pages.

## EXAMPLE
## SLURRY SEAL MIX DESIGN REPORT

### RESIDUE BY EVAPORATION

Residue by evaporation, average of three points: 61.1%

***Table 4.8 Slurry Seal Mixture Tests (ISSA Methods)***

| ISSA Test Procedure | Parameter | Results | Specified Limits |
|---|---|---|---|
| TB 115 | Consistency at 2.5 Centimeters | Satisfactory | No tacky surface |
| TB 115 | Split Consistency | Satisfactory | No asphalt or aggregate migration |
| TB 102 | Slurry Seal Mixing Test, 70°F to 85°F, 120-second cure | Satisfactory | Uniform aggregate dispersion, no tacky surface at 120 seconds |
| TB 102 | Slurry seal setting test, 70°F to 85°F, 60-minute cure | Satisfactory | No brown stain after a 60-minute cure |
| TB 102 | Slurry water resistance test, 70°F to 85°F, 60-minute cure | Satisfactory | No more than slight discoloration at 60 minutes |

***Table 4.9 Slurry Seal Properties (ISSA Method TB 100)***

| Emulsion Content (%) | Mixing Water (%) | Total Fluid (%) | Consistency Test (cm) | Residual AC Content | Abrasion ($g/ft^2$) | Specification ($g/ft^2$) |
|---|---|---|---|---|---|---|
| 12 | 20 | 32 | 2.5 | 7.3 | 62.5 | Less than 75 |
| 14 | 18 | 32 | 2.5 | 8.5 | 28.4 | Less than 75 |
| 16 | 16 | 32 | 2.5 | 9.8 | 21.0 | Less than 75 |

Notes: AC = asphaltic cement, $g/ft^2$ = grams per square foot

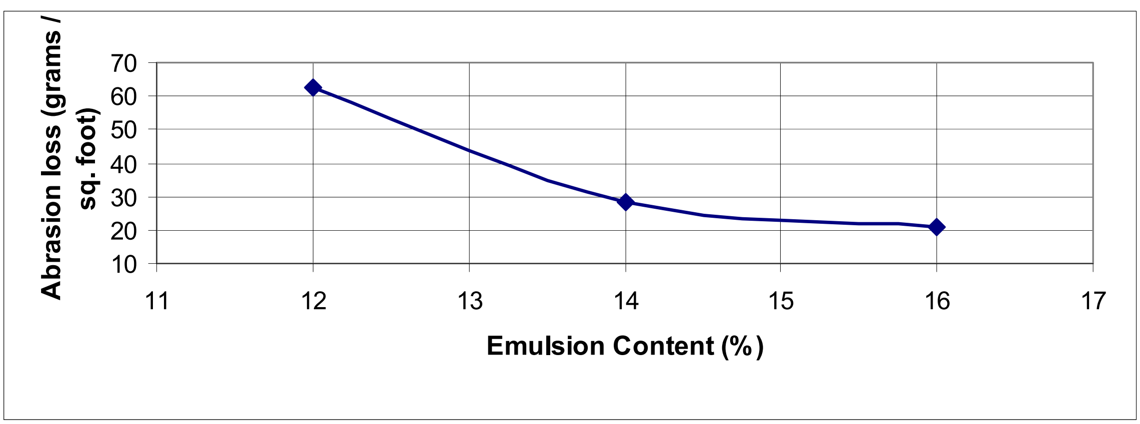

***Table 4.10 Aggregate***

| Sieve Size | Passing (%) | Spec. |
|---|---|---|
| 3/8 inch (9.5 mm) | 100 | 100 |
| No. 4 (4.75 mm) | 94 | 90 to 100 |
| No. 8 (2.36 mm) | 68 | 65 to 90 |
| No. 16 (1.18 mm) | 49 | 45 to 70 |
| No. 30 (0.600 mm) | 38 | 30 to 50 |
| No. 50 (0.300 mm) | 27 | 18 to 30 |
| No. 100(0.150 mm) | 18 | 10 to 21 |
| No. 200 (0.075 mm) | 12.7 | 5 to 15 |

| Property | Values | Spec. |
|---|---|---|
| Sand Equivalent | 50 | Greater than 45 |
| Los Angeles Wear | 25 | Less than 35 |
| Sodium Sulfate | 8 | Less than 12 |

Notes: mm = millimeter(s), Spec. = Specification

***Table 4.11 Theoretical Batch Proportions***

| Material | Quantity (lbs) | Percentage by Weight of Dry Aggregate (%) | Tolerances | |
|---|---|---|---|---|
| | | | Minimum | Maximum |
| Type II Slurry Seal Aggregate | 2000 | - | - | - |
| Aluminum Sulfate | 4 | 0.2 | - | 2.0 |
| Optimum Emulsion Content | 265 | 13.3 | 12.3 | 14.3 |
| Mixing Water | 375 | 18.7 | - | - |
| Theoretical Asphalt Content | - | 8.1 | 7.5 | 8.7 |

Notes: lbs = pounds

Mix Design - Microsurfacing

The quality requirements for microsurfacing are more stringent than those for slurry seals. The FAA does not have a specification for microsurfacing. The reader is referred to the International Slurry Seal Association (www.slurry.org) for a current specification (A143) for microsurfacing. Table 4.12 presents the ISSA mix design requirements from A143 for developing a mix design for microsurfacing. (The ASTM procedure for a microsurfacing slurry seal design is ASTM D6372-99a. The Texas Transportation Institute also has developed a mix design procedure for microsurfacing, TTI 1289.)

***Table 4.12 ISSA Quality Tests for Microsurfacing***

| ISSA Test Procedure | Description | Specification |
|---|---|---|
| TB 115 | Slurry Seal Consistency | No tacky surface and no asphalt or aggregate migration |
| TB 139 | Wet Cohesion: 30-Minute Minimum (set)<br>Wet Cohesion: 60-Minute Minimum | 12 kg-cm Minimum<br>20 kg-cm Minimum |
| TB 109 | Excess Asphalt by LWT Sand Abrasion | 50 g/ft$^2$ Minimum<br>538 g/ft$^2$ Maximum |
| TB 114 | Wet Stripping | Pass (90% Minimum) |
| TB 100 | Wet Track Abrasion Loss<br>• One-Hour Soak<br>• Six-Day Soak | 50 gm/ft$^2$ Maximum<br>75 gm/ft$^2$ Maximum |
| TB 113 | Mix Time at 77°F | Controllable to 120 Seconds Minimum |
| TB 147 | Lateral Displacement<br>Specific Gravity after 1,000 Cycles at 125 Pounds | 5% Maximum<br>2.10 Maximum |
| TB 144 | Classification Compatibility | 11 Grad Points Minimum |

Notes: g/ft$^2$ = grams per square foot, kg-cm = kilograms of force applied when a torque wrench is moved 1 centimeter, LWT = loaded wheel tester

Mix Design - Coal Tar Emulsion Slurry Seal

EB-35A does not have detailed requirements for a mix design. Rather it requires that the contractor verify that the process will provide the desired results by placement of a test section of approximately 16 feet wide by 100 feet long. The area to be for the test section will be designated by the engineer and will be located on the existing pavement.

The test section is used to verify the adequacy of the mixture and to determine the exact application rate. The same equipment and method of operations are to be used on the test section as will be used on the remainder of the work. If the test section results are unsatisfactory, the necessary adjustments to the mix composition, application rate, placement operations and equipment need to be made. Then additional test sections are to be placed and evaluated. .

### 4.4.7 Construction Process

Surface Preparation

Before any work is started, a thorough surface examination must be made to determine needed repairs and to evaluate requirements for treatment. Soft spots that may result in future failures are noted, as are variations in width, cross section, and profile that would leave the road unsightly. Side drainage defects are especially critical. If an old surface is being reconditioned, look for potholes, cracked areas, depressions, slick or bleeding asphalt areas, absorbent areas, and other surface defects.

Repairs and corrections must be made so the old surface will be in sound condition before treatment is begun. A slurry seal should not be used on a pavement that has extensive load-induced cracking. Some old pavements do not need repairs before a slurry seal is placed. However, most pavements need some patching and removal of excess asphalt. When surface repairs such as patching are performed, sufficient time should be allowed before placing the slurry system to ensure consolidation under traffic. Any surface cracks wider than ⅛ inch are sealed. Cracks wider than ¾ inch should be prefilled and sealed with slurry prior to surfacing. The crack sealing should be done sufficiently early to allow the sealant to cure before the slurry surfacing system is applied to the pavement surface.

If the surface to be covered is not completely clean, the slurry surfacing system may not adhere to the pavement (Figure 4.24). It is therefore necessary to clean the surface before spraying the asphalt emulsion. A power street sweeper is recommended to pick up dust and loose particles; however, if one is not available, a rotary power broom can be used. When brooms are used, flushing with water may be necessary to meet clean air standards or to remove caked-on materials. Any manholes or storm drainage structures should be covered with a polyethylene film to prevent a slurry buildup on those surfaces.

***Figure 4.24 The Effect of Placing Slurry Seal on a Dirty Surface***

Power sweepers or brooms are also used to remove loose particles after the treatment is completed and the asphalt has properly cured. Only light broom pressure should be used in order to prevent dislodgment of the aggregate particles embedded in the asphalt membrane.

Calibration of the Slurry Seal Machine

FAA Specification P-626 requires that slurry seal machine be calibrated in the presence of the engineer prior to construction. An exception in the specification to this requirement is that a previous calibration will be acceptable if during that calibration the contractor used the exact materials to be used on the project to be built and that it was done in the previous year. The purpose of the calibration to achieve the following:

- To set the machine for a given mix design
- To maintain mix design consistency on all machines when using two or more machines
- To develop a database on a given machine

Calibration of Slurry Seal Components

The following details the procedure for calibrating the three components of the slurry seal: the emulsion, the dry additive/mineral filler and the aggregate.

To calibrate the emulsion feeding system:

- Empty the machine of all aggregate. Fill the slurry machine with emulsion and determine the gross weight.
- Hook the pump outlet to a second container such as a tanker.
- Run the desired turns of the head-pulley counter.
- Determine the weight of the emulsion by reweighing the machine.
- Determine the weight of the emulsion pumped per count of the pulley machine.
- Run three tests to ensure accuracy. If variable pumps are to be used and will be reset during the project, calibration must be done for enough settings to draw a graph.
- The emulsion pump should deliver emulsion to the pug mill with such consistency that the deviation for any individual delivery-rate check run shall be within 2 percent of the mathematical average of three runs of at least 300 gallons each.

To calibrate the dry additive/mineral filler process, the following steps should be followed:

- Check that all aggregate is removed from the machine, as the conveyor belt must turn while calibrating the fines meter.
- Use a small pan or box to catch the mineral filler that falls from the feeder. Weigh this container prior to continuing.

- Using a count of the turns or the head pulley or the fines auger box, run approximately 20 pounds of material into the box.
- Weigh the container of material and subtract the weight of the container. The weight of the material divided by the count of the pulley head or the fines feeder gives the weight per turn.
- Repeat at three settings to develop a curve for the material at various gate settings.
- Calculate the desired setting to meet the mix design requirements. Set the gate or hydraulic controls and run another test to verify the delivery rate.

To calibrate the aggregate process, the following steps should be followed. Prior to starting the calibration process, the moisture content of the aggregate should be determined to determine the dry weight. The following are some guidelines for the process.

- Select and record three or more gate settings.
- At least three tons of aggregate should be run per gate setting.
- The machine should deliver such volumetric consistency that the deviation of any aggregate delivery-rate check run shall not exceed 2 percent of the mathematical average of three runs of at least 3 tons in duration.
- The results should produce a straight line on an arithmetic graph.

Application of Slurry Seal

Slurry seal is placed through the use of a specially designed slurry machine (see Figure 4.25) that has a single- or double-shaft pug mill. The mixed slurry seal is discharged from the pug mill into a spreader box. The spreader box is equipped with flexible squeegees and has an adjustable width. Spreader boxes may be equipped with hydraulically powered augers to uniformly distribute the material across the spreader box width. The difference between the slurry and microsurfacing equipment is the spreader box used. A slurry seal spreader box is a drag box (Figure 4.26).

The microsurfacing spreader box (Figure 4.27) has to move a much stiffer mix, do it quickly and spread it before the emulsion breaks. To accommodate this, two sets of augers are used and a texturing rubber is added at the rear of the box. The texturing rubber is usually spread using an outrigger. The outrigger creates the desired surface texture for the surface. Additionally, a microsurfacing box is rigidly attached to the rear of the paver, allowing a preset thickness of material to be placed.

Any of the slurry surfacing systems should be placed when the air temperature is 50$^{o}$F and rising. Humidity should be 60 percent or less, and a slight breeze is advantageous. Work should also not be attempted if freezing temperatures are anticipated in the next 24 hours. Slurry seal should not be placed when rain is imminent. Slurry seals will usually resist rain after as little as one hour, but typically they need three hours to become fully waterproof.

The surface should be prewetted by fogging ahead of the slurry spreader box. Water used for prewetting the surface should be applied at such a rate that the entire surface is damp with no apparent flowing water in front of the slurry spreader box. This water is applied through the slurry seal machine directly in front of the spreading of the slurry. The slurry mixture should be of the desired consistency when deposited on the surface, and no additional elements should be added. Total time of mixing should not exceed two minutes. A sufficient amount of slurry should be carried in all parts of the spreader box at all times so that complete coverage of all surface voids and cracks is obtained. Care should be taken not to overload the spreader box.


***Figure 4.25 Slurry Seal Machine***

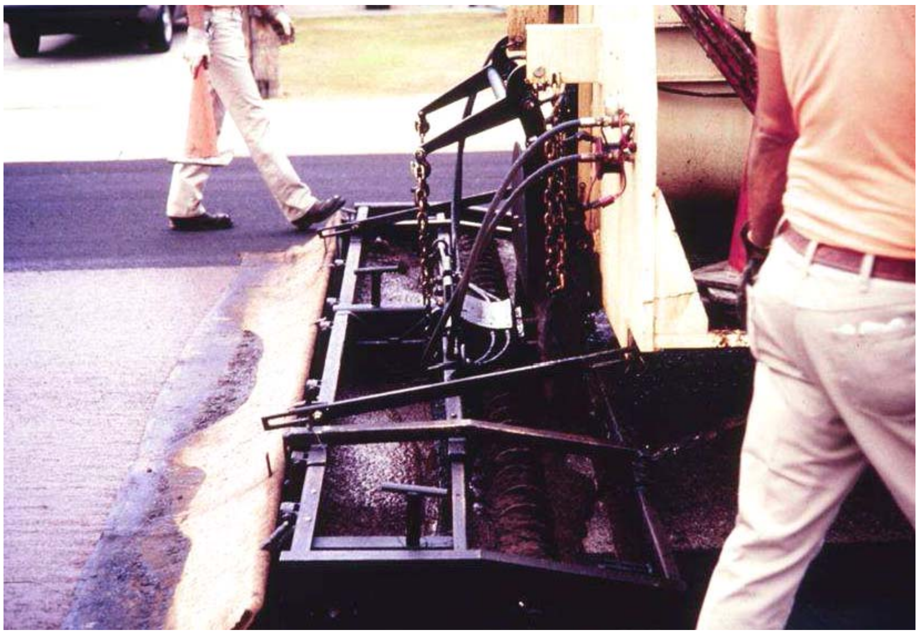

***Figure 4.26 Slurry Seal Spreader Box***

***Figure 4.27 Microsurfacing Spreader Box***

The spreader box should be towed at a slow and uniform rate not to exceed 5 miles per hour. No lumping, balling, or unmixed aggregate should be permitted. No segregation of the emulsion and fines from the coarse aggregate should be permitted. If the coarse aggregate settles to the bottom of the mix, the slurry should be removed from the pavement surface. A sufficient amount of slurry should be fed into the box to keep a full supply against the full width of the spreader box. The mixture should not be permitted to overflow the sides of the spreader box. No breaking of the emulsion should be allowed in the spreader box. The finished surface should have no more than four tear or drag marks greater than ½ inch wide and 4 inches long in any 12-foot-by-22-foot section, and it should have no tear or drag marks greater than 1 inch wide and 3 inches long.

The longitudinal joints may be overlapped or butt jointed. The overlaps should not be in the wheel paths, and they should be a minimum of 2 inches to a maximum of 4 inches in width. At all stops and starts, the machine should be started on roofing felt to ensure sharp, uniform joints. Transverse joints must be smooth to avoid creating a bump in the surface. All joints shall have no more than ¼-inch difference in elevation when measured across with a 10-foot straightedge (see Figure 4.28)

*Figure 4.28 Starting from Roofing Felt*

After placement, the slurry seal generally will build sufficient cohesion to resist abrasion from traffic. If traffic is allowed on the slurry before it cures it may scuff (see Figure 4.29). Some stone shedding may occur, but should not exceed 3 percent. Generally if the slurry seal has turned black, the area can be opened to traffic.

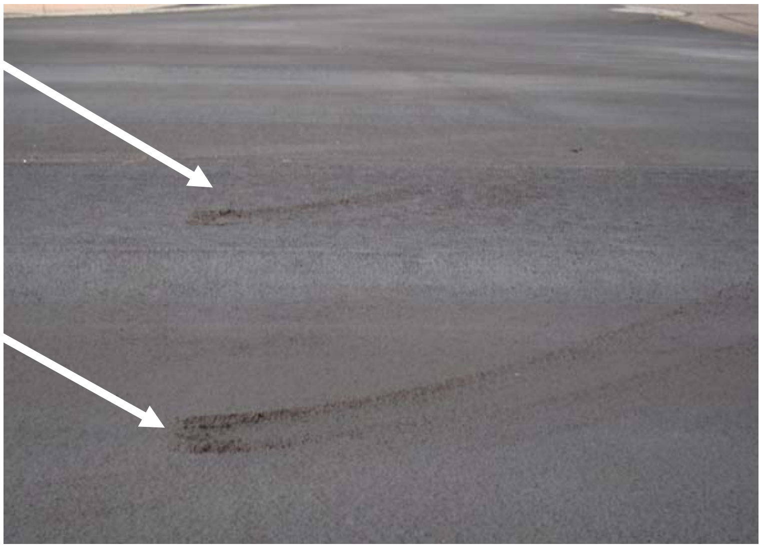

*Figure 4.29 Initial Scuffing of Slurry Seal*

Rolling

Slurry seals generally do not need to be rolled, but to limit the loss of aggregate, rolling with light pneumatic rollers (6 to 7 tons) may be done. One or two passes is recommended. This allows the water to be pressed to the surface, promoting evaporation and curing. For airfield pavements where loose surface aggregates pose FOD problems, microsurfacing with light compaction is recommended.

Sanding

If a slurry seal is used on a street, sanding may reduce the amount of time that a cross street or intersection is closed. Sanding is an application of a fine layer of dry, washed sand that is broadcast over the slurry surface. Sand may also be used on wet spots. It is not recommended for use on airfield surfaces due the possibility of creating an FOD problem for aircraft.

Sweeping

After placement of the slurry seal, the pavement should be swept to remove any potential loose material from the surface (Figure 4.30). The swept material should be disposed of in a manner satisfactory to the engineer.

***Figure 4.30 Airfield Vacuum Sweeper***

### 4.4.8 Quality Assurance

The inspector should monitor the project to keep track of the materials being placed. This may be accomplished by tracking each truck delivery as the material is placed, or by tracking deliveries to the project and deducting any waste. Dividing the weight of materials by the project surface area will provide the best estimate of application rates.

Samples should be taken to verify that the materials being supplied to the job site are the same as those used during the mix design. A certificate of compliance should be provided to the engineer to verify that the contractor is supplying the asphalt binder required by the specifications. In addition, samples of the slurry should be taken (one test daily or one per 500 tons) to verify the gradation of the aggregate and to determine the residual asphalt in the slurry. These will be determined by conducting a burn test of the mixture using an oven similar to the NCAT ignition furnace. The aggregates and residual asphalt content must meet the requirements shown in Table 4.13.

***Table 4.13 Quality Assurance Tolerances***

| Sieve Size | Tolerance (percent by weight passing sieve, %) |
|---|---|
| 3/8 inch (9.5 mm) | ±0 |
| No. 4 (4.75 mm) | ±2 |
| No. 8 (2.36 mm) | ± 5 |
| No. 16 (1.18 mm) | ±5 |
| No. 30 (600 µm) | ±5 |
| No. 50 (300 µm) | ±4 |
| No. 100 (150 µm) | ±3 |
| No. 200 (75 µm) | ± 2 |
| Residual Asphalt (percent dry weight of aggregate) | ±1 |

Notes: µm = micrometer(s), mm = millimeter(s)

### 4.4.9 Troubleshooting

Table 4.14 presents a set of troubleshooting guidelines that have been developed by the Federal Highway Administration and the California Department of Transportation.

***Table 4.14 Troubleshooting Guidelines - Slurry Surfacing Systems***

| Problem | Solution |
|---|---|
| Drag Marks | • Clean the squeegee rubbers<br>• Check the aggregate gradation for oversized aggregates |
| Flushing Surface | • Reduce the total fluids in the mix<br>• Reduce the asphalt emulsion content of the mix<br>• Increase the filler/additive<br>• Reduce the water content and increase the filler/additive<br>• Increase the time prior to release to traffic |
| Uneven Surface – "Wash Boarding" | • Ensure that the spreader box is correctly calibrated and settings are used<br>• Evaluate the mix and, if necessary, adjust the mix so that it does not break too fast<br>• Wait until the ambient temperature cools down<br>• Use water sprays if from of the slurry seal mixture<br>• Make sure the viscosity of the mix is not too high<br>• Increase the water content to reduce the viscosity of the mix |
| Poor Joints | • Reduce the amount of water at startup<br>• Use water spray if runners of the spreader box are running on fresh material<br>• For transverse joints (at startup) use building paper or felt to delineate joint |
| Excessive Raveling | • Make adjustments in the mix (add cement and reduce additive) so that the slurry mix breaks and cures faster<br>• Control the traffic for longer periods and/or do not open the section to traffic as early (allow more curing time).<br>• Wait until the mix is properly set and cured before brooming. |

## 4.5 CHIP SEALS

### 4.5.1 Introduction

Description

A chip seal is a binder (asphalt emulsion or hot-applied asphalt) that is spray-applied by a distributor, which is then followed immediately by the application of clean, single-sized aggregate (chips). It can a single-chip seal (Figure 4.31), which is an application of asphalt binder followed by an aggregate layer, or it can be a multiple-chip seal, which consists of multiple applications of binder and aggregate (Figure 4.32). Both double- and triple-chip seals are used. In most cases, multiple surface treatments are used as a surfacing over a base — either untreated or chemically stabilized with Portland cement or lime/fly ash. Chip sealing is a preventive maintenance tool that provides a skid-resistant surface, arrests raveling and seals minor cracking.

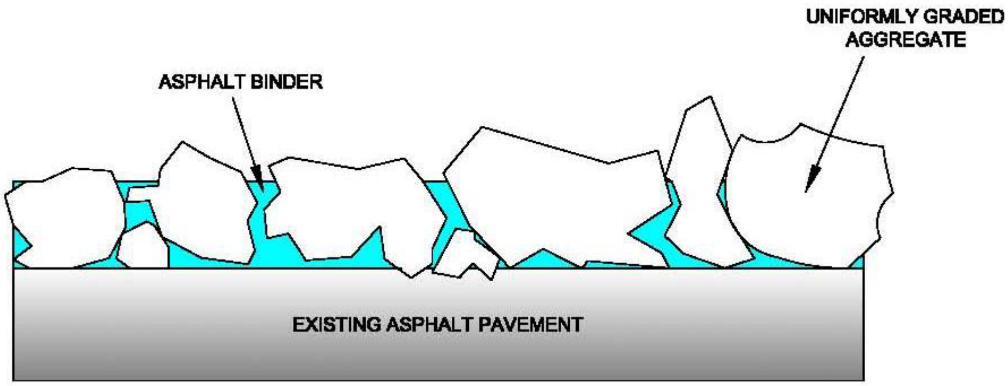


***Figure 4.31 Single-Chip Seal***

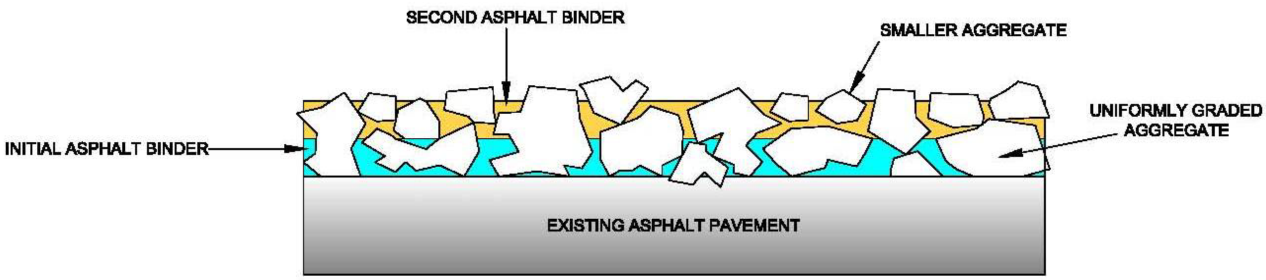


***Figure 4.32 Double-Chip Seal***

<u>Function</u>

Chip seals are effective maintenance techniques for pavements with the following problems:

- Low to moderate block cracking
- Low to moderate raveling
- Low to moderate transverse and longitudinal cracking
- A smooth surface with low friction numbers

Defects such as flushing of the HMA pavement, base failures, and rutting or shoving of the HMA surface **cannot** be solved with a chip seal.

### 4.5.2 Advantages/Disadvantages

A chip seal will waterproof the surface and seal small cracks and imperfections. Furthermore, it <u>may</u> soften a hardened and oxidized asphalt, improve skid resistance and surface texture and protect the underlying pavement from oxidation, aging and traffic wear. The primary disadvantage of a chip seal is that it may leave loose, unbound aggregates on the surface that can contribute to FOD. This problem typically limits its use to areas that are unused by aircraft, unless the aircraft is being towed. A chip seal can be used as a surface treatment on aggregate bases or as a preventive maintenance tool on HMA surfaces at locations on the airport other than the airfields themselves (for example, roads and parking lots).

### 4.5.3 Life Expectancy

The life of a chip seal will range from 5 to 10 years and is a function of climate, existing pavement condition, traffic and type of chip seal. The following is an estimate of the life of a chip seal based on the condition of the surface:

- PCI = 80, good condition – 7 to 10 years
- PCI = 60, fair condition – 3 to 5 years
- PCI = 40, poor condition – 1 to 3 years

A pavement that has a PCI of less than 60 should probably be treated with multiple surface treatments.

### 4.5.4 Materials

Asphalt Binder

The primary purpose of the asphalt binder is to seal the surface of an HMA pavement to prevent water and air intrusion into underlying asphalt layers and the subgrade. It further provides the glue to hold chips so that adequate friction and wear can be maintained. The base asphalt cement for either emulsion or hot-applied applications is usually one or two grades softer than that recommended for a surface HMA mixture in the same climate. Chip seal emulsions are frequently modified with elastomeric polymers such as styrene-butadiene-styrene (SBS) or styrene-butadiene rubber (SBR), whereas hot-applied materials can also be modified with crumb rubber.

The asphalt emulsion is generally either a cationic or anionic rapid set (RS) emulsion (RS-1, RS-2, CRS-1, CRS-2). Some state highway agencies also use medium set (MS) emulsions (MS-1, HFMS-1), with HFMS-1 being the more popular of the two. One advantage of a high-float emulsion is that it performs better with a dusty aggregate; however, the best chip seal is built using a clean aggregate. Also, many states are using polymer-modified asphalt emulsions to construct chip seals, particularly in areas with traffic levels above 1,000 vehicles of average daily traffic. Local materials and conditions play an extremely important role in chip seal binder selection. Important factors include traffic, pavement surface temperatures, aggregate quality and the ability of construction operations to provide traffic control and adapt to local weather conditions.

Aggregates

The primary purpose of the aggregate is to protect the asphalt binder from damage and to develop a surface texture that results in a skid-resistant surface. The aggregate should be either crushed stone, crushed gravel or crushed slag, although some agencies now favor manufactured lightweight aggregate. The goal is to provide hard, durable, angular aggregates that provide good particle interlock after rolling. The following are the requirements for the aggregate according to FAA Specification P609, Seal Coats and Bituminous Surface Treatments:

- Have an overall gradation that is of one size and uniformly graded.
- Have a percentage of wear (ASTM C131) of not more than 40 percent at 500 revolutions.
- Have sodium sulfate soundness (ASTM C88) of 12 percent or less.
- Be cubical or pyramidal and angular (75 percent of the aggregate must have two fractured faces).
- Be clean. Any dust on the aggregate will prevent the asphalt from adhering to the aggregate.

***Table 4.15 Gradation of Aggregates For Chip Seal***

| Sieve Size | Percent by Weight Passing Sieve | | |
|---|---|---|---|
| | Coarse No. 6 ¾ in. to ⅜ in. (19 mm to 9.5 mm) | Medium No. 8 ⅜ in. to No. 8 (19 mm to 9.5 mm) | Fine No. 9 Nos. 4 to 16 (4.75 mm to 1.18 mm) |
| 1 inch (15 mm) | 100 | | |
| ¾ inch (19 mm) | 90 to 100 | | |
| ½ inch (12.5 mm) | 90 to 100 | 100 | |
| ⅜ inch (9.5 mm) | 0 to 15 | 85 to 100 | 100 |
| ¼ inch (6.2 mm) | 0 to 5 | | 90 to 100 |
| No. 4 (4.75 mm) | | 10 to 30 | 60 to 85 |
| No. 8 (2.36 mm) | | 0 to 10 | 0 to 25 |
| No. 16 (1.18 mm) | | 0 to 5 | 0 to 5 |

Notes: in.= inch(es), µm = micrometer(s), mm = millimeter(s)

### 4.5.5 Design

Chip seal design methods are either empirical procedures based on past experience or methodology based upon an engineering algorithm that includes material testing. Some DOTs have developed their own formal design procedures, but most are based on the experience of the agency and the chip seal contractor.

Experience-Based Design

Experience-based design is performed by starting with a base application rate for the binder and aggregate that is based on years of experience in the field. The major problem in the development of material application rates is the lack of uniformity of the existing pavement surface. The engineer must take into account that the condition of the existing pavement will vary in both transverse and longitudinal directions. The transverse variation is usually defined as the difference in surface texture outside, within and between the wheel paths. Longitudinal variation occurs as the surface condition varies along the road from areas where the underlying surface is oxidized to other areas where the surface may be smooth, bleeding or patched. Particular attention should be paid to varying surface textures that may require significant adjustments to binder application rates. In summary, careful characterization of the existing surface throughout the length of the chip seal project is vital to producing a successful end product.

For aggregate particles to remain embedded on the pavement, approximately 70 percent of their height should be buried in the residual asphalt. Since a chip seal emulsion contains 30 to 35 percent water, the applied emulsion must rise near the top of the single-sized aggregate particles. This is illustrated in the Figure 4.33. If the emulsion rises just below the top of the aggregate (voids are approximately 100 percent filled), the voids will be roughly two-thirds filled after curing, since about one-third of the binder will evaporate. Failure to allow emulsions to rise to this level will result in insufficient embedment and loss of the cover aggregate as soon as the seal coat is exposed to snow plows and traffic. During construction, the inspector should watch the embedment depth of the aggregate both before and after the emulsion cures and the water evaporates.

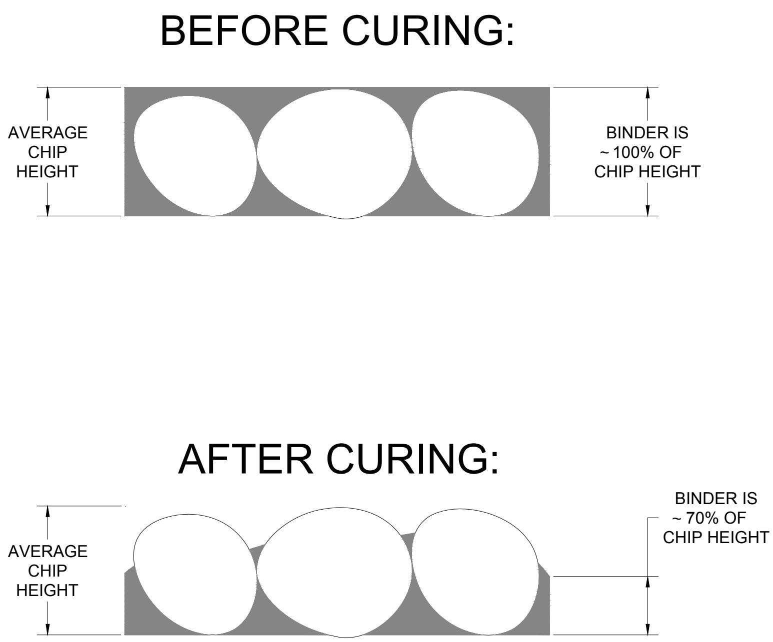


***Figure 4.33 Change in Level of Emulsion after Curing***

Another key to a successful project is the experience level of the contractor placing the chip seal. A contractor prequalification program is recommended for those participating in the design and construction of chip seals.

The Asphalt Institute's *Asphalt Handbook* (MS-4) provides guidance on the proper quantities of aggregates and asphalt application rates. Table 4.15 provides gradation requirements for the aggregates to be used for single-chip seals; Table 4.16 provides recommendations for the aggregate sizes and the application rates for a single surface treatment; Table 4.17 provides recommendations for a double surface treatment; and Table 4.18 provides recommendations for a triple surface treatment. Table 4.19 provides recommendations for corrections that should be made to allow for variations in surface condition.

***Table 4.16 Quantities of Asphalt and Aggregate per Square Yard (Square Meter) for Single Surface Treatments***

| Gradation | Quantity of Aggregate lbs/yd$^2$ | Quantity of Asphalt gal/yd$^2$ | Type and Grade of Asphalt |
|---|---|---|---|
| **¾ inch to 3/8 inch** | | | |
| Coarse | 40 to 50 | 0.35 to 0.45 | Asphalt Cement |
| | | 0.40 to 0.50 | RS-2, CRS-2 |
| **½ inch to No. 4** | | | |
| Medium | 25 to 30 | 0.20 to 0.30 | Asphalt Cement |
| | | 0.30 to 0.45 | RS-1, RS-2<br>CRS-1, CRS-2 |
| **No. 4 to No. 16** | | | |
| Fine | 15 to 20<br>(8 to 11) | 0.15 to 0.20 | RS-1, MS-1<br>CRS-1, HFMS-1 |

Notes: gal/yd$^2$ = gallons per square yard, lbs/yd$^2$ = pounds per square yard

The mass (weight) of aggregate shown in the table is based on aggregate with a specific gravity of 2.65. In case the specific gravity of the aggregate used is lower than 2.55 or higher than 2.75, the amount shown in the table above should be multiplied by the ratio so that the bulk specific gravity of the aggregate used bears to 2.65.

The lower application rates of asphalt shown in this table should be used for aggregate having gradations on the fine side of the specified limits. The higher application rates should be used for aggregate having gradations on the coarser side of the specified limits.

It is important to adjust the asphalt content for the condition of the road, increasing it if the road is absorbent or badly cracked, or decreasing it if the road is “fat” with flushed asphalt.

***Table 4.17 Quantities of Asphalt and Aggregate per Square Yard for a Double Surface Treatment***

| Application | Nominal Size of Aggregate | Quantity of Aggregate lb/yd$^2$ | Quantity of Asphalt gal/yd$^2$ | Type of Asphalt |
|---|---|---|---|---|
| **½ inch Thick** | | | | |
| First* | Medium ⅜ inch to No. 8 | 25 to 35 | 0.20 to 0.35 | Emulsified Asphalt |
| | | | 0.15 to 0.25 | Asphalt Cement |
| Second | Fine No. 4 to No. 16 | 10 to 15 | 0.30 to 0.40 | Emulsified Asphalt |

Notes: gal/yd$^2$ = gallons per square yard, lbs/yd$^2$ = pounds per square yard,

* If applied on untreated granular (aggregate) base, use cutback asphalt in lieu of emulsions or prime the base course with a cutback asphalt.

The mass (weight) of aggregate shown in the table is based on aggregate with a specific gravity of 2.65. In case the specific gravity of the aggregate used is lower than 2.55 or higher than 2.75, the amount shown in the table above should be multiplied by the ratio so that the bulk specific gravity of the aggregate used bears to 2.

The lower application rates of asphalt shown in this table should be used for aggregate having gradations on the fine side of the specified limits. The higher application rates should be used for aggregate having gradations on the coarser side of the specified limits.

It is important to adjust the asphalt content for the condition of the road, increasing it if the road is absorbent or badly cracked, or decreasing it if the road is “fat” with flushed asphalt.

***Table 4.18 Quantities of Asphalt and Aggregate per Square Yard (Square Meter) for a Triple Surface Treatment***

| Application | Nominal Size of Aggregate | Quantity of Aggregate lb/yd$^2$ | Quantity of Asphalt gal/yd$^2$ | Type of Asphalt* |
|---|---|---|---|---|
| ¾ inch (19.0 mm) Thick | | | | |
| First | Coarse ¾ in. to ⅜ in. | 40 to 50 | 0.35 to 0.45 | Asphalt Cement |
| | | | 0.40 to 0.50 | Emulsified Asphalt |
| Second | Medium ⅜ in. to No. 8 | 20 to 25 | 0.15 to 0.25 | Asphalt Cement |
| | | | 0.20 to 0.35 | Emulsified Asphalt |
| Third | Fine No. 4 to No. 16 | 15 to 20 | 0.15 to 0.20 | Emulsified Asphalt |

Notes: gal/yd$^2$ = gallons per square yard, in. = inch(es), lbs/yd$^2$ = pounds per square yard,

* If applied on untreated granular (aggregate) base, use cutback asphalt in lieu of emulsions or prime with a cutback asphalt.

The mass (weight) of aggregate shown in the table is based on aggregate with a specific gravity of 2.65. In case the specific gravity of the aggregate used is lower than 2.55 or higher than 2.75, the amount shown in the table above should be multiplied by the ratio that the bulk specific gravity of the aggregate used bears to 2.

The lower application rates of asphalt shown in this table should be used for aggregate having gradations on the fine side of the specified limits. The higher application rates should be used for aggregate having gradations on the coarser side of the specified limits.

It is important to adjust the asphalt content for the condition of the road, increasing it if the road is absorbent, badly cracked, or decreasing it if the road is “fat” with flushed asphalt.

**Table 4.19 Corrections for Surface Conditions**

| Texture | Gallons per Square Yard |
|---|---|
| Black, Flushed Asphalt | -0.01 to -0.6 |
| Smooth, Nonporous | 0.00 |
| Slightly Porous, Oxidized | +0.03 |
| Slightly Pocked, Porous, Oxidized | +0.06 |
| Badly Pocked, Porous, Oxidized | +0.09 |

### 4.5.6 Construction Procedures

Surface Preparation

The preparation of the surface is critical to the performance of the chip seal. Areas of the pavement exhibiting structural failures (such as potholes and deteriorated patches) should be addressed by the removal or patching and sealing of the failed area. All crack sealing should be completed at least three months before the placement of the chip seal. This will allow the crack sealing material to cure and set up prior to placement of the chip seal. If this is not done, the crack sealing material may bleed through the chip seal and cause the chip to flush.

Avoid the use of cold mix for patching prior to applying the chip seal. The cutback material in the cold patch will bleed through the chip seal. All patching should be done at least six months prior to placement to allow it to cure and set. If there is extensive cracking (any crack over ¼ inch), the cracks should be sealed prior to the placement of the chip seal. The asphalt binder being used for the first layer of the chip seal will seal the finer cracks in the pavement. If the surface to be sealed has extensive bleeding, it may be necessary to mill the very top surface of the pavement before chip sealing. If this is done, care should be taken to ensure that the dust associated with the milling operation is completely removed. Finally, the prepared surface must be clean, dry and free of any loose material before applying the binder.

Weather

Chip sealing must not be done in marginal weather. Chip seals should be placed in the warmest, driest weather for optimum performance. They should be placed in warm weather, when the ambient temperature is 60°F and rising. It is suggested that the pavement surface temperature be above 70°F and below 140°F. The relative humidity should be below 50 percent.

Wind may cause the emulsion spray to be diverted and compromise the uniformity of the application rate. A gentle breeze will assist in accelerating cure times. The pavement must be dry. Any rainfall immediately before, during or after the construction of the chip seal will contribute to failure of the treatment. Thus, placement of chip seals should be avoided during rainy conditions.

Traffic Control

Early dislodging of the chips can occur if traffic is allowed on the finished chip seal too early. It is recommended that, if possible, the traffic be restricted from driving on the chip seal for at least two hours. If that is not possible, pilot cars should be used to keep the speed to less than 20 miles per hour.

Application of Binder

The asphalt binder is placed using an asphalt distributor (see Figure 4.34). Many chip seal failures can be attributed to improper application of the emulsion or to poor equipment maintenance. The distributor consists of a truck-mounted asphalt tank with a system of spray bars and nozzles at the back of the truck that apply a uniform liquid application. The truck is equipped with heaters and a circulation system that heats and circulates the emulsion in the tank and transports it to the spray bar. The amount sprayed is controlled by a valve system. On newer distributors the operation of the distributor is computer-controlled such that the spray rate self-adjusts to the speed of the truck.

***Figure 4.34 Asphalt Distributor***

Prior to the construction of the chip seal, the distributor should be calibrated (using a 500-foot-long test strip) to ensure that the distributor is placing the correct amount of material both across the roadway surface and longitudinally down the roadway. The initial calibration should be done using 2-foot–by-2-foot pieces of carpet (see Figure 4.35) at various locations along the test strip to determine the horizontal and longitudinal coverage of the asphalt. The pads should be weighed before and immediately after the distributor passes over them (to prevent evaporation of the solvent in the emulsion from altering the results). The weight of the asphalt on the pad or in the pan is used to calculate the application rate in gallons/square yard. If the result differs from the setting in the distributor, the setting should be adjusted and another calibration accomplished. After construction begins, the calibration should be checked each day by determining the amount of asphalt used that day as determined from the contractor's supply tickets and determining the amount left in the tank either by using the tank stab method or by weighing the truck. This, along with a measurement of the area chip sealed that day, can be used to calculate the application rate in gallons per square yard. If there is a concern about the transverse application rate, the procedure described above can be used.

***Figure 4.35 Fabric Being Used to Check Calibration of Distributor***

During the placement of the test strip, the spray pattern should be observed to verify that there is no streaking (see Figure 4.36). Streaking results when the spray nozzles are not set at the right angle, are plugged or the spray bar is not set at the proper height. The best results are obtained when there is double or triple overlap (see Figure 4.37). If streaking is observed, the operation should be stopped and the necessary adjustments made.

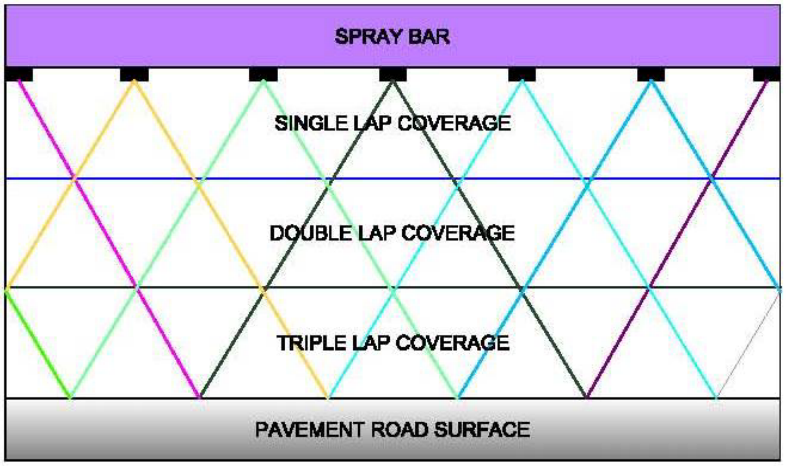


***Figure 4.36 Desired Spray Bar Pattern***

***Figure 4.37 Streaking of Asphalt***

Table 4.20 provides suggested temperatures for spraying the asphalt binder.

***Table 4.20 Suggested Temperatures for Spraying Asphalt***

| Type and Grade of Asphalt | Spraying Temperature of Asphalt<br>Degrees Fahrenheit |
|---|---|
| Emulsified Asphalts | |
| CRS-1 | 125 to 185 |
| CRS-2 | 125 to 185 |
| RS-1 | 70 to 140 |
| RS-2 | 125 to 185 |
| MS-1 | 70 to 160 |
| HFMS-1 | 70 to 160 |
| Asphalt Cements | 265 and higher |

Application of Aggregate

The aggregate is placed through a chip spreader, which can be a vane spreader attached to a truck or a self-propelled mechanical chip spreader (see Figure 4.38). The vane spreader is used for small projects. The chip spreader is a self-propelled unit with a hopper in the front where the aggregate is dumped. The chips are transported to the back of the machine where a gate system drops the chips uniformly across the pavement. The equipment includes a screen on the hoper to reject oversized rock, and a system that uses sloped screens that can separate out the larger chips and drop them ahead of the smaller chips.

The aggregate spreader should be calibrated in a manner similar to calibration of the distributer during the construction of the test strip. Pans or a tarp should be place in front of the spreader at regular intervals across the pavement and longitudinally down the test strip. Knowing the weight of chips on the pan or tarp and the area of the tarp will allow the inspector to calculate the pounds per square yard of aggregate that is being spread. During placement of the chip seal, the quantity being placed each day should be determined and checked against the design quantities. This can be done through the use of the contractors weigh tickets for each truck and the area chip sealed that day.

***Figure 4.38 Self-Propelled Mechanical Distributor***

Joints

Chip seal passes should begin and end on roofing paper or felt.. This ensures that the transverse joints are clean and sharp. Longitudinal joints may be made with an overlap. In this process, a wet edge (i.e., one without an application of aggregate) of 3 to 4 inches is left (not in a wheel path), and the next run overlaps this wet edge. The chip distributor then covers the whole run to the pavement's edge. Figure 4.39 illustrates the layout of felt paper at the end of a project lane.

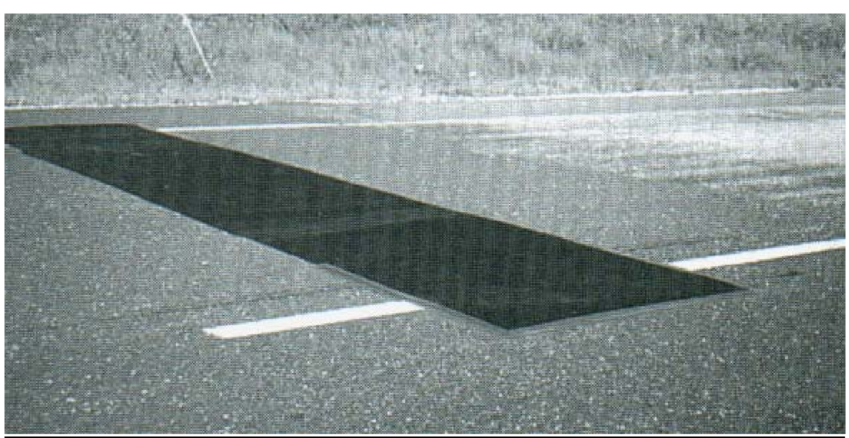

***Figure 4.39 Felt Paper Placed for Transverse Joint***

Rolling

Rolling should begin immediately after the aggregate has been spread. The objective of the rolling is not to compact the chip seal but rather to seat the chips into the asphalt binder. Typically, a 5-ton pneumatic roller (see Figure 4.40) is used. A steel-wheeled roller should not be used because it can crush the aggregate and it will bridge over low spots, resulting in no embedment in those areas. Sufficient rollers should be used to ensure that the rolling is accomplished prior to the asphalt setting up or curing. Once the asphalt hardens, the aggregate cannot be seated and may be pulled out by traffic.


***Figure 4.40 Pneumatic Roller Rolling a Chip Seal***

Application of Fog Seal

Many state specifications now call for fog sealing all chip seals. The standard application method is to lap the centerline in both directions. (For example, if the travel lanes are 12 feet wide, then the fog seal would be applied to a 13-foot-wide swath of roadway in both directions, lapping over the centerline.) The result is the maximum placement of embedment on the area of the roadway receiving the least amount of traffic. In states where plowing operations are used, fog seals improve protection of the chip seal from the impact of snow removal equipment during the winter months. In one test of fog sealing applied under these specifications, it was found that the fog-sealed roadway suffered no snowplow damage while the non-fog-sealed segment suffered close to a 15 percent loss of chips along the centerline. Figure 4.41 shows the condition of lanes after four years of service, where one lane was fog sealed and the other lane was not.

The normal application rate is from 0.06 to 0.12 gallon per square yard of diluted CSS-1h emulsion (depending on the size of chip used). A higher rate of application is used for coarser chips with the rate lowering as the chips become finer.


***Figure 4.41 Effect of Fog Sealing on Performance of Chip Seal after Four Years***

<u>Sweeping</u>

On the day following the placement of the chip seal, the pavement should be swept to remove any excess chips. If the chip seal is being placed on a perimeter road where the chips can be swept onto the shoulder, a broom with a plastic-bristled brush can be used (see Figure 4.42). If the chip seal was placed in an industrial area on the airfield with a curb and gutter section, then a broom that can pick up loose chips should be used, like the one shown in Figure 4.43.

*Figure 4.42 Kick Broom Used for Chip Seals*

*Figure 4.43 Pickup Sweeper*

### 4.5.7 Quality Assurance

The inspector on a chip seal project should ensure that the following:

- Building paper or roofing felt is used to start and stop the asphalt application to ensure straight edges.
- That the distributor does not have plugged nozzles.
- That the distributor speed is adjusted to match the chip spreader speed to prevent start-stop operations.
- Samples of the aggregate are taken for gradation determination. (This should be a washed-sieve analysis to determine if dust is attached to the rock.)
- The rate of application of the aggregate and asphalt is periodically determined by identifying the quantities of aggregate and asphalt from the weight tickets and dividing that amount by the area spread. As a minimum, this should be done at the end of each day's placement of the chip seal.

### 4.5.8 Troubleshooting

Table 4.21 presents some of the common problems (identified by the Federal Highway Administration and the California Department of Transportation) associated with chip sealing and the solutions to those problems.

***Table 4.21 Common Problems and Solutions***

| Problem | Solution |
|---|---|
| Streaking or Drill Marks in the Emulsion | • Ensure emulsion is at correct application temperature<br>• Ensure the viscosity of the emulsion is not too high<br>• Ensure all nozzles are at the same angle<br>• Ensure the spray bar is not too high or too low<br>• Ensure the spray bar pressure is not too high or too low<br>• Ensure nozzles are not plugged |
| Exposed Emulsion after Chip Application | • Ensure the chip spreader gate is not clogged or malfunctioning<br>• Ensure the chip spreader is covering all the binder |
| Excessive Chips/ Many Chips with Small Amounts of Asphalt | • Ensure the chip spreader gate is not malfunctioning or chipper head is not overloaded<br>• Lower the chip application rate |
| Uneven Chip Application | • Recalibrate the chip spreader<br>• Ensure all spreader gates are set the same way |

| Problem | Solution |
|---|---|
| Asphalt on Top of Chips | • Ensure the chip spreader is not operating too fast<br>• Ensure trucks, rollers and pilot cars are operating correctly at low speeds |
| Chips Being Dislodged | • Ensure the emulsion application is not too light<br>• Ensure the chips are not dirty or dusty<br>• Ensure the traffic or equipment speeds are not too high<br>• Ensure brooming does not occur before the emulsion is properly set |
| Emulsion Bleeding Or flushing | • Ensure the emulsion application is not too high<br>• Ensure the aggregate application is not too low |
| Loss of Chip at Centerlines after Brooming | • Check centerline procedure<br>• Check binder application rate |
| Excessive Splattering of the Emulsion | • Lower the spray pressure |

## 4.6 CAPE SEALS

### 4.6.1 Introduction

Description

A cape seal is a skid-resistant, durable preventive maintenance surfacing applied by a two-step system. Cape seals consist of the application of a chip seal followed by the application of either a slurry seal or microsurfacing. It can provide a smooth, dense surface with good skid resistance and a relatively long service life. The rich slurry mixture over the chip seal eliminates the problem of loose aggregates by holding the aggregate firmly in place.

Cape seals have been used extensively at in South Africa, Australia and New Zealand. The process has also been used by the Texas DOT and California Department of Transportation and on airfields in Arizona and California. Figures 4.44 and 4.45 show the placement of a cape seal at Yuma International Airport.

*Figure 4.44 Cape Seal at Yuma International Airport*

*Figure 4.45 Completed Cape Seal at Yuma International Airport*

Figure 4.46 shows a schematic of the cape seal system.

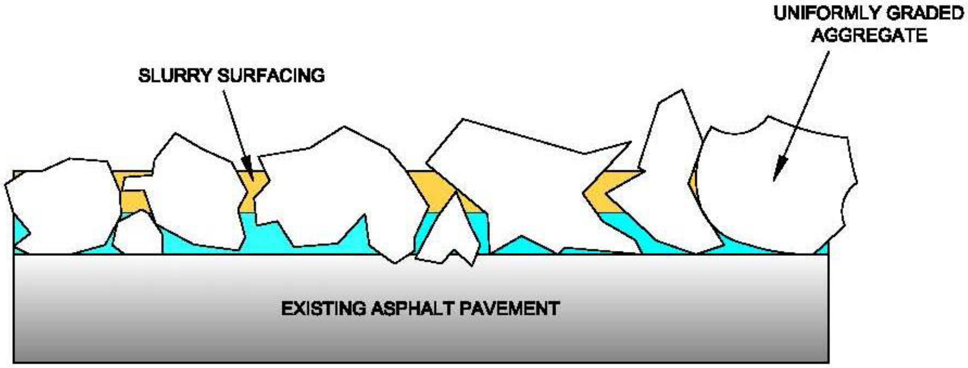


*Figure 4.46 Schematic of Cape Seal System*

Function

A cape seal will provide a thin surface for preventive maintenance and improvement of skid resistance on an airport. The pavement to be sealed should have an essentially sound base and be properly drained. It should have a good profile and alignment and may have raveling or minor asphalt aging or cracking. There should be no sign of sub-base movements or surface bleeding. Potholes and cracks should be filled. The surface should be swept of any stones, sand, mud or other loose debris.

### 4.6.2 Advantages/Disadvantages of Process

The cape seal increases the life of a chip seal by enhancing binding of the chips and by protecting the surface. The cape seal surface does not have any loose aggregate and creates a dense mat. Cape seals seal and waterproof pavement surfaces, restore skid resistance, blacken surfaces, prevent raveling, prevent FOD from loose chips, and protect the environment and worker safety with water-based emulsion applied at low temperatures. They provide cost-effective surface preventive maintenance or new surfacing for preserving pavements.

The disadvantage of the cape sealing process is that equipment for both the chip seal and the slurry or microsurfacing application is required. The construction process is longer, more complicated and more expensive than for either a chip seal or a slurry seal application.

### 4.6.3 Life Expectancy

The expected life of a cape seal is 7 to 10 years.

### 4.6.4 Materials

Asphalt Binder

The asphalt binder for the slurry seal should be as discussed in Section 4.2. The asphalt binder for the chip seal should be as delineated in Section 4.3

Aggregates

The aggregate for the cape seal should meet the requirements outlined in Section 4.4 for the slurry seal and Section 4.5 for the chip seal.

Mix Design

The mix design for a cape seal consists of establishing the quantities of aggregate and asphalt required for the pavement surface as outlined in Section 4.4 for the slurry seal and Section 4.5 for the chip seal. ISSA recommends that the Type I slurry seal/microsurfacing aggregate gradation be used where it is desired to have the chips in the chip seal to be remain uncovered (this produces a knobby surface) to increase skid resistance.

### 4.6.5 Construction Procedures

A cape seal should follow the procedures for placing a slurry seal and a chip seal as discussed in previous sections. The construction process is a delicate two-step surfacing operation involving the application of two layers — a chip seal and a slurry seal. Because of the delicacy of the operation, clear and effective communication must be established between the contractor constructing the chip seal and the contractor constructing the slurry seal. The goal is to integrate these two materials into one surfacing layer. According to ISSA, approximately 24 hours after a chip seal is constructed, it should be treated with a light tack coat of asphalt emulsion (diluted 50/50 with water) applied at a rate of 0.10 to 0.20 gallons per square yard. It should be lightly rolled in areas where FOD is a significant concern.

### 4.6.6 Quality Assurance

The quality control for the slurry seal should follow the guidance outlined in Section 4.2, and the quality control for the chip seal should follow the guidance outline in Section 4.3.

### 4.6.7 Troubleshooting

The troubleshooting for the slurry seal should follow the guidance outlined in Section 4.2,and the troubleshooting for the chip seal should follow the guidance outline in Section 4.3.

# CHAPTER 5.0 REFERENCES AND READING MATERIALS

The following is a listing of the references used to develop this Guide. Many of the publications on this list will provide an excellent source of information on asphalt pavement maintenance.

1. Asphalt Institute. 2008. *A Basic Asphalt Emulsion Manual*. 4th ed. Manual Series No. 19. Lexington, Kentucky.

2. Asphalt Institute. 2007. *The Asphalt Handbook.* 7th ed. Manual Series No. 4. Lexington, Kentucky.

3. Bekheet, Helali, Kazmierowski Khaled and Li Ningyuan. 2005. Integration of Pavement Maintenance in the Pavement Preservation Program. First Conference on Roadway Pavement Preservation, Transportation Research Board. October.

4. Button, Joe. 1991. Effect of Surface Seals on Aging of Underlying Asphalt Concrete. Texas Transportation Institute. Texas A&M University. *Proceedings* 1: 557-570.

5. Johnson, Ann M. 2000. *Best Practices Handbook on Asphalt Pavement Maintenance*. Manual No. 2000-04. Minnesota Department of Transportation, Office of Minnesota Road Research, Physical Research Section, Maplewood, Minnesota; and University of Minnesota, Center for Transportation Studies, Minneapolis, Minnesota. Available through the National Technical Information Services.

6. International Slurry Seal Association (ISSA). 2007. *Design Technical Bulletins: 2007 Edition.* Publication TB-2007. ISSA, Annapolis, Maryland.

7. International Slurry Seal Association (ISSA). 2005. *Recommended Performance Guidelines for Emulsified Asphalt Slurry Seal Surfaces.* Publication A-105. ISSA, Annapolis, Maryland.

8. International Slurry Seal Association (ISSA). 2005. *Recommended Performance Guidelines for Polymer Modified Micro-Surfacing.* Publication A-143. ISSA, Annapolis, Maryland.

9. State of California Department of Transportation, Office of Pavement Preservation, Division of Maintenance. 2003. *Maintenance Technical Advisory Guide (TAG).* Sacramento, California. October.

10. Janisch, David W., and Frank S. Gaillard. 2006 [1998]. *Minnesota Seal Coat Handbook,* revised by Thomas J. Wood. Minnesota Department of Transportation, Office of Minnesota Road Research, Physical Research Section, Maplewood, Minnesota. June 2006.

11. New Mexico Department of Transportation, Office of Transportation and Highway Operations. 2007. *Pavement Maintenance Manual.* Santa Fe, New Mexico.

12. Sahin, M.Y. 2006. *Pavement Management for Airports, Roads and Parking Lots.* 2nd Edition. Springer Science.

13. U.S. Army and U.S. Air Force. 1993. *Standard Practice for Sealing Joints and Cracks in Rigid and Flexible Pavements.* Air Force Pamphlet 88-6, Chapter 7.

# APPENDIX A

## DEFINITIONS

**Aggregate** – A hard, inert mineral material, such as gravel, crushed rock, slag or crushed stone, used in pavement application either by itself or for mixing with asphalt.

**Alligator Cracks** – Interconnected cracks forming a series of small blocks resembling an alligator's skin or chicken wire, and caused by excessive deflection of the surface over unstable subgrade or lower courses of the pavement.

**Application** – The application of sprayed asphalt coatings not involving the use of aggregates.

**Asphalt (Asphalt Cement)** – A dark brown to black cementitious material wherein the predominating constituents are bitumens, which occur in nature or are created through petroleum processing. Asphalt is a constituent in varying proportions of most crude petroleum and used for paving, roofing, industrial and other special purposes.

**Asphalt Binder** – Asphalt cement that is classified according to the standard specification for performance-graded asphalt binder, American Association of State Highway and Transportation Officials (AASHTO) Designation MP1. It can be either unmodified or modified asphalt cement, as long as it complies with the specifications.

**Asphalt Distributor** – A truck or a trailer having an insulated tank, heating system and distribution system. The distributor applies asphalt to a surface at a uniform rate.

**Asphalt Emulsion** – An emulsion of asphalt binder and water that contains a small amount of an emulsifying agent. Emulsified asphalt droplets may be of either the anionic (negative charge), cationic (positive charge) or nonionic (neutral).

**Bleeding or Flushing Asphalt** – The upward migration of asphalt in an asphalt pavement, resulting in the formation of asphalt film on the surface.

**Brooming** – The use of a power street sweeper or rotary power broom to remove dust and loose particles from the surface.

**Cape Seal** – A surface treatment where a chip seal is followed by the application of either a slurry seal or microsurfacing.

**Chip Seal** – A surface treatment using one or more layers of aggregate chips and asphalt binding agent.

**Coal Tar** – A dark brown to black cementitious material produced by the destructive distillation of bituminous coal.

**Compaction** – The act of compressing a given volume of material into a smaller volume.

**Consistency** – The degree of fluidity of asphalt cement at any particular temperature. The consistency of asphalt cement varies with its temperature; therefore, it is necessary to use a common or standard temperature when comparing the consistency of one asphalt cement with another.

**Cutback Asphalt** – Asphalt cement that has been liquefied by blending with petroleum solvents (diluents). Upon exposure to atmospheric conditions the diluents evaporate, leaving the asphalt cement behind.

**Emulsified Asphalt** – A suspension of minute globules of asphalt cement in water or an aqueous solution.

**Fog Seal** – A spray-on application of low-viscosity, slow- to medium-setting emulsified asphalt, which seals a pavement surface, controls water infiltration and retards oxidation.

**Hot-Mix Asphalt** – High-quality, thoroughly controlled hot mixture of asphalt binder (cement) and well-graded, high-quality aggregate, which can be compacted into a uniform dense mass.

**Longitudinal Crack** – This is a vertical crack in the pavement that follows a course approximately parallel to the centerline.

**Medium-Curing Asphalt** – A cutback asphalt composed of asphalt cement and a diluent of medium volatility such as kerosene..

**Microsurfacing** – A mixture of polymer-modified asphalt emulsion; crushed. dense-graded aggregate; mineral filler; additives; and water. It provides a thin resurfacing of up to ⅜ to ¾ inch to the pavement.

**Multiple Surface Treatment** – Two or more surface treatments placed one on top the other. The aggregate maximum size of each successive treatment is usually half that of the previous one. A multiple surface treatment may be a series of single treatments that produces a pavement course up to 1 inch or more thick. A multiple surface treatment provides a more waterproof course than a single surface treatment.

**Performance Graded** – This is a designation for an asphalt binder grade used in Superpave. It is based on the binder's mechanical performance at critical temperatures and aging conditions.

**Pneumatic Roller** – Also called rubber-tired rollers. A self-propelled pneumatic-tire roller will have two to eight pneumatic tires in the front and four to eight in the rear. The wheels on these rollers generally oscillate. The wheels on the roller will conform to the surface being compacted.

**Polymer** – A synthetic additive that is mixed into asphalt binder to alter and improve performance characteristics.

**Polymer-Modified Asphalt** – Polymer modified asphalts (PMA) are asphalt binders that can be produced by the addition elastomeric polymers or chemical modification.

**Present Condition Index (PCI) –** A numerical index, ranging from 0 for a failed pavement to 100 for a pavement in perfect condition. It is based on a visual condition survey in which distress type, severity, and quality are identified.

**Prime Coat** – This is the application of an asphalt primer (generally a medium curing asphalt) to an absorbent surface. It is used to prepare an untreated base for an asphalt surface. The prime penetrates or is mixed into the surface of the base and plugs the voids, hardens the top and helps bind it to the overlying asphalt course.

**Rapid-Curing Asphalt –** A cutback asphalt composed of asphalt cement and a diluent of high volatility such as naphtha.

**Seal Coat** – A thin surface treatment used to improve the surface texture and protect an asphalt surface. The main types of seal coats are fog seals, sand seals, slurry seals, microsurfacing, cape seals, sandwich seals and chip seals.

**Single Surface Treatment** – A single application of asphalt to a road surface followed immediately by a single layer of aggregate. The thickness of the treatment is about the same as the nominal, maximum size aggregate particles.

**Slow-Curing Asphalt** – Cutback asphalt composed of asphalt cement and oils of low volatility.

**Slurry Seal** – A mixture of emulsified asphalt, well-graded fine aggregate, mineral filler or other additives, and water. A slurry seal will fill minor cracks, restore a uniform surface texture and restore friction values.

**Transverse Crack** – A crack that is generally oriented perpendicular to the pavement centerline.

**Voids** – Internal spaces in a compacted mix surrounded by asphalt-coated particles, expressed as a percentage by volume of the total compacted mix.

# APPENDIX B

## SPECIFICATIONS

# Joint Sealing

http://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.list

## ITEM P-605 JOINT SEALING FILLER

DESCRIPTION

**605-1.1** This item shall consist of providing and installing a resilient and adhesive joint sealing filler capable of effectively sealing joints and cracks in pavements.

MATERIALS

**605-2.1 JOINT SEALERS.** Joint sealing materials shall meet the requirements of **[ ].**

**[Each lot or batch of sealing compound shall be delivered to the jobsite in the manufacturer's original sealed container. Each container shall be marked with the manufacturer's name, batch or lot number, the safe heating temperature, and shall be accompanied by the manufacturer's certification stating that the compound meets the requirements of this specification.]**

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**The Engineer shall specify one or more of the following:**

**FED SPEC SS-S-200E(2) -– Sealants, Joint, Two-Component, Jet-Blast Resistant, Cold Applied.**

**ASTM D 1854 - Jet-Fuel-Resistant Concrete Joint Sealer, Hot-Applied Elastic Type**

**ASTM D 3406 - Joint Sealants, Hot-Applied, Elastometric-Type, for Portland Cement Concrete Pavements**

**ASTM D 3569 - Joint Sealants, Hot-Applied, Elastometric, Jet-Fuel-Resistant type, for Portland Cement Concrete Pavements**

**ASTM D 3581 - Joint Sealant, Hot-Applied, Jet-Fuel-Resistant Type, for Portland Cement Concrete and Tar-Concrete Pavements**

**ASTM D 5893 - Standard Specifications for Cold Applied, Single Component, Chemically Curing Silicone Joint Sealant for Portland Cement Concrete Pavements.**

**ASTM D 6690 - Joint and Crack Sealants, Hot-Applied, for Concrete and Asphalt Pavements**

**Additionally, if silicone sealants are elected, add the ASTM to the listing of Material Requirements.**

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## CONSTRUCTION METHODS

**605-3.1 TIME OF APPLICATION.** Joints shall be sealed as soon after completion of the curing period as feasible and before the pavement is opened to traffic, including construction equipment. The pavement temperature shall be above **[40°F (4°C)][(50°F (10°C)] at the time of installation of the [preformed joint seal][poured joint sealing material].**

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**Specify 40°F (4°C) for preformed seal and 50°F (10°C) for poured seals.**

**If the pavement must be opened to traffic prior to placement of the sealant, this paragraph should be modified to require the Contractor to temporarily fill the joint with a jute or nylon rope immediately after the joint is sawed. The rope should be slightly larger than the joint and should be forced into the joint so that the top of the rope is 1/8 inch (3 mm) below the pavement surface. The rope shall be removed immediately prior to cleaning.**

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**605-3.2 PREPARATION OF JOINTS.**

**a. Sawing.** All joints shall be sawed in accordance with specifications and plan details. Immediately after sawing the joint, the resulting slurry shall be completely removed from joint and adjacent area by flushing with a jet of water, and by use of other tools as necessary.

**b. Sealing.** Immediately before sealing, the joints shall be thoroughly cleaned of all remaining laitance, curing compound, and other foreign material. Cleaning shall be accomplished by sandblasting. Sandblasting shall be accomplished in a minimum of two passes. One pass per joint face with the nozzle held at an angle directly toward the joint face and not more that 3 inches from it. Upon completion of cleaning, the joints shall be blown out with compressed air free of oil and water. Only air compressors with operable oil and water traps shall be used to prepare the joints for sealing. The joint faces shall be surface dry when the seal is applied.

**605-3.3 INSTALLATION OF SEALANTS**. Joints shall be inspected for proper width, depth, alignment, and preparation, and shall be approved by the Engineer before sealing is allowed. Sealants shall be installed in accordance with the following requirements:

**[Hot Poured Sealants. The joint sealant shall be applied uniformly solid from bottom to top and shall be filled without formation of entrapped air or voids. A backing material shall be placed as shown on the plans and shall be nonadhesive to the concrete or the sealant material. The heating kettle shall be an indirect heating type, constructed as a double boiler. A positive temperature control and mechanical agitation shall be provided. The sealant shall not be heated to more than 20°F (-11°C) below the safe heating temperature. The safe heating temperature can be obtained from the manufacturer's shipping container. A direct connecting pressure type extruding device with nozzles shaped for insertion into the joint shall be provided. Any sealant spilled on the surface of the pavement, structures and/or lighting fixtures, shall be removed immediately.]**

**[Cold Applied Sealants. Cold applied joint sealing compound shall be applied by means of pressure equipment that will force the sealing material to the bottom of the joint and completely fill the joint without spilling the material on the surface of the pavement. A backing material shall be placed as shown on the plans and shall be nonadhesive to the concrete or the sealant material. Sealant that does not bond to the concrete surface of the joint walls, contains voids, or fails to set to a tack-free condition will be rejected and replaced by the Contractor at no additional cost. Before sealing the joints, the Contractor shall demonstrate that the equipment and procedures for preparing, mixing, and placing the sealant will produce a satisfactory joint seal. This shall include the preparation of two small batches and the application of the resulting material. Any sealant spilled on the surface of the pavement, structures and/or lighting fixtures, shall be removed immediately.]**

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**The use of a backup material or bond breaker in the bottom of the joint to be filled is recommended to control the depth of the sealant, to achieve the desired shape factor, and to support the sealant against indentation and sag. Backup materials and bond breakers should be compatible with the sealant, should not adhere to the sealant, should be compressible without extruding the sealant, and should recover to maintain contact with the joint faces when the joint is open.**

**Jute, paper, or other moisture absorbing material shall not be used for the backing material. The backing material shall be rubber, butyl rubber, or other approved material that will not react with the joint sealer and will not form a gas when the hot joint sealer is applied.**

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**The Engineer should select either hot poured or cold applied sealant and include the appropriate paragraph in the specifications.**

**Insert:**

**"both non-reactive and…"**

**before:**

**"…non-adhesive to the concrete…" in the second sentence of each paragraph regarding hot poured and cold applied sealant.**

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METHOD OF MEASUREMENT

**605-4.1** Joint sealing material shall be measured by the **[gallon (liter)] [pound (kg)] [linear foot (meter)]** of sealant in place, completed, and accepted.

BASIS OF PAYMENT

**605-5.1** Payment for joint sealing material shall be made at the contract unit price per [gallon (liter)] [pound (kg)] [linear foot (meter)]. The price shall be full compensation for furnishing all materials, for all preparation, delivering, and placing of these materials, and for all labor, equipment, tools, and incidentals necessary to complete the item.

Payment will be made under:

Item P-605-5.1 Joint Sealing Filler -– per gallon (liter)

Item P-605-5.2 Joint Sealing Filler -– per pound (kg)

TESTING REQUIREMENTS

ASTM D 412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers – Tension

ASTM D 1644 Test Methods for Nonvolatile Content of Varnishes

MATERIAL REQUIREMENTS

ASTM D 1854 Jet-Fuel-Resistant Concrete Joint Sealer, Hot-Applied Elastic Type

ASTM D 3406 Joint Sealants, Hot-Applied, Elastomeric-Type, for Portland Cement Concrete Pavements

ASTM D 3569 Joint Sealant, Hot-Applied, Elastometric, Jet-Fuel-Resistant Type, for Portland Cement Concrete Pavements

ASTM D 3581 Joint Sealant, Hot-Applied, Jet-Fuel-Resistant Type, for Portland Cement Concrete and Tar-Concrete Pavements

ASTM D 5893 Standard Specifications for Cold Applied, Single Component, Chemically Curing Silicone Joint Sealant for Portland Cement Concrete Pavements

ASTM D 6690 Joint and Crack Sealants, Hot-Applied, for Concrete and Asphalt Pavements

FED SPEC SS-S-200E(2) Sealants, Joint, Two-Component, Jet-Blast Resistant, Cold Applied

**END ITEM P-605**

# Spray Applied Seals

**ENGINEERING BRIEF NO. 44B (May 21, 2008)**

## COAL-TAR SEALER/REJUVENATOR

### DESCRIPTION

**1.1** This item consists of a coal-tar sealer/rejuvenator applied on a previously prepared bituminous surface, in accordance with these specifications, for the areas shown on the plans or as designated by the Engineer. The purpose of this sealer is to provide a fuel resistant surface and to rejuvenate the asphalt binder.

MATERIALS

**2.1 BITUMINOUS MATERIALS.** The bituminous material must be composed of coal-tar oil(s) and coal-tar prepared from a high temperature coal-tar pitch conforming to the requirements of ASTM D 490, Grade RT-12. The material must meet the requirements of Table 1.

**Table 1. Property Requirements**

| Test Property | Test Method | Requirements |
|---|---|---|
| Specific Gravity<br>@ 25/ 25 °C | ASTM D 70 | 1.04 min. |
| Viscosity Engler<br>50 cc @ 50° C | ASTM D 1665 | 8.0 max. |
| Water, % by volume | ASTM D 95 | 2.0 max |
| Distillation<br>% by weight to 170°C<br>% by weight to 270°C<br>% by weight to 300°C | ASTM D 20 | 20 max<br>20 – 50<br>60 max |
| (Softening Point of Residue)<br>Residue above 300 °C, °C | ASTM D 36 | 65 max |

The material must not exceed the Volatile Organic Compound (VOC) Content limit established for the airport location.

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**NOTE TO ENGINEER. The material in this specification is defined as a bituminous coating and mastic according to Code of Federal Regulations (CFR) Title 40 Protection of Environment PART 59—NATIONAL VOLATILE ORGANIC COMPOUND EMISSION STANDARDS FOR CONSUMER AND**

**COMMERCIAL PRODUCTS. The limit in the CFR for bituminous coatings and mastics is 500 grams VOC per liter (4.2 pounds VOC per gallon). State and/or local requirements at the airport's location may be more restrictive than the CFR.**
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The manufacturer must certify the material does not contain, mercury, lead, halogenated solvents, creosote, or crude tar. The manufacturer must identify the inclusion of any recovered and or post consumer use materials in the mixture.
The manufacturer must certify the application will not release reportable quantities of hazardous substances identified under the Comprehensive Environmental Response, Compensation, and Liability Act and the Clean Water Act.

**CONSTRUCTION METHODS**

**3.1 WEATHER LIMITATIONS.** The coal-tar sealer must be applied only when the existing surface is dry and the pavement surface temperature is above 50 degrees F.

**3.2 EQUIPMENT.** The Contractor must furnish all equipment necessary for the performance of the work.
a. Pressure Distributor. The distributor must be designed, equipped, maintained, and operated so that coal-tar sealer at even heat may be applied uniformly on variable widths of pavement at the specified rate.
b. Power Broom. The Contractor must provide a power broom and/or blower for removing loose material from the pavement surface.

**3.3 CLEANING EXISTING SURFACE.** Prior to application of the sealer, the surface of the pavement must be clean and free from dust, dirt, and other foreign matter. When directed by the Engineer, the Contractor must clean the surface with a power broom and/or blower.

**3.4 APPLICATION RATE TEST SECTIONS.** Prior to full application, the Contractor must apply the material to a series of one-square yard test sections at the rate of 0.05, 0.06, and 0.075 gallons per square yard. The area to be tested will be designated by the Engineer and will be located on the existing pavement. The Engineer will examine the test sections 24 hours after application and advise the Contractor of the application rate for the remainder of the project and/or for additional friction survey testing, as appropriate. A test section is required for each different type of pavement surface.

**3.5 TEST SECTION FOR FRICTION SURVEYS.** Prior to full application on any runway or high speed taxiway exit, the Contractor must apply the material to a test section for friction survey testing at the application rate approved by the Engineer in paragraph 3.4. The area to be tested will be designated and tested by the Engineer and located on the existing runway or high speed taxiway exit pavement. Application rates that result in an average Mu value on the wet runway pavement surface less than the Maintenance Planning Friction Level contained in Federal Aviation Advisory Circular 150/5320-12, “Measurement, Construction, and Maintenance of Skid Resistant Airport Pavement Surfaces,” must not be approved for full application.

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**NOTE TO ENGINEER. A friction survey test is mandatory for applications to runways and high speed taxiway exits. The Engineer may require friction survey tests on other pavement, as deemed necessary.**

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**3.6 APPLICATION OF SEALER/REJUVENATOR.** The sealer/rejuvenator must be uniformly applied with a bituminous distributor at the rate determined in paragraph 3.4. The application rate must not be varied without the approval of the Engineer. The application temperature must be between 60 and 120 degrees F.
Following the application, the surface must be allowed to cure without being disturbed until the sealer has dried. This period will be determined by the Engineer. Surface protection precautions must be taken by the Contractor during this period, including the application of any sand necessary to blot up excess material.

**3.7 BITUMINOUS MATERIAL CONTRACTOR'S RESPONSIBILITY.** The Contractor must submit, in writing to the Engineer, manufacturer's certifications, including the certifications contained in paragraph 2.1, that each consignment of bituminous materials shipped to the project meets the requirements of the specification, together with a statement as to their sources. The manufacturer's certifications will not be interpreted as a basis for final acceptance.

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**NOTE TO ENGINEER. Certifications that reference previous revisions to this specification, or that reference unpublished FAA draft specification Item P-629, will not be interpreted as acceptable for the purposes of this specification.**

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**3.8 BITUMINOUS MATERIAL ENGINEER’S RESPONSIBILITY.** The Engineer will take samples of bituminous materials proposed for use on delivery in accordance with ASTM D 140 and conduct verification testing. Testing results from all test methods contained in paragraph 2.1 must be approved by the Engineer before using the material. Verification testing for Table 1 properties must be performed on samples taken during full application for each **[___]** square yards of treated pavement.

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**NOTE TO ENGINEER. Production testing does not require application interruption. The Engineer will insert the verification testing interval during**

**production. Testing intervals in excess of approximately 50,000 square yards are not recommended.**
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**3.9 FREIGHT AND WEIGH BILLS.** The Contractor must furnish the Engineer receipted bills when railroad shipments are made, and certified weigh bills when materials are received in any other manner, of the coal-tar sealer used in the construction covered by the contract. The Contractor must not remove material from the tank car or storage tank until the initial outage and temperature measurements have been taken by the Engineer, nor shall the car or tank be released until the final outage has been taken by the Engineer.

## METHOD OF MEASUREMENT

**4.1** The coal-tar sealer will be measured by the [gallon (liter)]
[square yard{square meter}].

## BASIS OF PAYMENT

**5.1** Payment will be made at the contract unit price per [gallon (liter)]
[square yard (square meter)] for the coal-tar sealer.

Payment will be made under: Item 5.1 Coal-Tar Sealer--per[gallon(liter)][square yard(square meter)]

## TESTING REQUIREMENTS

ASTM D 20 Distillation of Road Tars
ASTM D 36 Softening Point of Bitumen
ASTM D 70 Specific Gravity of Semi-Solid Bituminous Materials
ASTM D 95 Water in Petroleum Products and Bituminous Materials by Distillation
ASTM D 140 Sampling Bituminous Materials
ASTM D 1665 Engler Specific Viscosity of Tar Products

## MATERIAL REQUIREMENTS

ASTM D 490 Road Tar

End of Specification

# ITEM P-631 REFINED COAL TAR EMULSION WITH ADDITIVES, SLURRY SEAL SURFACE TREATMENT

**631-1.1 GENERAL.** This item shall consist of a mixture of refined coal tar emulsion, mineral aggregate, additives, and water properly proportioned, mixed and applied as a slurry seal on new or existing (aged) asphalt concrete pavement.

## MATERIALS

**631-2.1 Refined Coal Tar Emulsion.** A refined coal tar emulsion prepared from a high temperature refined coal tar conforming to the requirements of ASTM specification D 490 for grade 11-12. The use of oil and water gas tar is not allowed. Base refined coal tar emulsion must conform to all requirements of Federal Specification R-P-355.

**631-2.2 Aggregate.** The aggregate shall be washed dry silica sand or boiler slag free of dust, trash, clay, organic materials or other deleterious substances. The aggregate shall meet the gradation in Table 1, when tested in accordance with ASTM C 136.

**TABLE 1. GRADATION OF AGGREGATES***

| Sieve Size | | Percent Retained | |
|---|---|---|---|
| | | Minimum | Maximum |
| #20 or coarser | (0.850 mm) | 0 | 2 |
| #30 | (0.600 mm) | 0 | 12 |
| #40 | (0.425 mm) | 2 | 60 |
| #50 | (0.300 mm) | 5 | 60 |
| #70 | (0.212 mm) | 5 | 60 |
| #100 | (0.150 mm) | 5 | 30 |
| #140 | (0.106 mm) | 0 | 10 |
| #200 | (0.075 mm) | 0 | 2 |
| Finer than #200 | | 0 | 0.3 |

* Table 1 represents the maximum range of aggregate gradations.
In all cases the refined coal tar emulsion supplier is to give written approval of the aggregate used in the mix design.

**631-2.3 Additive.** As specified by the coal tar emulsion manufacturer.

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**Additives are one or more ingredients that can be added to a specific refined coal tar emulsion, water and/or sand mixture to improve the coatings final properties. These properties include durability, fuel resistance, drying time, color uniformity, and/or length of cure time. Additives may also be used to modify the wet mixture's viscosity to improve aggregate suspension.**

**The type of additive to be used should be specified by the coal tar emulsion manufacturer and will depend on which final properties are desired.**

**The engineer should specify the desired properties.**

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**631-2.4 Water.** Water for mixing shall be potable, free of harmful soluble salts, and at least 50ºF (10º C).

**631-2.5 Crack Sealant.** Crack sealant shall be certified for compatibility with the refined coal tar emulsion by the manufacturer of the refined coal tar emulsion, and approved by the engineer.

**631-2.6 Oil Spot Primer.** Oil spot primer shall be certified for compatibility with the refined coal tar emulsion by the manufacturer of the refined coal tar emulsion, and approved by the engineer.

**631-2.7 Pavement Primer.** Pavement primer shall be certified for compatibility with the refined coal tar emulsion by the manufacturer of the refined coal tar emulsion, and approved by the engineer.]

COMPOSITION AND APPLICATION

**631-3.1 Composition.** The refined coal tar emulsion seal coat is to consist of a mixture of refined coal tar emulsion, water, additive and aggregate, and be proportioned as shown in Table 2. The composition must have written approval of the coal tar emulsion manufacturer.

**631-3.2 Job Mix Formula.** The contractor shall submit the recommended formulation of water, emulsion, aggregate and application rate proposed for use to a testing laboratory together with sufficient materials to verify the formulation at least **[ ]** days prior to the start of operations. The mix design shall be within the range shown in Table 2. No seal coat shall be produced for payment until a job mix formula has been approved by the Engineer. The formulation shall pass the fuel resistance test in Appendix A.

The job mix formula for each mixture shall be in effect until modified in writing by the Engineer.

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**Improper formulations of coal-tar pitch emulsion seal produce coatings that crack prematurely or do not adhere properly to the pavement surface. A minimum of 5 days is recommended for job mix approval.**

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**TABLE 2.**
**COMPOSITION OF MIXTURE PER 100 GAL OF REFINED COAL TAR EMULSION**

| **Application** | **Refined Coal Tar Emulsion** | **Water** | **Additive** | **Aggregate** | **Formula Rate of Application of Mix per Square Yard (Liters)** | |
|---|---|---|---|---|---|---|
| | **Gallons (Liters)** | **Gallons (Liters)** | **Gallons (Liters)** | **LBS (Liters)** | **Minimum Gallons (Liters)** | **Maximum Gallons (Liters)** |
| Prime Coat (where required) as specified by the coal tar emulsion manufacturer. | | | | | | |
| 1st Seal Coat | 100 (379) | 25-70 (95-265) | 2-6 (7.6-22.7) | 300-700 (136-318) | 0.12 (0.54) | 0.20 (0.91) |
| 2nd Seal Coat | 100 (379) | 25-70 (95-265) | 2-6 (7.6-22.7) | 300-700 (136-318) | 0.12 (0.54) | 0.20 (0.91) |

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**The numbers shown in Table 2 represent the maximum recommended range of values. In all cases, the refined coal tar emulsion supplier is to give written approval of specific composition numbers to be used in the mix design.**

**Some specifications covering this type of coating have allowed sand loadings in excess of 10 pounds per gallon of refined coal tar emulsion. These coatings have not performed well in the field due to poor fuel resistance and loss of adhesion and are not recommended.**

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**631-3.3 Application Rate**. Application rates are not to exceed 0.20 gal/yd. $^2$/coat (0.91 liters/m$^2$/coat), and at no time are total coats to exceed 0.51 gal/yd$^2$ (2.3 liters/m$^2$).

**631-3.4 Test Section.** Prior to full production, the Contractor shall prepare a quantity of mixture in the proportions shown in the approved mix design. The amount of mixture shall be sufficient to place a test section a minimum of 250 square yards at the rate specified in the job mix formula. The area to be tested will be designated by the Engineer and will be located on a representative section of the pavement to be seal coated. The actual application rate will be determined by the Engineer during placement of the test section and will depend on the condition of the pavement surface.

The test section shall be used to verify the adequacy of the mix design and to determine the application rate. The same equipment and method of operations shall be used on the test section as will be used on the remainder of the work.

If the test section should prove to be unsatisfactory, the necessary adjustments to the job mix formula, mix composition, application rate, placement operations, and equipment shall be made. Additional test sections shall be placed and evaluated, if required. Full production shall not begin without the Engineer's approval. Acceptable test sections shall be paid for in accordance with paragraph 631-7.1.

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**The test section affords the Contractor and the Engineer an opportunity to determine the quality of the mixture in place as well as the performance of the equipment.**

**The application rate depends on the surface texture.**

**If operational conditions preclude placement of a test section on the pavement to be seal coated, it may be applied on a pavement with similar surface texture.**

**The only test required on the composite mix placed in the field is the viscosity test. The fuel resistance test may be specified, however, this test takes 96 hours to run.**

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## CONSTRUCTION METHODS

**631-4.1 Weather Limitations.** The seal coat shall not be applied when the surface is wet or when the humidity or impending weather conditions will not allow proper curing. The seal coat shall be applied only when the atmospheric or pavement temperature is 50°F (10°C) and rising and is expected to remain above 50°F (10°C) for 24 hours, unless otherwise directed by the Engineer.

**631-4.2 Equipment and Tools.** The Contractor shall furnish all equipment, tools, and machinery necessary for the performance of the work.

**a. Distributors.** Distributors or spray units used for the spray application of the seal coat shall be self-propelled and capable of uniformly applying 0.12 to 0.55 gallons per square yard (0.54 to 2.5 liters per square meter) of material over the required width of application. Distributors shall be equipped with removable manhole covers, tachometers, pressure gauges, and volume-measuring devices.

The mix tank shall have a mechanically powered, full-sweep, mixer with sufficient power to move and homogeneously mix the entire contents of the tank.

The distributor shall be equipped with a positive placement pump so that a constant pressure can be maintained on the mixture to the spray nozzles.

**b. Mixing Equipment.** The mixing machine shall have a continuous flow mixing unit capable of accurately delivering a predetermined proportion of aggregate, water, and emulsion, and of discharging the thoroughly mixed product on a continuous basis. The mixing unit shall be capable of thoroughly blending all ingredients together and discharging the material to the spreader box without segregation.

**c. Spreading Equipment.** Spreading equipment shall be a mechanical-type squeegee distributor attached to the mixing machine, equipped with flexible material in contact with the surface to prevent loss of slurry from the spreader box. It shall be maintained to prevent loss of slurry on varying grades and adjusted to assure uniform spread. There shall be a lateral control device and a flexible strike-off capable of being adjusted to lay the slurry at the specified rate of application. The spreader box shall have an adjustable width. The box shall be kept clean; coal-tar emulsion and aggregate build-up on the box shall not be permitted.

**d. Hand Squeegee or Brush Application.** The use of hand spreading application shall be restricted to places not accessible to the mechanized equipment or to accommodate neat trim work at curbs, etc. Material that is applied by hand shall meet the same standards as that applied by machine.

**e. Calibration.** The Contractor shall furnish all equipment, materials and labor necessary to calibrate the equipment. It shall be calibrated to assure that it will produce and apply a mix that conforms to the job mix formula. Commercial equipment should be provided with a method of calibration by the manufacturer. All calibrations shall be made with the approved job materials prior to applying the seal coat to the pavement. A copy of the calibration test results shall be furnished to the Engineer.

**631-4.3 Preparation Of Existing Asphalt Pavement Surfaces.** Existing asphalt pavements indicated to be seal coated shall be prepared as follows:

- Patch bituminous pavement surfaces that have been softened by petroleum derivatives or have failed due to any other cause. Remove damaged pavement to the full depth of the damage and replace with new bituminous concrete similar to that of the existing pavement. If a solvent containing cold-applied material is used, complete patching a minimum of 90 days prior to the planned application of the sealer to permit solvent to escape before sealing.

- Remove all vegetation and debris from cracks to a minimum depth of 1″. If extensive vegetation exists treat the specific area with a concentrated solution of a water-based herbicide approved by the engineer. Fill all cracks, ignoring hairline cracks (< 1/4″ wide) with a crack sealant. Wider cracks (over 1½″ wide (38.4 mm)), along with soft or sunken spots, indicate that the pavement or the pavement base should be repaired or replaced as stated above.

- Clean pavement surface immediately prior to placing the prime coat or seal coat by sweeping, flushing well with water leaving no standing water, or a combination of both, so that it is free of dust, dirt, grease, vegetation, oil or any type of objectionable surface film.

- Remove oil or grease that has not penetrated the asphalt pavement by scraping or by scrubbing with a detergent, then wash thoroughly with clean water. After cleaning, treat these areas with the oil spot primer.

- To insure adhesion to sound but oxidized pavements, mix and apply a prime coat of a type and at a rate recommended by the coal tar emulsion manufacturer, after all loose aggregate is removed.

**631-4.4 Preparation Of New Asphalt Pavement Surfaces.** New asphalt pavements indicated to be seal coated shall be prepared as follows:

- Cure new asphalt pavement surfaces so that there is no concentration of oils on the surface.
- A period of at least 60 days at +70ºF daytime temperatures must elapse between the placement of a hot mixed asphalt concrete surface course and the application of the seal coat.
- Perform a water-break-free test to confirm that the surface oils have degraded and dissipated. (Cast one gallon of clean water out over the surface. The water should sheet out and wet the surface uniformly without crawling or showing oil rings.) If asphalt does not pass this test, additional time must be allowed for extra curing and retesting prior to sealing.
- Where oil spot priming is needed, remove oil or grease that has not penetrated the asphalt pavement by scraping or by scrubbing with a detergent, then wash thoroughly with clean water. After cleaning, treat these areas with the oil spot primer.
- To ensure adhesion to sound but oxidized pavements, mix and apply a prime coat of a type and at a rate recommended by the coal tar emulsion manufacturer, after all loose aggregate is removed.

**631-4.5 MIXING.** Blend the coal tar emulsion mixture in the equipment described in paragraph 631-4.2 using the ingredients described in Table 2. The mixing must produce a smooth homogeneous mixture of uniform consistency. (Consult coal tar emulsion supplier for its recommended order of addition of the ingredients.) During the entire mixing and application process, no breaking, segregating or hardening of the emulsion, nor balling or lumping of the sand is to be permitted. Continue to agitate the seal coating mixture in the mixing tank at all times prior to and during application so that a consistent mix is available for application.

Small additional increments of water may be needed to provide a workable consistency, but in no case is the water content to exceed the specified amount.

**631-4.6 Application of Slurry Seal Coat.** The aggregate filled slurry seal coat shall be applied at a uniform rate determined in paragraph 631-3.4.

In order to provide maximum adhesion, the pavement shall be dampened with a fog spray of water if recommended by the supplier. No standing water shall remain on the surface.

If a prime coat is required, mix and apply the prime coat as specified in paragraph 631-4.3 for existing pavements or paragraph 631-4.4 for new pavements.

Apply the first coat uniformly to obtain the rate determined in paragraph 631-3.4.

Each coat shall be allowed to dry and cure initially before applying any subsequent coats. The initial drying shall allow evaporation of water of the applied mixture, resulting in the coating being able to sustain light foot traffic. The initial curing shall enable the mixture to withstand vehicle traffic without damage to the seal coat.

Apply the second coat in the same manner as outlined for the first coat.

Additional coats shall be applied over the entire surface as directed by the engineer.

The finished surface shall present a uniform texture.

The final coat shall be allowed to dry a minimum of eight hours in dry daylight conditions before opening to traffic, and initially cure enough to support vehicular traffic without damage to the seal coat.

Where marginal weather conditions exist during the eight hour drying time, additional drying time shall be required. The length of time shall be as specified by the supplier. The surface shall be checked after the additional drying time for trafficability before opening the section to vehicle traffic.

Where striping is required, the striping paint utilized shall meet the requirements of P-620, shall be compatible with the seal coat and as recommended by the coal tar emulsion manufacturer.

## QUALITY CONTROL

**631-5.1 CONTRACTOR'S CERTIFICATION.** The Contractor shall furnish the manufacturer's certification that each consignment of emulsion shipped to the project meets the requirements of Federal specification R-P-355, except that the water content shall not exceed 50 percent. The certification shall also indicate the solids and ash content of the emulsion and the date the tests were conducted. The certification shall be delivered to the Engineer prior to the beginning of work. The manufacturer's certification for the emulsion shall not be interpreted as a basis for final acceptance. Any certification received shall be subject to verification by testing samples received for project use.

The Contractor shall also furnish a certification demonstrating a minimum of three years experience in the application of coal-tar emulsion seal coats.

**631-5.2 INSPECTION.** The Owner shall have an independent technical consultant on the job site at the beginning of operations for application of coal-tar emulsion seal coats. The consultant shall have knowledge of the materials, procedures, and equipment described in this specification and shall assist the Contractor regarding proper mixing of the component materials and application of the seal coat. The consultant shall have a minimum of 3 years experience in the use of coal-tar seal coats. Documentation of this experience shall be furnished to the Engineer prior to the start of operations. The cost of the technical consultant shall be paid for by the Owner.

**631-5.3 SAMPLING.** A minimum of one sample per day shall be tested for the properties of Table 2. A random sample of approximately one-quart of the composite mix will be obtained daily by the contractor and stored in a glass container. The containers shall be sealed against contamination and retained in storage by the Owner for a period of six months. Samples shall be stored at room temperature and not be subjected to freezing temperatures.

A sample of undiluted coal-tar emulsion shall be obtained from each consignment shipped to the job.

**631-5.4 ENGINEER'S RECORDS.** The Engineer will keep an accurate record of each batch of materials used in the formulation of the seal coat.

## METHOD OF MEASUREMENT

**631-6.1** The refined coal tar emulsion with additives shall be measured by the **[gallon (liter)] [ton (kg)]**. Only the actual quantity of undiluted refined coal tar emulsion with additives will be measured for payment.

**631-6.2** Aggregate shall be measured by the ton (kg) of dry aggregate.

## BASIS OF PAYMENT

**631-7.1** Payment shall be made at the contract unit price per **[gallon (liter)] (ton (kg)]** for the refined coal tar emulsion with additives and at the contract price per ton (kg) for aggregate.

These prices shall be full compensation for furnishing all materials, preparing, mixing, and applying these materials, and for all labor, equipment, tools, and incidentals necessary to complete the item.

Payment will be made under:

| | |
|---|---|
| Item P-631-7.1 | Refined Coal Tar Emulsion with Additives for Slurry Coat—per [gallon (liter)] [ton (kg)] |
| Item P-631-7.2 | Aggregate—per ton (kg) of dry aggregate. |

TESTING REQUIREMENTS

| | |
|---|---|
| ASTM C 67 | Sampling and Testing Brick and Structural Clay Tile |
| ASTM C 136 | Sieve or Screen Analysis of Fine and Coarse Aggregates |
| ASTM D 160 | Practice of Sampling Bituminous Materials |
| ASTM D 2939 | Standard Test Methods for Emulsified Bitumens used as Protective Coatings. |

MATERIAL REQUIREMENTS

| | |
|---|---|
| ASTM D 490 | Standard Specification for Road Tar |
| ASTM D 692 | Standard Specification for Coarse Aggregate for Bituminous Paving Mixtures |
| ASTM C 3699 | Kerosene |
| ASTM D 4866 | Standard Performance Specification for Coal Tar Pitch Emulsion Pavement Sealer Mix Formations Containing Mineral Aggregates and Optional Polymeric Admixtures |
| FED SPEC R-P-355 | Pitch, Coal-tar Emulsion (Coating for Bituminous Pavements) ASTM D 5727 Emulsified Refined Coal Tar (Mineral Colloid Type) |

# APPENDIX A

## FUEL RESISTANCE TEST

ITEM P-631

## FUEL RESISTANCE TEST ITEM P-631
## TEST METHODS CRITERION

**1. Scope**

This method determines the resistance of the coal tar emulsion seal coat to kerosene.

**2. Apparatus**

2.1 2 6″ X 6″ square 16 gauge sheet metal masks with a 4″ × 4″ square center removed.

2.2 6″ X 6″ unglazed white ceramic tile with an absorption rate of 10-18 percent (determined in accordance with ASTM C 67.

2.3 Brass ring, 2″ diameter and 2″ high.

2.4 Kerosene meeting requirements of ASTM D 3699.

2.5 Silicone rubber sealant.

**3. Procedure**

3.1 Immerse the ceramic tile in distilled water for a minimum of ten minutes.

3.2 Remove excess water from the tile to produce a damp surface before applying the seal coat.

3.3 Using the mask described in 2.1 apply one layer of the coal tar emulsion mixture to the tile. Spread even with the top of the mask using a spatula or other straight edge.

3.4 Allow the sample to cure for 96 hours at 77 $\pm$ 2 degrees F. and 50 $\pm$ 10 percent relative humidity.

3.5 Position a second mask on top of the first mask.

3.6 Apply a second coat of coal tar emulsion mixture. Spread even with the top of the second mask.

3.7 Cure as in step 3.4.

3.8 After curing, affix the brass ring to the seal coat on the tile with silicone rubber sealant.

3.9 Fill the brass ring with kerosene.

3.10 After 24 hours, remove the kerosene from the brass ring, blot dry and immediately examine the film for softness and loss of adhesion. Immediately after the film is examined, break the tile in half, exposing that part of the tile whose film was subjected to the kerosene.

3.11 Evaluate for penetration of kerosene through the sealer and loss of adhesion.

**4. Report**

4.1 Report the results as pass or fail. Visible evidence of leakage or discoloration shall constitute failure of the fuel resistance test.

**Criterion:** A “pass” rating in the fuel resistance test is required prior to full production.

## END OF ITEM P-631

### ITEM P-632, BITUMINOUS PAVEMENT REJUVENATION[1]

GENERAL

**632-1.1 Description.** This item governs the application of an asphalt pavement rejuvenation product applied to a previously placed hot-mix asphalt (HMA) surface in accordance with these specifications, as shown on the plans, or as directed by the engineer. The purpose of this product is rejuvenation of the upper 3/8 inch of oxidized or otherwise aged asphalt binder without causing an unacceptable reduction in the friction characteristics (skid resistance) of the pavement section. Additionally, the rejuvenation product should not introduce unacceptable pavement distresses such as raveling, high temperature deformation (rutting), and loss of strength. The rejuvenation product should not contribute to accelerated deterioration of the pavement.

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**NOTE TO THE ENGINEER: Project Selection. The performance of a rejuvenation product is contingent on the pavement condition at the time of application. The pavement condition survey provides a measure of the pavement condition by analyzing the type, amount, and severity of the distresses, and by determining the pavement condition index (PCI) in accordance with AC 150/5380-6A, *Guidelines and Procedures for Maintenance of Airport Pavements,* and ASTM D 5340. A typical asphalt pavement candidate for rejuvenation is one without structural, load associated distresses (or has provisions to correct these distresses) and with low to moderate environmental, temperature associated distresses. The recommended corrected PCI should be equal to or greater than 70 to qualify as a candidate for asphalt rejuvenation.**

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MATERIAL

**632-2.1 Rejuvenation Product.**

**a.** The rejuvenation product must be capable of achieving the minimum changes in the asphalt binder properties shown in Tables 1 or 2 after proper application and field exposure.

**b.** The binder extracted per ASTM D 2172, Method A and recovered per ASTM D 1856 or D 5404 from samples of the upper 3/8 inch of the surface of the treated pavement must exhibit the percent decrease in absolute viscosity or complex viscosity and corresponding phase angle increase listed in Table 1 or 2, when compared to the values from adjacent untreated samples from the same pavement in the prescribed timeframe.

**c.** The bid submittal must include, from previous projects, independent laboratory test results accredited by an American Association of State Highway Transportation Officials (AASHTO) Materials Reference Laboratory (AMRL). The test results should verify the ability of the proposed rejuvenation product to achieve the minimum changes in asphalt binder properties shown in Table 1 or 2.

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[1] In this specification, the term "**rejuvenation product**" will carry the same connotation as the term "rejuvenator" or "rejuvenator/sealer." The term "**rejuvenation product**" will be used throughout this specification for the purpose of recognizing rejuvenation performance for each class of rejuvenation products.

**TABLE 1. Pavement Three (3) Years or Less in Age**

| Item # | Property of Recovered Binder [2] | Requirement | Test Method |
|---|---|---|---|
| 1 | Absolute Viscosity $_{60°C}$, P | ≥ 25% Decrease [2] | ASTM D 2171 |
| 2a | Complex Modulus $_{60°C}$, G* | | AASHTO T 315 |
| 2b | Viscosity $_{60°C}$, η = G* / ώ Pa·s | | |
| 2c | Phase Angle $_{60°C}$, δ, ° | Report | |

**TABLE 2. Pavement More than Three (3) Years in Age**

| Item # | Property of Recovered Binder [2] | Requirement | Test Method |
|---|---|---|---|
| 1 | Absolute Viscosity $_{60°C}$, P | ≥ 40% Decrease [2] | ASTM D 2171 |
| 2a | Complex Modulus $_{60°C}$, G*, kPa | | AASHTO T 315 |
| 2b | Viscosity $_{60°C}$, η* = G* / ώ Pa·s | | |
| 2c | Phase Angle $_{60°C}$, δ, ° | Report | |

## 632-2.2 Rejuvenation Documentation/Certification.

**a. Performance.** The bid submittal must include documentation of previous use and test data conclusively demonstrating that the rejuvenation product has been used successfully for a period of two or more years by other user agencies; and that the asphalt rejuvenation product has been proven to perform in a manner equivalent to this specification, through field testing by/for using agencies as to the required change in the recovered asphalt binder properties. Testing data must be submitted indicating such product performance from at least two projects representative of two different HMA mix designs, each being tested for a minimum of two years to insure reasonable longevity of the treatment, as well as product consistency. The performance documentation must be presented from a geographically similar climatic region of the United States as that for this project, e.g., wet-warm, wet-cool, dry-warm, and drycool, and contain data specified in 632-2.1.c.

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**NOTE TO THE ENGINEER: For projects calling for application of rejuvenation product on “Runway and High Speed Taxiway Surfaces,” the Engineer must consider testing and documentation of skid resistance in accordance with AC 150/5320-12, *Measurement,***

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[2] Procedures: Sample collection for application and acceptance as noted in this specification. Sample weights and measure by ASTM D 3549; Extraction by: ASTM D 2172, Method A using toluene (conditioning to remove moisture will not be accomplished); Recovery by: ASTM D 1856 (Abson) or ASTM D 5404 (Roto-Vap); and binder extraction, recovery and testing within 48 hours of obtaining pavement cores or equivalent surface area samples.

*Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces,* **prior to bidding.**

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**b. Friction Characteristics [For Runway and High Speed Taxi Exit Surfaces].** The bidder must provide evidence of past performance that the material, a minimum of 48 hours after application, does not cause a decrease in pavement frictional characteristics [skid resistance] below the maintenance planning requirements specified in AC 150/5320-12, *Measurement, Construction, and Maintenance of Skid-resistant Airport Pavement Surfaces*, Table 3-2, when tested at the speed of 40 mph with approved continuous friction measuring equipment [CFME].

**c. Health, Safety, and Environment.** The bidder must provide a complete material safety data sheet (MSDS) and the manufacturer's certification that the rejuvenation product compliance with the Code of Federal Regulation Title 40 – Protection of Environment. The manufacturer's certification shall address compliance for Air Programs, Part 59, National Volatile Organic Compound Emission Standards for Consumer and Commercial Products [for the airport location] and Water Programs, Part 116, Designation of Hazardous Substances. The MSDS, Section II, shall include the chemical abstracts service (CAS) registry numbers for all applicable hazardous ingredients in the rejuvenation product.

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**NOTE TO THE ENGINEER:**

**(1) US Department of Labor, Occupational Safety and Health Administration (OSHA), Regulations (Standards – 29 CFR), 1910.1200 establishes the requirement and minimum information for the MSDS for hazardous materials. The CAS registry numbers for the components identified in the rejuvenation product are the basis for compliance with Title 40 of the CFR – Protection of the Environment limitations.**

**(2) Title 40 of the CFR – *Protection of Environment*, Chapter 1, Environmental Protection Agency, Subchapter C – Air Programs, Part 59, National Volatile Organic Compound Emission Standards for Consumer and Commercial Products, includes a rejuvenation product as a bituminous coating and mastic. The limit in the CRF for bituminous coatings and mastics is 500 grams VOC per liter (4.2 pounds VOC per gallon). The airport may have more restrictive limits than listed in the CFR.**

**(3) Title 40 of the CFR – *Protection of Environment*, Chapter 1, Environmental Protection Agency, Subchapter D – Water Programs, Part 116, Designation of Hazardous Substances, lists the elements and compounds that are designated as hazardous substances under the Clean Water Act. This designation includes any isomers and hydrates, as well as any solutions and mixtures containing these substances. The CAS registry numbers are listed for cross-reference with the MSDS.**

**(4) Title 40 of the CFR – *Protection of Environment*, Chapter 1, Environmental Protection Agency, Subchapter J – Superfund, Emergency Planning, and Community Right-To-Know Programs, Part 302, Designation, Reportable Quantities, and Notification, identifies reportable quantities for hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act and the Clean Water Act, and sets forth the notification requirements for releases of these substances. The CAS registry numbers are listed for cross-reference with the MSDS.**

**(5) Environmental Protection Agency, EPA 550-B-01-003. Lists of Lists, Consolidated List of chemicals Subject to the Emergency Planning and Community Right-To-Know Act (EPCRA) and Section 112(r) of the Clean Air Act, October 2001, provides information and includes chemicals subject to reporting requirements under the Emergency Planning and Community Right-to-Know Act (EPCRA), also known as Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA)1, and chemicals listed under section 112(r) of the Clean Air Act (CAA). The CAS registry numbers are listed for cross-reference with the MSDS.**

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**632-2.3 RESERVED.**

APPLICATION RATE

**632-3.1 Test Sections.** Prior to full application, the contractor must place a series of test sections (minimum one square yard) at application rates as judged necessary by the manufacturer to establish the appropriate project rejuvenation product application rates for the specific product. As a minimum, a test section is required for each different HMA mix design identified in the project. Additional test sections may be required due to highly variable traffic areas, e.g., taxiway pavement wheel paths versus taxiway edge areas or specific areas identified by the engineer. The contractor must select test sections to obtain pavement cores or saw cut 'slabs' (equivalent surface area samples) in accordance with 632-6.1A. The pavement cores or equivalent surface area samples must be taken 48 hours after application of the rejuvenation test sections and tested in accordance with Table 1 or 2, Item #1 and Item #2a, paragraph 632-2.1 for the purpose of determining a recommendation for the rejuvenation product application rates. The contractor is responsible for all sampling and testing associated with the test sections.

**632-3.2 Approval.** The contractor and the engineer shall examine the test sections 24 hours after treatment to determine if the entire rejuvenation product has penetrated into the surface. Application rates that have not allowed full penetration into the pavement surface after 24 hours must not be permitted to be used for full production. The application rates for full production must be determined by the contractor and approved by the engineer based on the contractor's recommendation and observation of test sections and test section data from 632-3.1.

CONSTRUCTION

**632-4.1 Worker Safety.** The rejuvenation product must be handled with caution. The contractor must obtain a Material Safety Data Sheet (MSDS) for the rejuvenation product and require workmen to follow the manufacturer's recommended safety precautions.

**632-4.2 Weather Limitations**. The rejuvenation product must be applied only when the existing surface is dry and the weather forecast is in accordance with the manufacturer's recommendations for application and curing. The rejuvenation product must not be applied during inclement weather or when rain or freezing temperatures are anticipated within 24 hours before or after application. If weather conditions interfere with application and/or curing, the engineer may at his discretion suspend the job or require remedial action as deemed necessary.

**632-4.3 Equipment.** The contractor must furnish all equipment and hardware necessary for the performance of the work. The rejuvenation product should be delivered in dedicated tankers and/or containers with agitating equipment and filters, per manufacturer's recommendations. The distributor must be designed and equipped in accordance with the manufacturer's recommendations, but include as a minimum, the following characteristics:

**a.** Adequate heating capability for rapid heating of the rejuvenator to the proper application temperature.

**b.** A positive displacement pump capable of pumping low viscosity material and providing a preselected constant pressure to deliver the specified rates of application.

**c.** A full circulation spray bar and applicator that maintain proper nozzles, which provide the specified rate of application.

**d.** A hooded spray bar and applicator that maintain proper nozzle height.

**e.** A positive shut-off for the spray bar and a hand spray (with hose) equipped with a positive shut-off at the spray gun.

**f.** A thermometer installed in the distributor tank to measure the temperature of the rejuvenation product at the time of the application.

**g.** A speedometer calibrated to a minimum of tenths of miles per hour.

**h.** A chart listing the capacity of the tank (in gallons) for each one (1) inch of depth. A chart showing speed/pressure application rates must also be included.

**632-4.4 Cleaning and Preparing Existing Surface.**

**a.** Prior to placing the rejuvenation product, the surface of the pavement must be clean and free of all vegetation, rubber deposits, oil/fuel spills, debris, dust, dirt, or other loose foreign matter to the satisfaction of the engineer.

**b.** Cracks that are ¼ inch wide or greater must be routed and cleaned prior to application of the rejuvenation product in accordance with the instructions of the selected joint sealer. The cracks must be sealed with a hot-pour joint sealant compatible with the rejuvenation product as approved by the engineer subsequent to rejuvenation acceptance in accordance with the paragraph titled – REJUVENATION ACCEPTANCE.

**632-4.5 Application of Rejuvenation Product.**

**a.** Following preparation and subsequent inspection of the surface and consideration for skid resistance, the rejuvenation product shall be uniformly applied over the surface to be treated at the approved rate with an allowable variation from the approved rate of application of plus or minus 5 percent, in accordance with ASTM D 2995.

**b.** Materials shall be applied at the temperature recommended by the manufacturer.

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**NOTE TO THE ENGINEER: To obtain uniform application of the material on the surface treated at the junction of previous and subsequent applications, heavy paper or cardboard, equivalent technique, must be spread on the surface at a sufficient distance back from the ends of each application so that the material may be started and stopped on the paper. Immediately after application, the building paper must be removed and properly disposed.**

**Areas missed by the distributor must be properly treated with the hand spray.**

**Following application of the rejuvenation product, the surface should not be disturbed for a period of at least 24 hours.**

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**c.** Other rejuvenation product application procedures include:

- Calibration Test – contractor must furnish all equipment, materials, and labor necessary to calibrate the bituminous distributor or other application equipment. Calibration must be made with approved job material and prior to applying the rejuvenation product to the prepared surface. Calibration of the bituminous distributor and the specialized bituminous spray applicator must be in accordance with ASTM D 2995.

- Excess Rejuvenation Product Removal – Manufactured sand, as approved by the engineer, must be provided by the contractor and must be spread in sufficient quantity to effectively blot up any excess rejuvenation product remaining on the treated pavement surface after 24 hours.

- Ponding and Puddling of Rejuvenation Product – If low spots and depressions in the pavement surface cause ponding or puddling of the rejuvenation product, the pavement surface must be broomed with a broom drag. Brooming should continue until the pavement surface is free of any pools of excess material. Ponding and/or puddling must not cause excess pavement softening and/or additional distress. The engineer must inspect and approve areas after 'brooming.'

- Excess Runoff of Rejuvenation Product – The application rate should be reduced, and the engineer notified, if the surface grade of the pavement surface causes excessive runoff of the rejuvenation product. Additional rejuvenation product, if necessary, may be subsequently applied after the first application of material has penetrated into the pavement to achieve the required properties of the treated binder

- Insufficient Rejuvenation Product – When it is determined by the engineer that the actual application rate of the rejuvenation product is more than 5 percent below the approved application rate, subsequent applications of materials must be made to bring the actual application rate up to the approved rate; additional rejuvenation product must penetrate into the pavement surface within 24 hours after application. Multiple applications may be required at the discretion of the engineer, requiring additional pavement sampling and rejuvenation testing to assure compliance with Table 1 or 2 of 632-2.1.

**632-4.6 Cure Time Remedial Option – Application of Sand.**

**a.** The contractor must apply sand to the surface of the treated asphalt pavement(s) if the rejuvenation product does not meet the cure time requirement and/or the frictional characteristics (skid resistance) have been reduced to a level not acceptable to the engineer. An unacceptable level of frictional characteristics (skid resistance) is defined in 632-6.6.

**b.** The manufactured sand must be dry, hard, durable, free from clay, salt and foreign matter and well graded (100 percent passing #8 sieve and less than 10 percent passing #200 sieve). The sand must be uniformly applied at a rate of 3.0 lb/yd$^2$ ± 0.5 lb/yd$^2$, rolled (as recommended by the contractor and accepted by the engineer) into the treated surface and any surplus removed with a power broom, or as directed by the engineer. The contractor is responsible for all materials, equipment, and costs associated with the application of sand.

**c.** All manufactured sand or approved substitute used during the treatment must be removed as soon as practical after treatment of a pavement and prior to opening any airfield runway, taxiway, etc. This should be accomplished by a combination of hand and mechanical sweeping. All turnouts must be cleaned of any sand to the satisfaction of the engineer. Pavement sweeping will be included in the price bid per square yard for asphalt rejuvenation product.

**d.** If, after sand is swept and in the opinion of the engineer, a hazardous condition exists on the pavement, the contractor must apply additional sand and sweep same immediately following reapplication. No additional compensation will be allowed for reapplication and removal of sand.

QUALITY CONTROL

**632-5.1 Manufacturer Representation.** The contractor must have a manufacturer's authorized representative on the job site at the beginning of the work and during all rejuvenation product application. The manufacturer's representative must have knowledge of the material, procedures, and equipment described in the specification and will be responsible for determining the application rates and must oversee the preparation and application of the rejuvenation product. Documentation of the manufacturer representative's experience and knowledge for applying the rejuvenation product must be furnished to the engineer a minimum of 10 work days prior to placement of the test sections. The cost of the manufacturer's representative will be included in the bid price.

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**NOTE TO THE ENGINEER: The requirement for the Contractor to require a manufacturer's authorized representative on the job site at the beginning of the work and during all rejuvenation product application may be deleted, at the discretion of the Engineer. Past experience has demonstrated that improper application rates have resulted through subcontract agreements, and this decision must be predicated on the Engineer's ability to control selection and placement of the application rate under the Contract provisions.**

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**632-5.2 Quality Control Plan.** The contractor must submit a quality control plan to the engineer a minimum of 10 days prior to applying test sections in accordance with 632-3.1. The quality control plan must address all items that affect the quality of the rejuvenation application including, but not limited to:

**a.** Qualifications of personnel.

**b.** Schedule for the project.

**c.** Procedure to monitor the weather/temperature limitations.

**d.** Inspection requirements including rejuvenation product, test sections, storage of rejuvenation product, preparation of the pavement surface, and equipment calibration.

**e.** Provisions for obtaining, packaging and shipping acceptance samples and repair of the pavement.

**f.** Provisions for sample testing, testing laboratory name, location, accreditation, contact person, all contact information, testing requested, and report on information.

**632-5.3 Warranty.** The contractor must provide a manufacturer's/applicator warranty that the treated pavement will retain the lower binder properties of Table 1 or 2, for a period of two (2) years from the date of treatment. For compliance with the warranty, the owner may obtain cores and perform tests in accordance with REJUVENATION ACCEPTANCE. The contractor must further warrant that from the date the rejuvenation product was applied, the material will not flake, peel, chip, spall, nor otherwise contribute to or accelerate the aging of the pavement. The contractor must reapply the rejuvenation product, as necessary, or provide remedial actions at no cost to the owner, and/or refund all payments at the owner's discretion. The Engineer must designate and record an area of no less than 10 square yards of untreated and 10 square yards of treated pavement as the control sections for warranty testing. In the event a pay reduction, or no payment, is enforced, the warranty is rescinded.

REJUVENATION ACCEPTANCE

**632-6.1 Product Sampling.** The Engineer will take samples of the rejuvenation product proposed for use upon delivery of each shipment in accordance with ASTM D 140 and store in accordance with MSDS, Section VII for a period of at least six months after payment in accordance with Paragraph 632 8.1. Testing, as necessary, will be accomplished by the Engineer to verify information provided by the MSDS information.

**632-6.2 Freight and Weigh Bills.** The Contractor must furnish the Engineer receipted bills when railroad shipments are made, and certified weigh bills when materials are received in any other manner, of the rejuvenation product used in the construction covered by the contract. The Contractor shall not remove rejuvenation product from the tank car or storage tank until the initial outage and temperature measurements have been taken by the Engineer, nor shall the car or tank be released until the final outage has been taken by the Engineer.

**632-6.3 Field Sampling Procedures.** Sampling of the pavement sections to be treated must be performed before and after the pavement has been treated with the rejuvenation product. The contractor will be responsible for obtaining all pavement core samples or equivalent surface area samples as approved by the engineer for testing. At the discretion and approval of the engineer, the before samples collected and tested for application may suffice for before samples for acceptance.

**a.** At each sampling location, three (3) cores or equivalent surface area samples must be taken before the rejuvenation product is placed [**untreated**] and three (3) cores or equivalent surface area samples after treatment of the pavement [**treated**]. The treated pavement samples must be taken close to the untreated samples, at a minimum within the same paving lane and within one foot of each other. All pavement cores taken by the contractor must be six (6) inches in diameter. The contractor must repair any sample holes resulting from the removal of asphalt concrete pavement cores or equivalent surface area samples (with suitable materials and methods as approved by the engineer) at no cost to the owner.

**b.** The **treated** pavement cores or equivalent surface area samples must be taken 30-45 days after application of the rejuvenation product.

**c.** Both **untreated** and **treated** pavement cores or equivalent surface area samples must be performed for each 30,000 square yards or fractional part of pavement section per pavement plan or as required by the engineer. Material acceptance in accordance with 632-2.1, Table 1 or Table 2, will be based on the test results for each 30,000 square yards or fractional part of treated pavement section per pavement plan or as required by the engineer. Locations for **untreated** samples should be determined by the engineer on a random basis in accordance with the procedures contained in ASTM D 3665 provided requirements of 632-6.3.a. can be satisfied for both untreated and treated samples.

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**NOTE TO THE ENGINEER: It is recognized, the rate of recovered viscosity reduction in addition to product type and application rate is influenced by the climatic conditions and time of exposure prior to sampling and testing. All means to standardize these parameters should be taken. Time factor and weather conditions for all should be noted and recorded.**

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**d.** Pavement core samples or equivalent surface areas samples must be placed in labeled sealable plastic bags immediately after taking, cleaning and removing sampling water (blotting). The sealed samples must then be placed in labeled plastic core canisters. For equivalent surface area samples, an equivalent processing for the sample is required as approved by the engineer. The specimens must be shipped to the designated laboratory within 24 hours of collection.

**632-6.4 Rejuvenation Testing Responsibility.** All acceptance testing necessary to determine conformance with this specification must be performed by the engineer, or accredited independent test agency, to verify that the rejuvenation product achieves the minimum decrease in the asphalt binder properties as measured from binder in the top 3/8 ± 1/32 inch of the samples.

**632-6.5 Rejuvenation Testing.** Tests must be conducted to extract the bituminous binder from the top 3/8 ± 1/32 inch of the cores/slabs precisely cut from the field specimens.

**a.** Binder extraction must be by ASTM D 2172, Method A (centrifuge) with toluene, and recovered according to ASTM D 1856 (Abson Method) or ASTM D 5404 (Roto-Vap Method).

- Viscosity of the bituminous material must be measured in accordance with ASTM D 2171. The percent decrease in the binder properties must be computed as follows:

100 [(absolute viscosity, P, of untreated sample) – (absolute viscosity, P, of treated sample)] / (absolute viscosity, P, of untreated samples)

- The complex modulus, G*, kPa, must be measured in accordance with AASHTO T 315 C, at 60°C (140°F) 10 rad/sec or other recorded frequency. The percent decrease in the binder properties must be computed as follows:

100 [(complex modulus, G*, kPa of untreated sample) – (complex modulus, G*, kPa, of treated sample)] / (complex modulus, G*, kPa, of untreated samples)

The complex viscosity, $\eta^*$, at 60°C (140°F) must be calculated and reported from the complex modulus, G* and angular frequency, ώ (radians/sec).

**b.** Test results for absolute viscosity, complex modulus (and viscosity), and phase angle must be reported. The maximum percent reduction calculated for absolute viscosity or complex modulus must be considered in BASIS OF PAYMENT.

**c.** In the event of binders recovered from aged pavements and/or pavements using polymer modified binders (before treatment) exhibiting absolute viscosities ≥ 200,000 P (data becomes suspect, viscosity exceeds test capabilities) the viscosity reduction compliance requirement should be determined based on the complex modulus, G*, kPa.

**632-6.6 Skid Resistance.** Special attention must be afforded to skid resistance based on the use of the pavement surfaces.

**a. For Runway and High Speed Taxiway Exit Surfaces.** The pavement surface areas treated with rejuvenation product must be tested for skid resistance a minimum of forty-eight (48) hours after application of the rejuvenation product. The results of the friction evaluation must be equal or greater than the Maintenance Planning levels provided in Table 3-2, "Friction Level Classification for Runway Pavement Surfaces," in AC 150/5320-12, *Measurement, Construction, and Maintenance of Skid-resistant Airport Pavement Surfaces*, when tested at speeds of 40 and 60 mph with approved continuous friction measuring equipment [CFME].

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**NOTE TO THE ENGINEER: A test section is recommended prior to full production.**

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**b. For Taxiway and Apron Surfaces.** The skid resistance for taxiway and apron surfaces must be inspected by the contractor and engineer a minimum of forty-eight (48) hours after application of the rejuvenation product. In the event either the contractor or the engineer has concern on the skid resistance of these surfaces, the contractor must exercise 632-4.6. Cure Time Remedial Option – Application of Sand to the satisfaction of the Engineer Otherwise, the provisions of P-632-6.6.a may be directed by the engineer.

METHOD OF MEASUREMENT

**632-7.1 Asphalt Crack Preparation and Seal.** The quantity of asphalt crack preparation and seal to be paid for must be the number of linear feet performed in accordance with the plans and specifications and accepted by the engineer.

**632-7.2 Asphalt Rejuvenation.** The quantity of rejuvenation product to be paid for will be the number of square yards performed in accordance with the plans and specifications and accepted by the engineer. The contractor must furnish the engineer with the certified weigh bills when materials are received for the rejuvenation product used under this contract. The contractor must not remove material from the tank car or storage tank until initial amounts and temperature measurements have been verified.

BASIS OF PAYMENT

**632-8.1 Payment.** Payment for accepted rejuvenation product will be made at the contract unit price per square yard (square meter) for bituminous rejuvenation adjusted according to 632-8.1.a. Payment for the crack preparation and seal will be made at the contract unit price per linear foot (linear meter).

**a. Basis of Adjusted Payment.** The payment for accepted rejuvenation product must be calculated in accordance with Table #3.

**TABLE 3. Rejuvenation Pay Reduction.**

| **Binder Rejuvenation at Acceptance; % Reduction in Absolute Viscosity or Complex Modulus** | | **% Payment** |
|---|---|---|
| Pavement **More Than** 3 Years in Age | Pavement **Less Than** 3 Years in Age | |
| ≥ 40 | ≥ 25 | **100** |
| 30.0 - 39.9 | 20.0 - 24.9 | **75** |
| Less than 30.0 | Less than 20.0 | **No payment** |

**b. Final Payment.** Final payment will not be made until rejuvenation success has been confirmed by acceptance testing, which does not occur until 30-45 days after application. Final payment will be full compensation for furnishing all materials and for all labor, equipment, tools, and incidentals necessary to complete the item. Payment will be made under:

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**NOTE TO THE ENGINEER: Since 'No Payment' is an option to the Owner, partial payment is an option at the discretion of the Engineer.**

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Item P-632-1 Asphalt Crack Preparation and Seal – per linear foot (linear meter) Item P-632-2 Asphalt Rejuvenation – per square yard (square meter)

**TESTING REQUIREMENTS**

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|---|---|
| ASTM D 140 | Standard Practice for Sampling Bituminous Materials. |
| ASTM D 1856 | Standard Test Method for Recovery of Asphalt from Solution by Abson Method. |
| ASTM D 2171 | Standard Test Method for Viscosity of Asphalts by Vacuum Capillary Viscometer. |
| ASTM D 2172 | Standard Test Methods for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures. |
| ASTM D 2995 | Standard Practice for Estimating Application Rate of Bituminous Distributors. |
| ASTM D 3549 | Standard Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens. |
| ASTM D 3665 | Standard Practice for Random Sampling of Construction Materials. |
| ASTM D 5340 | Standard Test Method for Airport Pavement Condition Index Surveys. |
| ASTM D 5404 | Standard Practice for Recovery of Asphalt from Solution Using the Rotary Evaporator. |
| AASHTO T 315 | Standard Method of Test for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR). |

## END OF ITEM P-632

# Slurry Surfacing Systems

# ITEM P-626 EMULSIFIED ASPHALT SLURRY SEAL SURFACE TREATMENT

DESCRIPTION

**626-1.1** This item shall consist of a mixture of emulsified asphalt, mineral aggregate, and water properly proportioned, mixed, and spread on an asphalt prepared underlying course or existing wearing course in accordance with these specifications and shall conform to the dimensions shown on the plans or as directed by the Engineer.

MATERIALS

**626-2.1 AGGREGATE**. The aggregate shall consist of sound and durable manufactured sand, slag, crusher fines, crushed stone, or a combination thereof. The aggregate shall be clean and free from vegetable matter, dirt, and other deleterious substances. The aggregate shall have a sand equivalent of not less than **[45]** percent when tested in accordance with ASTM D 2419. The aggregate shall show a loss of not more than **[35]** percent when tested in accordance with ASTM C 131. The sodium sulfate soundness loss shall not exceed **[12]** percent, or the magnesium soundness loss shall not exceed **[20]** percent after 5 cycles when tested in accordance with ASTM C 88. Aggregate shall be 100 percent crushed.

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**The sand equivalent should not be less than 45. The percent loss when tested under ASTM C 131 should not exceed 35. The sodium sulfate loss should not exceed 12 percent; the magnesium sulfate loss should not exceed 20 percent. In certain specific cases, where aggregates complying with these requirements cannot be economically obtained, aggregates with a higher percentage loss (15 percent using sodium sulfate and 25 percent using magnesium sulfate has been used) or wear may be specified, provided a satisfactory service record under similar conditions of service and exposure has been demonstrated.**

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The combined aggregate shall conform to the gradation shown in Table 1 when tested in accordance with ASTM C 136 and ASTM C 117.

**TABLE 1. GRADATION OF AGGREGATES**

| Sieve Size | Percent by Weight Passing Sieve | | | |
|---|---|---|---|---|
| | Type I | Type II | Type III | Type IA |
| 3/8 in. (9.5 mm) | 100 | 100 | 100 | 100 |
| No. 4 (4.75 mm) | 100 | 90 - 100 | 70 - 90 | 98 - 100 |
| No. 8 (2.36 mm) | 90 - 100 | 65 - 90 | 45 - 70 | 85 - 95 |
| No. 16 (1.18 mm) | 65 - 90 | 45 - 70 | 28 - 50 | 50 - 75 |
| No. 30 (600 micro m) | 40 - 65 | 30 - 50 | 19 - 34 | 30 - 50 |
| No. 50 (300 micro m) | 25 - 42 | 18 - 30 | 12 - 25 | 18 - 35 |

| | | | | |
|---|---|---|---|---|
| No. 100 (150 micro m) | 15 - 30 | 10 - 21 | 7 - 18 | 10 - 21 |
| No. 200 (75 micro m) | 10 - 20 | 5 - 15 | 5 - 15 | 5 - 10 |
| Residual asphalt content percent dry weight of aggregate | 10% - 16% | 7.5% - 13.5% | 6.5% - 12% | 9% - 13.5% |

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**Table 1 – Gradation of Aggregates. Projects that have specified coarser aggregate gradations have reported problems with excessive tire wear. A coarser Type I gradation will provide considerable skid resistance and may be considered for most projects. A finer Type II gradation will provide sufficient friction and will not cause excessive tire wear. Tire wear appears to be related to the amount a material passing the #4 and retained on the #8 sieve. We recommend that no more than 10-15% be retained on the #8 sieve.**

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The job mix formula (mix design) shall be run using aggregate within the gradation band for the desired type shown in Table 1. Once the mix design has been submitted and approved, the aggregate used on the project shall not vary by more than the tolerances shown in Table 2. At no time shall the aggregate used go out of the gradation bands in Table 1.

The aggregate will be accepted at the job location or stockpile. The stockpile will be accepted based on five gradation tests samples in accordance with ASTM D 75. If the average of the five tests is within the gradation tolerances, then the materials will be accepted. If the tests show the material to be out of tolerance, the Contractor will be given the choice either to remove the material or blend other aggregates with the stockpile material to bring it into specification. Materials used in blending shall meet the quality tests before blending and shall be blended in a manner to produce a consistent gradation. This blending may require a new mix design.

Screening shall be required at the project stockpile site if there are any problems created by having oversize materials in the mix.

Precautions shall be taken to prevent segregation of the aggregate in storing and handling. The stockpile shall be kept in areas that drain readily.

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**The aggregate gradation band applicable to a project shall be specified by the Engineer from the gradations shown in Table 1. The appropriate gradation shall be shown on the plans. Type I gradation is used for maximum crack penetration and is usually used in low density traffic areas where the primary objective is sealing. Type II and Type III gradations are used to seal and improve skid resistance. Type III gradation is not recommended for runway use by the ISSA.**

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**a. Aggregate Tolerance.** Once the mix design has been accepted, the aggregate gradation used on the project may vary from the aggregate gradation used in the mix design on each sieve by the percentages shown in Table 2. If the project aggregate fails to remain within this tolerance, a new mix design will be required by the Engineer at the expense of the Contractor.

| Sieve Size | Tolerance, percent by weight passing sieve |
|---|---|
| 3/8 in. (9.5 mm) | + or – 0% |
| No. 4 (4.75 mm) | + or - 2% |
| No. 8 (2.36 mm) | + or - 5% |
| No. 16 (1.18 mm) | + or - 5% |
| No. 30 (600 micro m) | + or - 5% |
| No. 50 (300 micro m) | + or - 4% |
| No. 100 (150 micro m) | + or - 3% |
| No. 200 (75 micro m) | + or - 2% |
| Residual Asphalt, percent dry weight of aggregate | + or - 1% |

**626-2.2 MINERAL FILLER.** If mineral filler, in addition to that naturally present in the aggregate, is necessary, it shall meet the requirements of ASTM D 242 and shall be used in the amounts required by the mix design. The mineral filler shall be considered as part of the aggregate.

**626-2.3 EMULSIFIED ASPHALT.** The emulsified asphalt shall conform to the requirements of ASTM D **[ 977 and/or 2397 ]** and shall be SS, CSS, CQS, or QS type emulsions.

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**The cement mixing test is waived for these slurry type emulsions. The emulsified asphalt shall be either anionic or cationic, whichever is best suited to the aggregate and job conditions to be encountered. The type of emulsified asphalt to use will be determined by the mix design. The Engineer shall specify the type of emulsion and the controlling specification, which**

**shall be from ASTM D 977 or ASTM D 2397, and the material shall be SS, CSS, CQS, or QS.**

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**626-2.4 WATER.** All water used in making the slurry shall be potable and free from harmful soluble salts and chemicals.

COMPOSITION AND APPLICATION

**626-3.1 COMPOSITION.** The slurry seal shall consist of a mixture of emulsified asphalt, mineral aggregate, and water.

**626-3.2 JOB MIX FORMULA.** No slurry seal for payment shall be placed until a mix design has been approved by the Engineer. The mix design shall be developed by a laboratory with experience in designing slurry seal mixes and a signed copy shall be submitted in writing by the Contractor to the Engineer at least 10 days prior to the start of operations.

The laboratory report (mix design) shall indicate the proportions of aggregates, mineral filler (min. and max.), water (min. and max.) and asphalt emulsion based on the dry aggregate weight. It shall also report the quantitative effects of moisture content on the unit weight of the aggregate (bulking effects). The mix design shall be in effect until modified in writing by the Engineer. Should a change in sources of materials be made, a new mix design shall be established before the new material is used.

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**The main items of design in emulsified asphalt slurry seals are aggregate gradation, emulsified asphalt content, and consistency of the mixture. The aggregates, emulsified asphalt, and water should form a creamy-textured slurry that, when spread, will flow ahead of the strike-off squeegee. This will allow the slurry to flow down into the cracks in the pavement and fill them before the strike-off passes over. Technical Bulletin No. 111, Outline Guide Design Procedure for Slurry Seal, and publication A 105 Recommended Performance Guidelines published by the International Slurry Surfacing Association (ISSA) contains information to aid designers of slurry mixes.**

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The Contractor shall submit to the Engineer for approval a complete mix design on the materials proposed for use, prepared and certified by an approved laboratory**.** Compatibility of the aggregate, emulsion, mineral filler, and other additives shall be verified by the mix design. The mix design shall be made with the same aggregate and grade of emulsified asphalt that the Contractor will provide on the project. At a minimum the required tests and values needed are as follows:

| | DESCRIPTION | SPECIFICATION |
|---|---|---|
| ISSA TB-100 | Wet Track Abrasion Loss One Hour Soak | 50 $g/ft^2$ Max ($538 g/m^2$) |
| ISSA TB-115 | Determination of Slurry Seal Compatibility | Pass |

**626-3.3 APPLICATION RATE.** Unless otherwise specified, the slurry seal shall be applied to at the application rates shown in Table 3 for that gradation of material used.

**TABLE 3. APPLICATION RATES**

| | Type I | Type II | Type III | Type IA |
|---|---|---|---|---|
| Pounds of mixture per square yard | 8 - 12 | 12 - 20 | 18 - 30 | 10 – 16 |
| Kilograms of mixture per square meter | 4.3 - 6.5 | 6.5 - 10.9 | 9.8 - 16.3 | 5.4 – 8.6 |

The rate of application shall not vary more than ± 2 pounds per square yard (±1.1 kilograms per square meter).

**626-3.4 TEST SECTIONS.** Test sections shall be placed prior to the start of the slurry seal work in the presence of the Engineer. The test area will be designated by the Engineer and will be located on the existing pavement. Test strips shall be made by each machine after calibration. Samples of the slurry seal may be taken and the mix consistency verified by using ISSA TB-106 Slurry Seal Consistency test. In addition, the proportions of the individual materials may be verified by the Engineer by using the calibration information provided after machine calibration. If any test does not meet specification requirements, additional tests shall be made at the expense of the Contractor, until an acceptable test strip is placed.

CONSTRUCTION METHODS

**626-4.1 WEATHER LIMITATIONS.** The slurry seal shall not be applied if either the pavement or air temperature is below 50 °F (10 °C) and falling but may be applied when both pavement and air temperature are above 45 °F (7 °C) and rising. No slurry seal shall be applied when there is danger that the finished product will freeze before 24 hours. The mixture shall not be applied when weather conditions prolong opening to traffic beyond a reasonable time.

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**The Engineer should not specify a lower permissible temperature range than that stated in 626-4.1, since slurry placed at lower temperatures usually will not cure properly due to poor dehydration and poor asphalt coalescence.**

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**626-4.2 EQUIPMENT AND TOOLS.** The Contractor shall furnish all equipment, tools, and machinery necessary for the performance of this work.

**a. Slurry Mixing Equipment.** The machine shall be specifically designed and manufactured to lay slurry seal. The material shall be mixed by a self-propelled slurry seal mixing machine of either truck mounted or continuous run design. Either type machine shall be able to accurately deliver and proportion the aggregate, emulsified asphalt, mineral filler, and water to a revolving mixer and discharge the mixed product on a continuous flow basis. The machine shall have sufficient storage capacity for materials to maintain an adequate supply to the proportioning controls.

If continuous run equipment is used, the machine shall be equipped to allow the operator to have full control of the forward and reverse speed of the machine during application of the slurry seal, with a self-loading device, with opposite side driver stations, all part of original equipment manufacturer design.

The aggregate shall be prewetted immediately prior to mixing with the emulsion. The mixing unit of the mixing chamber shall be capable of thoroughly blending all ingredients. No excessive mixing shall be permitted. The mixing machine shall be equipped with a fines feeder that provides an accurate metering device or method to introduce a predetermined proportion of mineral filler into the mixer at the same time and location that the aggregate is fed into the mixer.

The mixing machine shall be equipped with a water pressure system and fog-type spray bar adequate for complete fogging of the surface with an application of 0.05 to 0.10 gallon per square yard (0.23 to 0.45 liter per square meter) preceding the spreading equipment.

Sufficient machine storage capacity to mix properly and apply a minimum of 5 tons (4 500 kg) of the slurry shall be provided. Proportioning devices shall be calibrated prior to placing the slurry seal.

**b. Slurry Spreading Equipment.** The mixture shall be spread uniformly by means of a conventional surfacing spreader box attached to the mixer and equipped to agitate and spread the material evenly throughout the box. A front seal shall be provided to insure no loss of the mixture at the surface contact point. The rear seal shall act as the final strike-off and shall be adjustable. The spreader box and rear strike-off shall be so designed and operated that a uniform consistency is achieved to produce a free flow of material to the rear strike-off. The spreader box shall have suitable means provided to side shift the box to compensate for variations in the pavement geometry. A burlap drag or other approved screed may be attached to the rear of the spreader box to provide a uniform mat.

**c. Auxiliary Equipment.** Other tools or equipment such as brushes, hand squeegees, hose equipment, tank trucks, water distributors and flushers, power blowers, barricades, etc., shall be provided as required.

**d. Roller.** The roller, if required, shall be a self-propelled pneumatic-tired roller capable of exerting a contact pressure during rolling of 50 pounds per square inch (350 000 Newton's per square meter). It shall be equipped with a water spray system, to be used if the slurry is picking up on the tires during rolling.

**e. Tack Coat and Distributor**. Normally a tack coat is not required unless the surface to be covered is extremely dry and raveled or is concrete or brick. If required, the tack coat should consist of one part emulsified asphalt and three parts water. The emulsified asphalt may be the same as that used in the mix. Pressure distributors used for application of the diluted asphalt emulsion tack coat shall be self-propelled, equipped with pneumatic tires, and capable of uniformly applying 0.05 to 0.15 gallon per square yard (0.23 to 0.68 liter per square meter) of the diluted emulsion over the required width of application. Distributors shall be equipped with tachometers, pressure gages, and volume-measuring devices. The tack coat shall be applied at least 2 hours before the slurry seal but within the same day.

**626-4.3 EQUIPMENT CALIBRATION.** Each slurry mixing unit to be used on the project shall be calibrated in the presence of the Engineer prior to construction. Previous calibration documentation covering the exact materials to be used may be accepted by the Engineer provided they were made during the calendar year. The documentation shall include an individual calibration of each material at various settings, which can be related to the machine's metering devices. No machine will be allowed to work on the project until the calibration has been completed and/or accepted.

**626-4.4 PREPARATION OF EXISTING SURFACE.** Prior to placing the tack coat and slurry seal coat, unsatisfactory areas shall be repaired and the surface shall be cleaned of dust, dirt, or other loose foreign matter, grease, oil, excessive rubber accumulation, or any type of objectionable surface film. Any standard cleaning method will be acceptable except that water flushing will not be permitted in areas where considerable cracks are present in the pavement surface.

Any painted stripes or markings on the surface of the runways or taxiways to be treated, shall be removed.

Cracks wider than 1/4 inch (6 mm) shall be cleaned with compressed air, and sealed with a compatible crack sealer prior to applying the slurry seal. Cracks wider than 3/4 inch (19 mm) should be pre-filled and sealed with the slurry mixture prior to surfacing. Cracks that show evidence of vegetation shall be cleaned and treated with an approved herbicide.

**626-4.5 APPLICATION OF SLURRY SEAL COAT.** The surface shall be prewet by fogging ahead of the slurry spreader box. Water used in prewetting the surface shall be applied at such a rate that the entire surface is damp with no apparent flowing water in front of the slurry spreader box. The slurry mixture shall be of the desired consistency when deposited on the surface, and no additional elements shall be added. Total time of mixing shall not exceed 2 minutes. A sufficient amount of slurry shall be carried in all parts of the spreader box at all times so that complete coverage of all surface voids and cracks is obtained. Care shall be taken not to overload the spreader box that shall be towed at a slow and uniform rate not to exceed 5 miles per hour (8 kilometers per hour). No lumping, balling, or unmixed aggregate shall be permitted. No segregation of the emulsion and fines from the coarse aggregate will be permitted. If the coarse aggregate settles to the bottom of the mix, the slurry shall be removed from the pavement surface. A sufficient amount of slurry shall be fed into the box to keep a full supply against the full width of the spreader box. The mixture shall not be permitted to overflow the sides of the spreader box. No breaking of the emulsion will be allowed in the spreader box. The finished surface shall have no more than four (4) tear or drag marks greater than 1/2 inch (13 mm) wide and 4 inches (100 mm) long in any 12 foot by 22 foot (25 sq. meter) section. It shall have no tear or drag marks greater than 1 inch (25 mm) wide and 3 inches (15 mm) long.

The finished surface shall have no transverse ripples of 1/4 inch (6 mm) or more in depth, as measured with a 10-foot (3 meter) straight edge laid upon the surface.

Adjacent lanes shall be lapped at the edges a minimum of 2 inches (50 mm) with a maximum of 4 inches (100 mm) to provide complete sealing at the overlap. Construction longitudinal and transverse joints shall be neat and uniform without buildup, uncovered areas, or unsightly appearance. All joints shall have no more than 1/4 inch (6 mm) difference in elevation when measured across with a 10 foot (3 meter) straight edge.

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**Generally, where normal traffic will iron out the slurry and close any hairline cracks of dehydration, it is not necessary to roll a normal thickness, 1/4 inch (6 mm) or less, slurry seal. However, in some instances the somewhat lattice-like structure of the slurry should be densified by pneumatic-tire rolling to improve durability, such as areas subjected to severe braking or acceleration. Rolling of the slurry seal is at the option of the Engineer and, if required, shall be designated in the plans.**

**If rolling is required by the Engineer, the surface shall be subjected to a minimum of two full coverage passes by the roller. These rolling passes are to be done as soon as the slurry mixture will support the roller without damage. When the surface of the existing pavement is irregular or broken, it shall be repaired or brought to uniform grade and cross section by patching as directed in the project plans. With the exception of standard debris cleaning, all other repairs, crack sealing, and required removal of materials shall be a line item in the bid and noted in the plans.**

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The fresh slurry seal application shall be protected by barricades and markers and permitted to dry for 4 to 24 hours, depending on weather conditions. Any damage to uncured slurry shall be repaired at the expense of the Contractor.

In areas where the spreader box cannot be used, the slurry shall be applied by means of a hand squeegee. Upon completion of the work, the seal coat shall have no holes, bare spots, or cracks through which liquids or foreign matter could penetrate to the underlying pavement. The finished surface shall present a uniform and skid resistant texture satisfactory to the Engineer. All wasted and unused material and all debris shall be removed from the site prior to final acceptance.

Upon completion of the project, the Contractor shall sweep the finished surface with a conventional power rotary broom, to remove any potential loose material from the surface. The material removed by sweeping shall be disposed of in a manner satisfactory to the Engineer.

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**The cured slurry shall have a homogeneous appearance, fill all cracks, adhere firmly to the surface and have a skid resistant texture. The slurry seal will not stop shrinkage and other large thermal cracks from reflecting back through the new slurry surface.**

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**626-4.6 EMULSION MATERIAL (CONTRACTORS RESPONSIBILITY).** Samples of the emulsion that the Contractor proposes to use, together with a statement as to its source, shall be submitted, and approval shall be obtained before using such material. The Contractor shall submit to the Engineer a manufacturer's certified report for each consignment of the emulsion. The manufacturer's certified report shall not be interpreted as a basis for final acceptance. All such reports shall be subject to verification by testing samples of the emulsion as received for use on the project.

METHOD OF MEASUREMENT

**626-5.1** The emulsified asphalt shall be measured by the **[gallon (liter)] [ton (kg)]**. Only the actual quantity of undiluted emulsified asphalt will be measured for payment.

**626-5.2** Aggregate shall be measured by the ton (kg) of dry aggregate.

**[626-5.3 Crack sealing shall be measured by the linear foot (meter) of cracks sealed.]**

**[626-5.4 Surface repair shall be measured by the ton (kg) or square measurement of material placed.]**

**[626-5.5 Paint and rubber removal shall be measured by the linear foot (meter) or square measurement.]**

BASIS OF PAYMENT

**626-6.1** Payment shall be made at the contract unit price per **[gallon (liter)] (ton (kg)]** for the emulsified asphalt and at the contract price per ton (kg) for aggregate **[and the contract unit price for crack sealing per linear foot] [and the contract unit price for surface repair per ton (kg) or square measurement] [and the contract unit price for paint and rubber removal per lineal foot (meter) or square measurement]**.

These prices shall be full compensation for furnishing all materials, for preparing, mixing, and applying these materials, and for all labor, equipment, tools, and incidentals necessary to complete the item.

Payment will be made under:

Item P-626-6.1 Emulsified Asphalt for Slurry Coat—per [gallon (liter)] [ton (kg)]

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Item P-626-6.2 Aggregate—per ton (kg) of dry aggregate.

[Item P-626-6.3 Emulsified Asphalt for Tack Coat—per [gallon (liter)] [ton (kg)]]

[Item P-626-6.4 Crack sealing — per linear [feet] (meter)]

[Item P-626-6.5 Surface Repair—per [ton] (kg) or square measurement]

[Item P-626-6.6 Paint and Rubber removal—per linear foot (meter) or square measurement (meter)]

TESTING REQUIREMENTS

| | |
|---|---|
| ASTM C 88 | Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate |
| ASTM C 117 | Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing |
| ASTM C 128 | Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate |
| ASTM C 131 | Resistance to Degradation of Small Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine |
| ASTM C 136 | Sieve or Screen Analysis of Fine and Coarse Aggregates |
| ASTM D 75 | Sampling Aggregates |
| ASTM D 2419 | Sand Equivalent Value of Soils and Fine Aggregate |
| ISSA A 105 | Recommended Performance Guidelines |
| ISSA TB-100 | Wet Track Abrasion Loss |
| ISSA TB-106 | Slurry Seal Consistency |
| ISSA TB 111 | Outline Guide Design Procedure for Slurry Seal |
| ISSA TB-115 | Determination of Slurry Seal Compatibility |

MATERIAL REQUIREMENTS

| | |
|---|---|
| ASTM D 242 | Mineral Filler for Bituminous Paving Mixtures |
| ASTM D 977 | Emulsified Asphalt |

ASTM D 2397 Cationic Emulsified Asphalt

**END OF ITEM P-626**

Airfield Asphalt Pavement Technology Program

# CHIP SEALS

http://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.list

## ITEM P-609 SEAL COATS AND BITUMINOUS SURFACE TREATMENTS

DESCRIPTION

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**GENERAL NOTE: Although this type of surface sealant is approved for use on general aviation airports, we remind the user that this method of treatment may leave excessive amounts of loose aggregate on the surface of the pavement.**

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**609-1.1** This item shall consist of a bituminous surface treatment as a wearing course composed of **[a single application][multiple applications]** of bituminous material and aggregate cover placed on the prepared primed base or properly cured wearing surface, in accordance with these specifications, and shall conform to the dimensions and typical cross section shown on the plans.

**609-5.1 QUANTITIES OF MATERIALS PER SQUARE YARD.** The approximate amounts of materials per square yard (square meter) for the bituminous surface treatment shall be as provided in Table 1 for the treatment specified on the plans or in the special provision. The exact amounts to be used shall be determined by the Engineer.

**TABLE 1. QUANTITIES OF MATERIALS**

| Application No. | Quantity of Aggregate lb/sq yd (kg/sq m) | Quantity of Asphalt gal/sq yd (l/sq m) | Type of Asphalt[1] |
|---|---|---|---|
| 1 | 40-50 (21.7-27.1) | 0.35-0.45 (1.58-20.3) | Asphalt Cement |
| | | 0.40-0.50 (1.81-2.26) | Emulsified Asphalt |
| 2 | 20-25 (10.9-13.6) | 0.15-0.25 (0.68-1.13) | Asphalt Cement |
| | | 0.20-0.35 (0.90-1.58) | Emulsified Asphalt |
| 3 | 15-20 (8.1-10.9) | 0.15-0.20 (0.68-0.90) | Emulsified Asphalt |

[1] See Table 3 for grades of asphalt and spraying temperatures.

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**The quantities of asphalt shown in Table 1 cover the average range of conditions that include primed granular bases and old pavement surfaces.**

**The quantities and types of materials should take into consideration local conditions and experience.**

**The lower application rates shown in Table 1 should be used for aggregate having gradations on the fine side of the specified limits. The higher application rates should be used for aggregate having gradations on the coarse side of the specified limits.**

**The asphalt content selected should reflect the condition of the pavement. If the pavement is highly oxidized, badly cracked, or coarse more asphalt should be used.**

609–□.□ ****************************************
MATERIALS

609–5.1 **AGGREGATE MATERIALS.** The aggregate material shall be either crushed stone, crushed gravel, or crushed slag. The cover material shall be screenings; sand may be used when specified.

If the material is to be crushed stone, it shall be manufactured from sound, hard, durable rock of accepted quality and crushed to specification size. All strata, streaks, and pockets of clay, dirt, sandstone, soft rock, or other unsuitable material accompanying the sound rock shall be discarded and not allowed to enter the crusher.

If the material is to be crushed gravel, it shall consist of hard, durable, fragments of stone or gravel of accepted quality and crushed to specification size. All strata, streaks, and pockets of sand, excessively fine gravel, clay, or other unsuitable material including all stones, rocks, and boulders of inferior quality shall be discarded and not allowed to enter the crusher. The crushing of the gravel shall result in a product in which the material retained on the separate No. 4, 3/8 inch, and 1/2 inch (4.75 mm, 9 mm, and 12 mm) sieves shall have at least 75% of particles with at least one fractured face.

Crushed slag shall be air-cooled, blast furnace slag, reasonably uniform in density and quality, and shall weigh not less than 70 pounds per cubic foot (1.12 mg/cubic meter) as determined by ASTM C 29.

The crushed aggregate shall not contain more than 8%, by weight, of elongated or flat pieces and shall be free from wood, roots, vegetable, organic, or other extraneous matter. The crushed coarse aggregate shall have a percentage of wear not more than 40 at 500 revolutions, as determined by ASTM C 131.

The aggregate shall show no evidence of disintegration or show a total loss greater than 12% when subjected to five cycles of the sodium sulphate accelerated soundness test specified in ASTM C 88.

The crushed aggregate for the applications shall meet the requirements for gradation given in Table 2 when tested in accordance with ASTM C 136.

**TABLE 2. REQUIREMENTS FOR GRADATION OF AGGREGATE**

| Aggregate for first application | |
|---|---|
| Sieve Designation (square openings) | Percentage by Weight Passing Sieves |
| 1 inch (25.0 mm) | 100 |
| 3/4 inch (19.0 mm) | 90-100 |
| 1/2 inch (12.5 mm) | 20-55 |
| 3/8 inch (9.5 mm) | 0-15 |
| No. 4 (4.75 mm) | 0-5 |
| **Aggregate for second application** | |
| Sieve Designation (square openings) | Percentage by Weight Passing Sieves |
| 1/2 inch (12.5 mm) | 100 |
| 3/8 inch (9.5 mm) | 85-100 |
| No. 4 (4.75 mm) | 10-30 |
| No. 8 (2.36 mm) | 0-10 |
| No. 16 (1.18 mm) | 0-5 |
| **Aggregate for third application** | |
| Sieve Designation (square openings) | Percentage by Weight Passing Sieves |
| 3/8 inch (9.5 mm) | 100 |
| 1/4 inch (6.2 mm) | 90-100 |
| No. 4 (4.75 mm) | 60-85 |
| No. 8 (2.36 mm) | 0-25 |
| No. 16 (1.18 mm) | 0-5 |
| No. 200 (0.075 mm) | 0-2 |

The gradations in the table represent the limits that shall determine suitability of aggregate for use for the specified applications from the sources of supply. The final gradations decided on, within the limits designated in the table, shall be uniformly graded from coarse to fine.

The cover aggregate used in the third application shall be a light-colored material whose color and reflectivity shall be approved by the Engineer.

The aggregate to be used shall show no evidence of stripping or swell when tested in accordance with AASHTO T 182. The use of antistrip agents for the control of stripping shall be used if necessary.

609–5.1 **BITUMINOUS MATERIAL.** The types, grades, controlling specifications, and application temperatures for the bituminous materials are shown in Table 3. The Engineer shall designate the specific material to be used.

**TABLE 3. BITUMINOUS MATERIALS**

| Type and Grade | Specification | Spraying Temperature[1] | |
|---|---|---|---|
| | | Deg. F | Deg. C |
| Asphalt Cement | | | |

| | | | |
|---|---|---|---|
| AC 2.5, AC-5 | ASTM D 3381 | 275+ | 135+ |
| AR-1000, 2000 | ASTM D 3381 | 280+ | 140+ |
| 120-150, 200-300 | ASTM D 946 | 270+ | 130+ |
| | | | |
| Emulsified Asphalt | | | |
| RS-1 | ASTM D 977 | 70-140 | 20-60 |
| RS-2 | ASTM D 977 | 125- | 50-80 |
| MS-1, HFMS-1 | ASTM D 977 | 175 | 20-70 |
| CRS-1 | ASTM D 2397 | 70-160 | 50-80 |
| CRS-2 | ASTM D 2397 | 125- | 50-80 |
| | | 175 | |
| | | 125- | |
| | | 175 | |

[1] The maximum temperature for asphalt cements shall be below that at which fogging occurs.

## CONSTRUCTION METHODS

**609-3.1 WEATHER LIMITATIONS.** Bituminous material shall be applied only when the existing surface is dry and the atmospheric temperature is above 60°F (15°C). No material shall be applied when rain is imminent or when dust or sand is blowing.

**609-3.2 OPERATION OF PITS AND QUARRIES.** The aggregate material shall be obtained from sources approved by the engineer. The Contractor shall make all necessary arrangements for obtaining the material, and all work involved in clearing and stripping pits or quarries and handling unsuitable material shall be performed by the Contractor at his/her own expense. The material in the pits shall be handled so that a uniform and satisfactory product shall be secured. Unless otherwise directed, pits shall be adequately drained and shall be left in a neat and presentable condition with all slopes dressed uniformly. Quarries shall be left as neat and presentable as practicable.

**609-3.3 EQUIPMENT AND TOOLS.** The Contractor shall furnish all equipment, tools, and machines necessary for the performance of the work.

**a. Pressure Distributor.** The distributor shall be designed, equipped, maintained, and operated so that bituminous material at even heat may be applied uniformly on variable widths of surface at the specified rate. The allowable variation from the specified rate shall not exceed 10 percent. Distributor equipment shall include a tachometer, pressure gages, volume-measuring devices or a calibrated tank, and a thermometer for measuring temperatures of tank contents. The distributor shall be self-powered and shall be equipped with a power unit for the pump and full circulation spray bars adjustable laterally and vertically.

**b. Aggregate Spreader.** The aggregate spreader shall be a self-propelled mechanical spreader or truck-attached mechanical spreader capable of uniformly distributing aggregate at the specified rates.

**c. Roller.** The roller shall be a pneumatic-tired roller with an effective rolling width of at least 60 inches (152 cm) and capable of exerting a minimum contact pressure of 40 pounds per square inch (280,000 newtons per square meter).

**d. Power Broom.** A power broom and/or blower shall be provided for removing loose material from the surface to be treated.

609–5.1 **PREPARING UNDERLYING COURSE.** The surface of the underlying course shall be prepared, shaped, and conditioned to a uniform grade and section, as shown on the plans and as specified. Loose dirt and other objectionable material shall be removed from the surface.

On those type of bases where a prime coat is required and specified, the prime shall be applied and satisfactorily cured before starting the bituminous surface treatment.

When specified, the Contractor shall be required to patch, with premixed material, any holes or other malformations deviating from the true cross section and grade. The premixed material shall be made of the bituminous material specified in the proposal or plans and prepared by the method as directed by the Engineer. All small patches shall be thoroughly hand tamped while the large patches shall be rolled with a power or pneumatic roller.

**609-3.5 APPLICATION OF BITUMINOUS MATERIAL.** Bituminous material shall be applied upon the properly prepared surface at the rate and temperature specified using a pressure distributor to obtain uniform distribution at all points. To insure proper drainage, the strips shall begin along the centerline of the pavement on a crowned section or on the high side of the pavement with a one-way slope. During all applications, the surfaces of adjacent structures shall be protected in such manner as to prevent their being spattered or marred. Bituminous materials shall not be discharged into borrow pits or gutters or upon the airport area.

609–5.1 **APPLICATION OF AGGREGATE MATERIAL.** Immediately after the application of the bituminous material or when directed, the aggregates at the rate specified for each designated application shall be spread uniformly over the bituminous material. Trucks spreading aggregate shall be operated backward so that the bituminous material will be covered before the truck wheels pass over it. The aggregate shall be spread in the same width of application as the bituminous material and shall not be applied in such thickness as to cause blanketing. Back-spotting or sprinkling of additional aggregate material, and pouring additional bituminous material over areas that show up having insufficient cover or bitumen, shall be done by hand whenever necessary. Additional spreading of aggregate material shall be done by means of a motor-patrol grader equipped with broom moldboard, a broom drag, or a power broom, as directed by the Engineer.

Immediately after spreading each application, the aggregate shall be rolled. The rolling shall be continued until no more aggregate material can be worked into the surface. In the construction of the second and third application, blading with the wire-broom moldboard attachment or broom dragging shall begin as soon as possible after the rolling has started and after the surface has set sufficiently to prevent excessive marking. Further blading and rolling on the strip being placed and on adjacent strips previously placed, shall be done as often as necessary to keep the aggregate material uniformly distributed. These operations shall be continued until the surface is evenly covered and cured to the satisfaction of the Engineer.

Succeeding applications shall not be applied until the preceding application has set and in no case until at least 24 hours have elapsed. If dust, dirt, or other foreign matter accumulates on the surface between the applications, the Contractor shall be required to sweep and clean the surface as specified herein. The bituminous material and the aggregate shall be spread upon the clean and properly cured surface and handled as required. Extreme care shall be taken in all applications to avoid brooming or tracking dirt or any foreign matter on any portion of the pavement surface under construction.

All surplus aggregate from the final application shall be swept off the surface and removed prior to final acceptance of the work.

**609-3.7 CORRECTION OF DEFECTS.** Any defects, such as raveling, low centers, lack of uniformity, or other imperfections caused by faulty workmanship, shall be corrected immediately to the satisfaction of the Engineer.

All defective materials resulting from over-heating, improper handling, or application shall be removed by the Contractor and replaced with approved materials as provided for in these specifications.

**609-3.8 BITUMINOUS MATERIAL CONTRACTOR'S RESPONSIBILITY.** Samples of the bituminous materials that the Contractor proposes to use, together with a statement as to their source and character, shall be submitted and approval obtained before use of such materials begins.

The Contractor shall furnish vendor's certified test reports for each carload, or equivalent, of bitumen shipped to the project. The report shall be delivered to the Engineer before permission is granted for use of the material. The furnishing of the vendor's certified test report for the bituminous material shall not be interpreted as a basis for final acceptance. All such test reports shall be subject to verification by testing sample materials as received for use on the project.

609–5.1 **FREIGHT AND WEIGH BILLS.** Before the final estimate is allowed the Contractor shall file with the Engineer receipted bills where railroad shipments are made, and certified weight bills when materials are received in any other manner, of the bituminous and covering materials actually used in the construction covered by the contract. The Contractor shall not remove bituminous material from the tank car or storage tank until the initial outage and temperature measurements have been taken by the Engineer, nor shall the car or tank be released until the final outage has been taken by the Engineer.

Copies of all freight bills and weigh bills shall be furnished to the Engineer during the progress of the work.

METHOD OF MEASUREMENT

**609-4.1** The bituminous material shall be measured by the **[gallon(liter)][ton (kg)]**. Volume shall be corrected to the volume at 60°F (15°C) in accordance with ASTM D 1250 for cutback asphalt and Table IV-3 of The Asphalt Institute's Manual MS-6 for emulsified asphalt. Water added to emulsified asphalt will not be measured for payment.

**609-4.2** The quantity of aggregate materials for the first application to be paid for shall be the number of tons (kg) of aggregate used for the accepted work.

**609-4.3** The quantity of aggregate material for the second application to be paid for shall be the number of tons (kg) of aggregate used for the accepted work.

**609-4.4** The quantity of aggregate material for the third application to be paid for shall be the number of tons (kg) of aggregate used for the accepted work.

BASIS OF PAYMENT

609–5.1 Payment shall be made at the contract unit price per **[gallon][ton]** for bituminous material for surface treatment and per ton for the first, second and third aggregate application. These prices shall be full compensation for furnishing all materials and for all preparation, hauling and application of the materials, and for all labor, equipment, tools, and incidentals necessary to complete the item.

Payment will be made under:

| | |
|---|---|
| Item P-609-5.1 | Bituminous Material—per **[gallon (liter)][ton (kg)]** |
| Item P-609-5.2 | First Application Aggregate—per ton (kg) |
| Item P-609-5.3 | Second Application Aggregate—per ton (kg) |
| Item P-609-5.4 | Third Application Aggregate—per ton (kg) |

TESTING REQUIREMENTS

| | |
|---|---|
| ASTM C 29 | Unit Weight of Aggregate |
| ASTM C 88 | Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate |
| ASTM C 131 | Resistance to Abrasion of Small Size Coarse Aggregate by Use of the Los Angeles Machine |
| ASTM C 136 | Sieve Analysis of Fine and Coarse Aggregates |
| AASHTO T 182 | Coating and Stripping of Bitumen-Aggregate Mixtures |

MATERIAL REQUIREMENTS

| | |
|---|---|
| ASTM D 946 | Penetration-Graded Asphalt-Cement for Use in Pavement Construction |
| ASTM D 977 | Emulsified Asphalt |
| ASTM D 1250 | Petroleum Measurement Tables |
| ASTM D 2397 | Cationic Emulsified Asphalt |
| ASTM D 3381 | Viscosity-Graded Asphalt-Cement for Use in Pavement Construction |
| Asphalt Institute Manual MS-6 Table IV-3 | Asphalt Pocketbook of Useful Information (Temperature-Volume Corrections for Emulsified Asphalts) |

END OF ITEM P-609