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An Introduction to Hot Mix Asphalt Spray and Surface Applications

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1. SPRAY APPLICATIONS.

1.1 GENERAL. Spray application is a term used to describe many different types of asphalt applications. More maintenance and repair work for flexible pavements is accomplished by spray applications of an asphalt material than by any other technique. When properly constructed, asphalt spray applications are economical as well as long lasting and are beneficial in treating or improving the pavement condition and increasing the life of the pavement. Where additional thickness is needed to increase the structural strength of pavements, spray applications are of little help because they contribute little to the structural strength. The different types of spray applications to be discussed in detail in here are as follows:

- Prime coats.
- Tack coats.
- Fog seals and rejuvenators

1.2 PRIME COAT.

1.2.1 GENERAL. Asphalt prime coat consists of a low-viscosity liquid asphalt material applied by a pressure distributor to an unbound base course before placement of a hot-mix asphalt pavement. The purposes of the prime coat are to prevent lateral movement of the unbound base during pavement construction; to waterproof during pavement construction; and to form a tight, tough base to which an asphalt pavement will adhere. To accomplish these purposes, the prime material must penetrate into the unbound base and fill the void spaces. A completed unbound base is susceptible to serious damage from rain, wind, and traffic. An adequate prime coat is insurance against this water and traffic damage. Prime coat material should be applied to a dust-free unbound base as soon as the base has been thoroughly compacted and before construction or other traffic loosens surface material in the compacted base. Sufficient time should be allowed to permit prime material to penetrate thoroughly into the compacted base. In instances where construction of an asphalt layer is to follow in less than seven days upon

completion of base course compaction, the application of a prime coat may be omitted. When construction of an asphalt layer will not occur for at least seven days, the compacted base will be primed. Whether the compacted base is primed or not, the contractor should take steps to protect the surface from any damage (water, traffic, etc.) until an asphalt layer is placed. Generally, it will take several days for a prime coat to properly cure and withstand construction traffic and cool or wet weather may further increase the time required. Construction traffic on an uncured or improperly aged prime coat can cause more base movement than construction on an unprimed base. Local conditions, local experience, type of base material, and the type of prime coat material available should all be considered when deciding on the application of a prime coat.

1.2.2 MATERIALS.

1.2.2.1 LOW-VISCOSITY ASPHALT material should be used as prime material, but the selection of type and grade must be given special consideration. Some items to consider in selecting the priming material are as follows:

- Air temperature.
- Humidity.
- Void content of base course
- Curing time of prime material.
- Environmental restrictions.
- Available materials.

1.2.2.2 THE RECOMMENDED PRIMING materials are emulsified asphalts and cutback (liquid) asphalt. The recommended types and grades are shown in Table 1.

Type	Grade
Cutback	SC-70
	SC-250
	MC-30
	MC-70
	MC-250
	RC-70
Emulsion	RC-250
	SS-1
	SS-1h
	CSS-1
Emulsion	CSS-1h

Type	Grade
Cutback	SC-70
	SC-250
	MC-30
	MC-70
	MC-250
	RC-70
Emulsion	RC-250
	SS-1
	SS-1h
	CSS-1
Emulsion	CSS-1h

Table 1
Prime coat materials

1.2.2.3 A PRIME COAT can only work if it penetrates into the base course. Open-textured (high-void content) bases can be primed easily, but a tight surface (low voids) cannot be readily penetrated. In cases of low voids the less viscous cutbacks such as RC-70, MC-30, MC-70, and SC-70 should be considered. If penetration does not occur, an asphalt film will be left on the surface of the base causing slippage of the bituminous surface during and after construction. Caution should also be urged in using RC-70 or RC-250 because the solvent in the cutback may evaporate rapidly or be absorbed by the basecourse fines and leave an asphalt film deposited on the surface. Undiluted emulsions can also cause asphalt film problems if the base-course surface is tight.

1.2.2.4 WEATHER CAN influence the choice of the correct priming materials. Since emulsions are dependent on the evaporation of water for curing, low temperature or high humidity can slow or stop the curing process. Cutbacks are not as dependent on weather conditions as emulsions. In cold weather, however, the rapid curing cutbacks (RC's) may perform better than the slower curing cutbacks (MC's and SC's).

1.2.2.5 ENVIRONMENTAL RESTRICTIONS have begun to limit the types of prime coat materials that are available in some areas of the United States. As a result, some cutback asphalts are not available for priming. Therefore, asphalt emulsion primes are becoming more numerous. Asphalt emulsions must be diluted with water before being applied as a prime, and special handling and storage considerations to prevent freezing, settling, and breaking must be exercised.

1.2.3 APPLICATION RATE. Prime coats are usually applied in quantities of 0.38 to 1.13 liters per square meter (0.10 to 0.25 gallons per square yard) of residual asphalt. The optimum amount of prime is highly dependent on the plasticity index of the base material, the amount of fines in the base, the nature of fines, the tightness of the surface, and the moisture content of the base. Therefore, the optimum amount of prime required should be determined by field trial. Test sections at various application rates are recommended for determining the optimum amount of prime. After 48 hours of curing, if there is free or excess bitumen on the surface or if the base continues to appear shiny, the base is probably overprimed. Generally, most of the prime should be absorbed into the base within 2 to 3 hours. When excessive prime is used, the surplus can be absorbed into the overlying asphalt layers. In turn, the absorption of the excess may contribute to pavement slippage or rutting. Where excessive prime is applied, the excess must be blotted with an application of clean fine sand or mineral dust. The ideal end result is to obtain maximum penetration without leaving free prime on the surface.

1.2.4 PLACEMENT. Surfaces to be primed which contain appreciable amounts of loose material or are dusty should be lightly broomed. A dusty surface will sometimes cause prime to “freckle,” that is, have small areas with no prime and adjacent areas with drops of excess prime. A light application of water just before applying the prime will aid in reducing “freckles” and getting good distribution of the prime. Priming should be uniformly applied with a pressure distributor at the required application rate and at the proper temperature for the asphalt used. Minimum curing time will vary according to the grade and type of asphalt being used, the nature of the base, temperature, and humidity, but generally curing should take place within 48 hours.

1.2.5 CONTROL. Since most prime is applied with a pressure distributor, the distributor must be calibrated and checked for the specified application rate before applying the prime. ASTM D 2995 offers a method for determining the application rate of bituminous distributors. In addition, all nozzles should be free and open, the same size, and to the same angle in reference to the spray bar to produce a uniform fan of prime. The height of the spray bar above the surface is important because a bar too high or too low will give an unequal application in the middle of the spray fan and at the ends, causing streaking. The height of the spray bar should be such that a double or triple lap of the spray fan is obtained.

1.3 TACK COAT.

1.3.1 GENERAL. A tack coat is a light application of an asphalt material to an existing pavement or asphalt base course immediately prior to placing the next pavement layer or course. The purpose of the tack coat is to provide a bond between the two pavement layers. The tack coat is applied by pressure distributor to cleaned surfaces. The tack coat must be applied in a light and uniform application.

1.3.2 MATERIALS.

1.3.2.1 EMULSIONS are the most common types of asphalt material used as tack, but cutbacks and asphalt cements may be used in some situations. The correct spraying viscosities (temperatures) need to be obtained for the type of material used. Recommended tack coat materials and spray application temperatures are shown in Table 2.

1.3.2.2 THE CUTBACKS AND emulsions can be sprayed at relatively low temperatures, but the asphalt cements may require considerable heating to reach a viscosity suitable for spraying.

1.3.2.3 IN COLD weather, the cutbacks can be used with less concern than emulsions which contain water. However, environmental restrictions limit the use of cutback materials, making them unavailable at many locations. The use of emulsions for tack coats may require that the emulsion be diluted with water so that a light tack is applied, and its use also requires that special consideration be given to weather conditions, storage and handling requirements, and curing time. All tack coats should be cured before placing the new pavement layer.

1.3.3 APPLICATION RATE. Tack coats are usually applied in quantities of 0.23 to 0.68 liters per square meter (0.05 to 0.15 gallons per square yard) of residual asphalt, but the exact quantities should be adjusted to suit field conditions. Light applications are preferred since heavy applications can cause serious pavement slippage and bleeding problems. However, failure to use any tack coat can also cause pavement slippage problems.

1.3.4 PLACEMENT. Tack coats should be applied to clean, dust free asphalt pavement courses prior to placement of the overlying pavement layer. The tack coat should be applied immediately before placement; therefore, unless an asphalt cement is used, the tack coat must be allowed time to cure. A tack coat may be required on a base course when the prime coat on that surface has been subjected to construction traffic or other traffic. A pressure distributor should be used to apply tack coats at an application temperature which will produce a viscosity between 10 and 60 seconds, Saybolt furol, or between 20 and 120 centistokes, kinematic viscosity. The suggested spray application temperatures in degrees Fahrenheit for tack coat materials are shown in Table 2. When an even or uniform coating is not obtained, an improved coverage may be possible by making several passes over the freshly applied tack coat with a pneumatic-tired roller. The tack coat should be completely cured (volatiles or water evaporated) before the overlying layer is placed. A properly cured surface will feel tacky. Work should be planned so that no more tack coat than is necessary for one day of operation is placed on the surface. All nonessential traffic should be kept off the tack coat so that dust, mud, or sand will not be tracked onto the surface.

Type	Grade	Application Temperature °F
Cutback	RC-70	120-200
	RC-250	165-250
Emulsion	RS-1	70-140
	MS-1	70-160
	HFMS-1	70-160
	SS-1	70-160
	SS-1h	70-160
	CRS-1	125-185
	CSS-1	70-160
	CSS-1h	70-160
Asphalt cement	200-300 pen	265 +
	120-150 pen	270 +
	85-100 pen	280 +
	AC-2.5	270 +
	AC-5	280 +
	AC-10	280 +
	AR-1000	275 +
	AR-2000	285 +
	AR-4000	290 +

Table 2

Tack coat materials and spray application temperatures

1.3.5 CONTROL. To insure that the tack coat is applied as specified, the asphalt distributor should be calibrated and inspected. ASTM D 2995 offers a method for determining the application rate of asphalt distributors. In addition, all nozzles must be free and open, the same size, and at the same angle in reference to the spray bar to produce a uniform spray of tack. Spray bar height above the surface is also important for uniform application. A bar too high or too low will give a variable application in the middle and at the edges. The spray bar should be adjusted to a height that provides a double or triple lap.

1.4 FOG SEALS.

1.4.1 GENERAL. A fog seal is a very light spray application of a diluted emulsified asphalt to an existing asphalt pavement surface. The fog seal is used to maintain old pavements, reduce raveling, waterproof, and in general, extend the life of the existing pavement. Fog

seals are especially good for treating pavements which carry little or no traffic. However, there are several considerations when using fog seals.

- The pavement skid resistance can be reduced.
- The pavement air voids or permeability can be reduced.
- The pavement should be closed to traffic for 12 to 24 hours to allow for proper cure of the seal material.

1.4.2 MATERIALS. In the past, asphalt emulsions and some cutbacks were used for fog seals, but in recent years the materials used are emulsions and rejuvenators. The emulsions most often used are SS-1, SS-1h, CSS-1, and CSS-1h. There are several products marketed as rejuvenators, they are proprietary products.

1.4.3 APPLICATION RATE.

1.4.3.1 THE PROPER application and dilution rate for fog seal will vary with the absorption characteristics of the existing pavement surface. Field test sections should be placed to determine the best application rate for the existing pavement. The application rate should be adjusted so that the pavement does not become slick or unstable nor have an excess of free material on the surface after curing 12 to 24 hours.

1.4.3.2 THE AMOUNT OF DILUTION must be evaluated for each job. Asphalt emulsion can be applied at full strength or can be diluted as much as 1 part emulsion to 10 parts water. Normal application dilution is in the range of 1 to 4 parts water. When highly diluted fog seals are used, a small amount of surface residue is obtained and the skid resistance is slightly reduced.

1.4.4 PLACEMENT. Only a pressure distributor which has been calibrated to deliver the fog seal at the specified rate should be used to apply the seal material. All surfaces to which the seal is applied must be clean. The fog seal should be applied when the ambient temperature is above 4.5 °C (40 °F), but warmer temperatures are desired because the

material will break and cure faster. The seal material may be applied to a damp pavement if the dilution material is water, but the pavement must not be too wet or the seal will not break properly and will not penetrate into the pavement. Excess seal left on the surface must be blotted with clean sand and broomed.

1.5 REJUVENATION.

1.5.1 GENERAL. Rejuvenation is the spray application of a material on an asphalt surface for the purpose of rejuvenating an aged asphalt cement binder. This rejuvenation is intended to extend the life of the asphalt pavement by softening or rejuvenating the surface asphalt toward the properties it had shortly after construction. Rejuvenators are spray applied to the pavement surface and allowed to penetrate into the pavement.

1.5.2 MATERIALS. Rejuvenators are not generally specified by ASTM or any other organization. The various rejuvenators available are proprietary products. Fog spray applications of emulsified asphalt cannot be considered to act as rejuvenators.

1.5.3 APPLICATION RATE. The rate of application will vary greatly with the condition of the pavement surface. Dry, oxidized, and open textured pavements will absorb the most material and will be able to absorb the highest amount of rejuvenator. The application rate used should be the amount of material that can be absorbed within 12 to 24 hours of application depending on the trafficking needs of the rejuvenated pavement. Manufacturer's recommendations concerning dilution and other factors must be followed.

1.5.4 PLACEMENT. Prior to placement of the rejuvenator the pavement surface shall be thoroughly cleaned of all loose material. Rejuvenators are usually placed with an asphalt distributor truck. Manufacturer recommendations concerning application temperature and dilution of the material should be followed. Areas with excess material should be blotted with clean sand and broomed. Rejuvenators can reduce the skid resistance of treated pavement surfaces. Any excess material not removed will reduce skid resistance.

1.5.5 CONTROL. The asphalt distributor should be calibrated and checked according to ASTM D 2995. Test sections should be done on small sections of the pavement to be rejuvenated to test various application rates and function of the distribution equipment.

2. SURFACE TREATMENTS

2.1 GENERAL. Surface treatments consist of a thin layer of aggregate cemented together with an asphalt (bituminous) material. Surface treatments are widely used because of their low cost and usefulness in light to medium traffic roadways and parking areas. These treatments are normally used to seal or waterproof the pavement, provide wear resistance, and increase skid resistance. All surface treatments are relatively thin coatings of material and do not add structurally to the pavement.

2.2 SINGLE AND DOUBLE BITUMINOUS SURFACE TREATMENTS.

2.2.1 GENERAL. A single bituminous surface treatment (SBST) consists of an application of bituminous material on a prepared surface followed immediately by a single layer of cover aggregate. Chip seal is a commonly used term for the same process. Double bituminous surface treatment (DBST) is similar to a SBST except that two applications of bitumen and cover aggregate are used. The first application of aggregate uses a coarser aggregate than the second application and usually determines the DBST thickness. The second application of aggregate partially fills the surface voids and keys into the aggregate in the first aggregate course. SBST's and DBST's are used on prepared base courses and on new or old pavements. The DBST's and more additional layers (third or more) are used to provide greater wearing resistance and some structural strength (minimal).

2.2.2 MATERIALS.

2.2.2.1 BINDER.

2.2.2.1.1 THE FUNCTIONS of the asphalt binder are to hold the aggregate in place, bond it to the underlying surface, and seal the underlying surface to prevent the entrance of moisture and air. The binders specified for SBST and DBST are cutback asphalts,

emulsified asphalts, and asphalt cements. The types and grades are shown in Table 3. ASTM D 1369 also provides a list of binder materials.

2.2.2.1.2 THE TYPE AND GRADE of binder must be carefully selected. Some items to consider are as follows:

- Climatic conditions.
- Curing time of binder.
- Environmental restrictions.
- Available materials.
- Temperature of surface.
- Condition of surface.
- Condition of aggregate.

2.2.2.1.3 HISTORICALLY, rapid curing cutback asphalts were used for surface treatments. RC-250 was used when cooler temperatures were anticipated, and RC-3000 when very warm temperatures were anticipated. Currently, environmental requirements limit the availability of cutback asphalts, and as a result, emulsified asphalt binders are the most widely used binder.

2.2.2.1.4 EMULSIONS REQUIRE some special handling and storage considerations to prevent freezing, settling, and premature breaking, but they can be applied with little or no additional heating. In selecting the type of emulsion, the compatibility of the aggregate and emulsion must be considered. As a general rule, anionic emulsions adhere better to limestones and other aggregates composed of predominantly calcium minerals. Cationic emulsions generally adhere better to aggregates high in silica, such as chert and quartz gravels. Cationic and anionic emulsions both adhere well to damp aggregates.

Type	Grade
Cutback	RC-250
	RC-800
	RC-3000
Emulsion	RS-1
	RS-2
	CRS-1
	CRS-2
Asphalt cement	120-150 pen
	200-300 pen
	AC-2.5
	AC-5

Table 3
Surface Treatment Asphalt Materials

2.2.2.1.5 ASPHALT CEMENTS harden quickly so that the cover aggregate is held in place better than other binders provided the asphalt cement does not chill before the cover aggregate is applied. Chilling of the binder before applying the aggregate is one major disadvantage with asphalt cement binders. To insure good bond, the aggregates are often heated when asphalt cements are used. Another disadvantage with the use of asphalt cements is the high amount of heat required for spraying. Because of the difficulties encountered with asphalt cements, cutbacks or emulsions instead of asphalt cement should be carefully considered.

2.2.2.2 AGGREGATES.

2.2.2.2.1 THE AGGREGATE will have an effect on the degree of wear resistance, riding quality, and skid resistance of the surface treatment. Only clean, dry aggregate fragments, free from dust or dried films of harmful material, should be used. The aggregate should have a single-size (uniform) gradation and it should be composed of hard, angular, polish-resistant material. Flat and elongated aggregate particles and wet or dusty aggregates are not used. Small quantities of moisture up to about 1 percent do not create a problem, especially in warm weather, but dust can prevent the adhesion of the binder to the aggregate. When an emulsion is used as the binder, aggregate with up

to 3 percent moisture may be used. ASTM D 1139 offers additional physical requirements for aggregates to be used in surface treatments.

2.2.2.2 TABLES 4 and 5 give the recommended aggregate gradations for SBST and DBST, respectively. The correlating size number designation from ASTM D 448 is also given. For DBST, gradation Nos. 1 and 2 and gradation Nos. 3 and 4 from Table 4-3 will be used in combination.

Sieve Size	Percent Passing by Weight, Gradation Designation		
	No. 1 (No. 6 ¹)	No. 2 (No. 7 ¹)	No. 3 (No. 8 ¹)
25 mm (1 inch)	100	--	--
19 mm (3/4 inch)	90-100	100	--
12.7 mm (1/2 inch)	20-55	90-100	100
9.5 mm (3/8 inch)	0-15	40-70	85-100
4.75 mm (No. 4)	0-5	0-15	10-30
2.36 mm (No. 8)	–	0-5	0-10
1.18 mm (No. 16)	–	–	0-5

¹ Number size designations from ASTM D 448.

Table 4
Gradations for SBST

Sieve Size	Percent Passing by Weight, Gradation Designation			
	No. 1 (No. 6 ¹) (First Spreading)	No. 2 (No. 8 ¹) (Second Spreading)	No. 3 (No. 7 ¹) (First Spreading)	No. 4 (No. 9 ¹) (Second Spreading)
25 mm (1 inch)	100	--	--	--
19 mm (3/4 inch)	90-100	--	100	--
12.7 mm (1/2 inch)	20-55	100	90-100	--
9.5 mm (3/8 inch)	0-15	85-100	40-70	100
4.75 mm (No. 4)	0-5	10-30	0-15	85-100
2.36 mm (No. 8)	--	0-10	0-5	10-40
1.18 mm (No. 16)	--	0-5	--	0-10
300 m (No. 50)	--	--	--	0-5

¹ Number size designation from ASTM D 448.

Table 5
Gradations for DBST

2.2.3 DESIGN. The type and amount of aggregate and bitumen to be used for surface treatments can be determined in accordance with ASTM D 1369. This practice provides guidance on typical rates of aggregate and bitumen for the various types of surface treatments. Various other ASTM standards that are applicable for measuring both bituminous and aggregate quantities are given. The standard lists recommended grades of various asphalt and tar materials for use with surface treatments. Similar guidance is also available in the Asphalt Institute publications: ES-11 “Asphalt Surface Treatments-Specifications” and ES-12 “Asphalt Surface Treatments-Construction Techniques.”

2.2.4 CONSTRUCTION.

2.2.4.1 PLACEMENT. Field construction practices can determine the success or failure of a well designed surface treatment; therefore, proper equipment, surface preparation, and construction techniques are very important.

2.2.4.2 EQUIPMENT. Among the equipment used in placing a surface treatment, the most important are the asphalt distributor and the aggregate spreader. Aggregate spreaders are used during the construction of bituminous surface treatments to apply the

aggregate to the surface being treated. The spreader should be designed and calibrated to apply a predetermined amount of aggregate uniformly over the surface. Some of the aggregate spreaders are self-propelled, while others are propelled by the truck hauling the aggregate. The self-propelled aggregate spreaders are desirable because they allow for a more uniform application of material and a smoother operation. Calibration and proper operation of the distributor and aggregate spreader should be insured.

2.2.4.3 SURFACE PREPARATION. Without proper surface preparation the life expectancy of a pavement will be reduced. Therefore, all soft or failed areas must be repaired and all loose material, dirt, and vegetation must be removed prior to placing the surface treatment. A bleeding surface may require either sanding or removal before construction of the surface treatment.

2.2.4.4 APPLICATION.

2.2.4.4.1 SPECIAL ATTENTION must be given to the application rates of both binder and aggregate. Field adjustments to the design application rates may be necessary. Too much binder will cause bleeding or low skid resistance, and too little binder will result in the loss of cover aggregate. Although there should be about 5 to 10 percent excess aggregate, too much aggregate will result in a waste of materials and damage to windshields.

2.2.4.4.2 THE AGGREGATE must be applied immediately after the binder application in order to obtain a good bond between asphalt and aggregate. Rolling with a rubber-tired roller immediately after applying the aggregate will seat the aggregate in the binder and improve the bond.

2.2.4.5 CONTROL.

2.2.4.5.1 SINCE THE DISTRIBUTOR and aggregate spreader are important for the successful application of materials, they must be calibrated and checked to insure that

the specified application rate is obtained. ASTM D 2995 offers a method for determining the application rate of asphalt (bituminous) distributors. In addition, all nozzles should be free and open, the same size, and at the same angle with reference to the spray bar to produce a uniform fan of asphalt. The height of the spray bar above the surface is important. A bar too high or too low will produce a variable application in the middle and at the ends, causing streaking. The height of the spray bar should be such that a double or triple lap of the spray fan is obtained. ASTM D 5624 offers a method for determining the application rate of aggregate transversely across the width of the spreader.

2.2.4.5.2 A TEST SECTION is another method to evaluate the construction techniques and the application rates required for surface treatment. At least one test section should be constructed before allowing surface treatment applications on a full scale.

2.3 SLURRY SEAL.

2.3.1 GENERAL. A slurry seal is a mixture of asphalt emulsion, well-graded fine aggregate, water, and mineral filler. These materials are combined in the proper proportions to produce a homogeneous, fluid like slurry. The consistency of the slurry must be such that it can be squeegeed over an existing pavement surface. A thick, sealed surface results after evaporation of the water and curing of the mix. When properly designed, constructed, and cured, the slurry seal should improve the qualities of an existing pavement surface, but the structural strength of the pavement structure is not significantly improved. Slurry seals are used to protect worn, weathered, or cracked pavements from the adverse effects of weather conditions and traffic wear. With proper use of aggregates, the slurry seal can also be used to reduce skid or slipperiness problems. Slurry seals have application to roads and streets, parking lots, and bridge decks. This type of seal coat is best suited for pavements that are not subjected to heavy traffic. Because aircraft can cause a rapid deterioration of the slurry seal, slurry seals should not be applied to airfields.

2.3.2 EQUIPMENT. Various types of equipment are needed on a slurry seal project, but the basic pieces of equipment required include a truck-mounted continuous-mix slurry machine, spreader box, power broom, front-end loader, distributor, and pneumatic-tired roller. The truck-mounted continuous mix slurry machine which serves as a portable mixing plant is the most important piece of equipment. It is the only type of mixing equipment recommended for mixing a slurry seal. A slurry seal machine is used to mix aggregate, filler, asphalt emulsion, and water in the correct proportions and to uniformly apply the material to the surface to be sealed. The slurry seal machine generally contains storage for the aggregate, filler, emulsion, and water. Before the machine is used, it must be calibrated and set to deliver the job materials in the correct proportions. The machine manufacturer's instructions usually offer the best guidance for calibrating the slurry machine. However, a calibration method based on a revolution counter is applicable to all machines. By attaching a revolution counter to any shaft that is mechanically interlocked with the emulsion pump, water pump, fines feeder, and aggregate conveyor, the relative quantities of each of these components per revolution can be determined for various gate openings, metering valve openings, or sprocket sizes. The materials are mixed and deposited into a squeegee box, which applies the slurry seal onto the surface at a thickness approximately equal to the maximum aggregate size.

2.3.3 MATERIAL REQUIREMENTS.

2.3.3.1 EMULSION. The binder used in a slurry seal is asphalt emulsion. The emulsion is often either slow-set anionic (SS-1 or SS-1h) or slow-set cationic (CSS-1 or CSS-1h). The slow-set emulsions are best suited for slurry seals, but some quick-set emulsions are specifically designed for slurry seal. The use of quick-set emulsions requires that an experienced slurry seal contractor perform the job because of the small amount of time available for handling the slurry seal before it cures. Slow-set cationic emulsions cure faster than slow-set anionic emulsions because the curing process is partly a chemical reaction that expels some of the water from the mix. Anionic emulsions cure primarily by evaporation of the water from the mix; therefore, they are greatly influenced by weather conditions. Low temperatures, high humidity, or rain can slow or stop the curing process.

Sometimes an emulsion will break, that is, the asphalt will separate from the water upon contact with certain types of aggregates. If a break occurs, either the emulsion or aggregate type must be changed.

2.3.3.2 AGGREGATE.

2.3.3.2.1 GENERAL The aggregate as well as the emulsion used in a slurry seal should be given close attention. All aggregates must be clean, and the particles should be crushed to produce an angular shape. Aggregates that contain plastic fines should not be used. These fines absorb excessive amounts of emulsion, leaving inadequate amounts of binder on the remaining aggregate. The fines also promote low-wear characteristics and premature break of the emulsion. Better performance can be expected from slurry seals that are produced using crushed aggregate. Furthermore, natural sands such as dune, river, and beach sands, and other rounded aggregates tend to have poor skid resistance and wear characteristics and therefore should not be used in slurry seal coatings.

2.3.3.2.2 GRADATIONS FOR AGGREGATES. The aggregates should be dense graded so that the particles will lock themselves together. Table 6 shows the gradations for use with slurry seals. Gradation type 1 is normally used for filling and sealing cracks in a pavement surface and it will provide a thin wearing surface. Gradation type 2 is probably the most generally used, and is used to fill voids, correct moderate surface irregularities, seal small cracks, and provide a wearing surface for traffic. Aggregate gradation type 3 assures a thicker seal and provides a coarser surface texture. This gradation might be used as the first course in a two-course slurry seal surface treatment.

Sieve Size	Percent Passing		
	Type 1	Type 2	Type 3
9.5 mm (3/8 inch)	–	100	100
4.75 mm (No. 4)	100	90-100	70-90
2.36 mm (No. 8)	90-100	65-90	45-70
1.18 mm (No. 16)	65-90	45-70	28-50
600 μ m (No. 30)	40-65	30-50	19-34
300 μ m (No. 50)	25-42	18-30	12-25
150 μ m (No. 100)	15-30	10-21	7-18
75 μ m (No. 200)	10-20	5-15	5-15

Table 6
Slurry seal aggregate gradations

2.3.3.2.3 MINERAL FILLER. When stability or segregation problems occur, mineral filler at a rate of 0.5 to 4.0 percent by weight of the total mixture may be required to overcome the problem. When mineral filler is needed, portland cement or hydrated lime is most often used in slurry seals. The filler is used to improve the mix stability, that is, suspend heavier aggregate particles throughout the slurry seal mixture; to reduce segregation of materials; and to meet gradation requirements. Care should be taken to insure that the fines content, including mineral filler, does not exceed the gradation limits. Excessive fines or mineral filler can cause shrinkage cracking to occur in the seal coat.

2.3.3.2.4 WATER. Water controls the workability of the slurry seal mixture. The mixture should contain enough water to produce a smooth, creamy, homogeneous fluid like appearance. If too much water is used, the resultant mixture will be soupy, and segregation or bleeding of the mixture will occur. On the other hand, if not enough water is used, the slurry mixture will be stiff and will neither spread smoothly nor perform satisfactorily. Only potable water should be used in a slurry seal mixture.

2.3.4 DESIGN. The method of developing a JMF for slurry seals selects the optimum asphalt content based on a desired film thickness of asphalt and the absorption characteristics of the aggregate. The water and mineral filler content requirements are determined by a cone test, and the wear characteristics are determined by the Wet Track

Abrasion Test as described in ASTM D 3910. The method is intended to furnish a starting point for field application. Slight adjustments may be required in the proportions of the mixture to satisfy field conditions; however, a field test section should be constructed using the laboratory developed JMF.

2.3.5. FACTORS AFFECTING DESIGN. Some important factors that should be considered before using a slurry seal are as follows:

2.3.5.1 THE COST OF placing a slurry seal is relatively small, but this mixture does not provide additional strength to the pavement and does wear rapidly under a high volume of traffic.

2.3.5.2 SLURRY SEAL will fill and seal many surface cracks.

2.3.5.3 SLURRY SEAL CAN BE used to seal a pavement surface to retard oxidation and raveling or to provide a thin (6 millimeter, 1/4-inch) wearing surface.

2.3.5.4 SKID RESISTANCE can be improved if the proper crushed aggregates are used in the mix.

2.3.5.5 UNCURED SLURRY seal can be adversely affected by changes in weather conditions.

2.3.5.6 A TREATED PAVEMENT must be closed to traffic to allow the slurry seal to cure (sometimes as long as 24 hours, but usually 6 hours).

2.3.5.7 SLURRY SEAL is better suited for a pavement subjected to low or moderate traffic because heavy traffic can cause a rapid deterioration of the thin layer.

2.3.5.8 ONLY STRUCTURALLY SOUND PAVEMENTS are suited for a slurry seal.

2.3.5.9 PROPER DESIGN and application are very important for obtaining a satisfactory job.

2.3.5.10 GENERALLY, slurry seals have a 2- to 5-year life.

2.3.5.11 A PROPERLY PLACED SLURRY SEAL will fill small cracks and coat the surface of the pavement to a depth of 3 to 6 millimeters (1/8 to 1/4 inch).

2.3.6 SURFACE PREPARATION. Without proper surface preparation, the life expectancy of a slurry seal surface is reduced. All loose material (including loose or flaky paint), dirt, and vegetation should be removed. Cracks wider than 3 millimeters (1/8 inch) should be treated before applying the seal coat. After the surface is cleaned, a light tack coat should be applied to improve the bond and to reduce the asphalt absorption of the old surface.

2.3.7 APPLICATION. Surface texture of the fresh slurry seal will be affected by the condition of the flexible lining of the spreader box, fragments of cured slurry adhering to the edges of the lining or to the squeegee, and the condition of the burlap drag. Worn lining will result in an uneven thickness of the seal coat. Fragments of cured slurry seal or large aggregate particles caught in the lining will produce gouges and streaks. The burlap drag should be washed or replaced as needed to insure that accumulations or crusts of mix do not cause scars or streaks. The mesh basket screen that is hung at the end of the discharge chute should be emptied and cleaned as required. The slurry seal should be checked for lumps or balling which can be caused by inadequate mixing or premature break of the asphalt emulsion. Deviation of the mix from the specified gradation may also result in an unsatisfactory product.

2.3.7.1 JOINTS. Whenever possible, joints should be made while the slurry-seal mixture applied in the first pass is still semifluid and workable. If operations preclude fresh working joints, the previously laid pass must be allowed to set and cure sufficiently to support the spreader box without scarring, tearing, or being scraped from the pavement surface.

2.3.7.2 HAND APPLICATION. Close attention should be given to spreading of the slurry-seal mixture by hand squeegee. Overworking will sometimes cause partial breaking of the emulsion before the final spreading is completed which results in a non-uniform material that will have poor appearance and durability.

2.3.8 CURING. Slurry seals, depending upon the emulsion characteristics in relation to the aggregate with which it is used, may cure primarily by evaporation of water from the surface, by deposition of asphalt on the aggregate which frees the water, or by a combination of both. If curing is from the surface downward, the surface may present a cured appearance but the material below may be uncured. Thorough curing of the slurry seal must be assured before traffic is permitted.

2.3.9 ROLLING. Rolling is advantageous in reducing voids in the slurry seal, smoothing out surface irregularities, and increasing the resistance to water. Rolling should begin as soon as the slurry seal has cured enough to support the roller without any pickup of the slurry seal mixture. A rubber-tired roller should be used for rolling the slurry seal mixture.

2.4 FUEL-RESISTANT SEALER.

2.4.1 GENERAL. Fuel-resistant sealer (FRS) material is a combination of coal-tar emulsion, fine aggregate, water, and occasionally other additives. These materials are mixed in batches and applied to hot-mix asphalt surfaces by hand or mechanical squeegees. The coal-tar emulsion binder provides a fuel-resistant surface and the fine aggregate provides suitable skid resistance. The FRS is placed in thin layers usually around 2 millimeters (1/16 inch) or less. Particle size will affect the minimum thickness that can be applied by squeegee. A FRS will not significantly enhance the structural strength of the pavement structure.

2.4.2 AREAS OF APPLICATION. FRS should be applied to any hot-mix asphalt surface subjected to fuel drippage or spillage. This includes vehicle maintenance and parking areas.

2.4.3 CONSIDERATIONS FOR USE. Some important factors that should be considered before using a FRS.

2.4.3.1 FRS SHOULD ONLY be used where a fuel-resistant surface is required.

2.4.3.2 FRS'S GENERALLY do not have as long a service life as surface treatments with asphalt cement binder, but they may last up to 4 years or more depending on traffic and climate conditions.

2.4.3.3 PARKING AREAS with low vehicle turnover or low usage (therefore lower instances of fuel spillage) rates may be better served with a single or double bituminous surface treatment or a slurry seal.

2.4.3.4 FRS'S WILL PROVIDE a seal to protect the underlying hot-mix asphalt pavement to retard oxidation and weathering.

2.4.3.5 THE PAVEMENT must be closed to traffic during the curing of FRS layers (usually 4 to 8 hours).

2.4.3.6 UNCURED FRS can be adversely affected by changes in weather conditions such as rain or freezing temperatures.

2.4.3.7 ONLY STRUCTURALLY sound pavements are suited for a FRS.

2.4.3.8 PROPER MIXTURE DESIGN and application are very important for obtaining a satisfactory job.

2.4.4 MATERIAL REQUIREMENTS.

2.4.4.1 COAL-TAR EMULSION. The binder material used in a fuel-resistant sealer is a coal tar emulsion. The coal tar emulsion is usually specified as having to meet the requirements of ASTM D 5727.

2.4.4.2 AGGREGATES. Aggregates shall be either natural or manufactured angular aggregate. The aggregate shall be clean and free of organic and other objectionable material. The aggregate shall meet the gradation requirements as given in Table 7.

Gradation Type	Coarse	Medium	Fine
Minimum Application Rate, L/m ² (gal/yd ²)	1.35 (0.3)	1.0 (0.22)	0.72 (0.16)
Sieve Size			
2.36 mm (No. 8)	100	100	100
1.18 mm (No. 16)	98-100	100	100
(No. 20)	85-100	98-100	100
600 μ (No. 30)	25-90	85-100	98-100
(No. 40)	5-30	30-90	85-100
300 μ (No. 50)	2-10	8-35	35-90
(No. 70)	0-4	3-11	10-40
150 μ (No. 100)	0-2	0-4	4-12
(No. 140)	--	0-2	0-4
75 μ (No. 200)	--	--	0-2

Table 7

Fuel resistant sealer minimum application rates and corresponding aggregate gradations

2.4.4.3 WATER. Only potable water shall be used in a FRS mixture. The amount of water required shall be determined from laboratory testing prior to construction. A small amount of additional water may be required under very high temperature pavement conditions.

2.4.4.4 ADDITIVES. Additives sometimes used in FRS's include various types of polymer and silicon materials. These materials may be added to the FRS mixture in the field or added to the coal-tar emulsion during the emulsifying process. The polymer materials most often used are latex combinations of acrylonitrile and butadiene.

2.4.4.5 DESIGN.

2.4.4.5.1 GENERAL. The design of FRS mixtures has historically been based on the selection of materials (sand, water, and additives) from an allowable range based on a per gallon of coal-tar emulsion. The current guide specification requires that the final FRS mixture developed be required to meet several test requirements. The tests include curing time, resistance to heat, resistance to water, resistance to kerosene, stiffness, and viscosity.

2.4.4.5.2 APPLICATION RATE. The rate of application of sealer will depend to a great extent on the gradation of the aggregate used. The coarser the gradation, the thicker the application required. This assures that the aggregate is embedded in the sealer and will not wear off under traffic. The rates given are for general guidance and may vary depending upon the final proportions (solids content) of the sealer that is applied.

2.4.4.5.3 REQUIREMENTS. The FRS mixture must meet the requirements as given in Table 8. A stiffness requirement is given in the current fuel-resistant sealer guide specification. The requirement for stiffness is not applicable for coal tar emulsion sealers. The stiffness test should be required where an alternate binder (i.e. an epoxy system) is used which may not be flexible enough for use as a sealer on a flexible pavement. The amount of sand added to the FRS mixture should not exceed 480 to 720 grams per liter (4 to 6 pounds per gallon) of coal tar emulsion. Sand loads of greater amounts will not normally be fuel resistant and will fail the resistance to kerosene test. Higher sand loadings are usually only possible through the use of polymer additives which increase the viscosity of the FRS mixture and can hold the sand in suspension.

Property	Requirement	Referenced ASTM Test Method
Curing time, firm set	8 hours maximum	D 2939
Resistance to heat	No blistering, sagging or slipping	D 2939
Resistance to water	No blistering, loss of adhesion or tendency to re-emulsify	D 4866
Resistance to kerosene	No penetration or loss of adhesion	D 4866
Viscosity of sealer	Viscosity shall be a minimum of 700 centipoises at 23°C ± 3°C (all constituents added excluding sand)	--

Table 8

Physical properties of sealer mixtures

2.4.4.6 EQUIPMENT. Various types of hand-held squeegees, brooms, and other non-mechanical equipment are needed on the typical FRS project. Small jobs can sometimes be completed with only small mixers and hand-held squeegees. However, the basic equipment required for mechanical application on a FRS project include a truck-mounted batch-mix machine, squeegee blades, power broom, and front-end loader or fork truck. The truck mounted batch-mix machine is where the FRS mixtures are proportioned and mixed and then taken to the project site and applied to the pavement surface. FRS mixtures are always batch mixed and then applied, unlike slurry seals which are made in a continuous mix operation. The batch-mix machine usually has a manufacturer supplied calibration sheet showing the number of gallons per depth in the tank. The depth is usually monitored with a marked dip stick. The squeegee blades apply the FRS material to the pavement surface. The power broom cleans the pavement surface prior to application. The front end loader can be used for aggregate handling; however, a fork lift is more often needed as bagged and manufactured aggregate is often used.

2.4.4.7 SURFACE PREPARATION. All loose material should be removed from the pavement surface prior to application of the FRS. Cracks wider than 3 millimeter (1/8 inch) or with vegetation should be cleaned and sealed prior to application of the FRS.

2.4.4.8 APPLICATION. After sufficient mixing the FRS mixture should be poured directly on the pavement surface and squeegeed across the pavement surface. In hot weather conditions where the pavement surface gets hot, the application of a fog spray of water prior to application of the FRS material would assist in bonding the FRS to the pavement surface. A minimum of two applications of the FRS material should be used to eliminate the possibility of any continuous, full-depth voids in the FRS. When possible, each additional application should be made perpendicular to the previous one. Whenever possible, consecutive lanes should be placed while the sealer mixture applied in the first lane is still semifluid and workable. If operations preclude fresh working joints, the previously laid pass must be allowed to set and cure sufficiently so it is not scarred, torn, or scraped from the pavement surface during the placement of the adjoining pass.

2.4.4.9 CURING. FRS's cure by evaporation of the water from the sealed pavement surface. Sunlight and warmer temperatures will increase the rate of curing. The time for curing can vary from 2 to 24 hours depending on the thickness of FRS applied and the existing climatic conditions. FRS's should not be applied when freezing temperatures are possible within the curing time required.

2.5 MICRO-SURFACING.

2.5.1 GENERAL. Micro-surfacing, also known as micro-texturing, macro-seal, or macro-pavement, is a latex-modified asphalt emulsion slurry paving system. This system was originally developed in West Germany in the 1970's and has been used in the U.S. since 1980. The total system generally consists of a latex-modified asphalt emulsion, chemical additives, high quality crushed aggregate and mineral filler (usually Type 1 portland cement), and water.

2.5.2 EQUIPMENT. The methods of mixing and application are similar to those of a slurry seal. Other equipment such as brooms, loaders, and asphalt distributors are the same as for a slurry seal. The equipment required for mixing and application of microsurfacing mixtures are different than these required for slurry seals. Mixing is accomplished in a

multi-bladed twin-shaft pug-mill mixer. Application equipment with constant agitation within the slurry box is required to achieve a uniform placement of slurry. Micro-surfacing mixtures are placed with self-propelled mixing and placement vehicles. These vehicles have bins and tanks to carry all the aggregate, filler, asphalt emulsion, water, and additives required to make the mixture. There are two basic types of continuous vehicles with the capability to keep placing with the help of nurse or resupply trucks, and units which place and then leave for resupply. These vehicles have the ability to apply a fog spray of water to the pavement directly in front of the spreader box. The spreader box will contain blades to continually agitate the slurry. On relatively smooth surfaces the rear seal is rubber and acts as a strike-off (screed). On rough surfaces a steel strike-off is normally used to form an intermediate leveling course with another slurry over it. Rut boxes are used to fill ruts in individual traffic lanes. These boxes are V-shaped with the point of the V toward the rear of the box. They have two shafts with multiple blades on each side of the V to continuously agitate the slurry. The box is designed to push the larger aggregate to the center and is equipped with two metal leveling plates and a rubber strike-off.

2.5.3 MATERIAL REQUIREMENTS.

2.5.3.1 EMULSION. The binder used in micro-surfacing is a latex-modified asphalt emulsion. The base asphalt emulsion used is normally a cationic slow setting emulsion with a hard base asphalt (CSS-1H) as specified in ASTM D 2397. The latex polymer is combined with the asphalt cement during the emulsifying process, typically at a rate of 3.0 percent by weight of residual material.

2.5.3.2 ADDITIVES. Liquid additives are added during the field mixing process to provide control of the set properties of the micro-surface mixture. The amount of additive used generally increases with decreasing temperatures. This is because the additive acts to cause the emulsion to break or cure faster. These additives are normally obtained from the emulsion manufacturer.

2.5.3.3 AGGREGATES.

2.5.3.3.1 GENERAL. The aggregate used should be a high quality 100 percent crushed aggregate. Aggregates previously used for micro-texturing include granite, flint, slag, limestone, basalt, chert, and gravel. The aggregate shall meet one of the gradation types as given in Table 9. The gradations used for microsurfacing are the same as those of an asphalt slurry seal, except that Type 1 the finest gradation used for a slurry seal (Table 6) is not used for microsurfacing.

Sieve Size	Type 2 Percent Passing	Type 3 Percent Passing
9.5 mm (3/8 inch)	100	100
4.75 mm (No. 4)	90-100	70-90
2.36 mm (No. 8)	65-90	45-70
1.18 mm (No. 16)	45-70	28-50
600 m (No. 30)	30-50	19-34
300 m (No. 50)	18-30	12-25
150 m (No. 100)	10-21	7-18
75 m (No. 200)	5-15	5-15

Table 9
Gradation Types for Micro-Surfacing

2.5.3.3.2 MINERAL FILLER. Mineral filler is added to the mixture to obtain the desired dispersion (reduce segregation) and working characteristics (speed up or slow down the rate of cure of the system) of the micro-surfaced mixture. The amount of mineral filler added shall be determined from laboratory testing and will normally not exceed 3.0 percent of the weight of the aggregate. The mineral filler may be non-air entrained portland cement, hydrated lime, or another approved mineral additives.

2.5.3.4 WATER. The water should be potable, free of soluble salts or any other harmful materials. The amount of water used should be limited to that required to produce a mixture of desired consistency. The amount of water required may increase slightly with increasing temperatures.

2.5.4 DESIGN. Procedures developed by the International Slurry Surfacing Association (ISSA) are recommended for use and are detailed here. These procedures can be broken down into three parts. The first is the evaluation of materials to verify they meet requirements. These materials include the aggregates and the polymer-modified asphalt cement. The second part involves testing the effects of mixing and application characteristics, water content, filler, and additives, and determination of optimum asphalt content through the preparation of trial mixes. The third part involves performance related tests on the mixture to ensure good long-term performance.

2.5.4.1 MIX CHARACTERISTICS. Trial mixes are used to determine if emulsion and aggregate are compatible, if a mineral filler or field control additive is needed, and if used, the concentration, and the range of water that produces homogeneous mixtures. Trial mixes are also prepared to determine the optimum filler content and the effects of mineral filler on wet cohesion. These mixes are prepared with constant asphalt emulsion contents and incremental changes in the amount of mineral filler, usually either hydrated lime or portland cement. Once the desirable mineral filler content has been determined, trial mixes are again prepared, this time holding the mineral filler content constant and making incremental changes in asphalt emulsion content.

2.5.4.1.1 COHESION TEST (ISSA TB-139). The cohesion test is the method used to classify the set and traffic time of micro-surfacing systems. The cohesion tester is a power steering simulator that measures the torque required to tear apart a 6 or 8 millimeter thick x 60 millimeter in diameter specimen under the action of a 32 millimeter diameter rubber foot loaded to 200 kPa. A system is defined as “quick-set” if it develops a torque value of 12-13 kg-cm within 20 to 30 minutes. A torque of 12-13 kg-cm is considered the cohesion value at which the mixture is set, water resistant and cannot be remixed. A system is defined as “quick traffic” if the mixture develops 20-21 kg-cm torque within 60 minutes. At 20-21 kg-cm, sufficient cohesion has developed to allow rolling traffic. Figure 3 provides a method to classify various slurry seals and micro-surfacing systems. All micro-surfacing mixtures are designed as quick set, quick traffic systems. Cohesion test results can also be used to optimize mineral filler by the use of the “Benedict Curve” (see figure 2), in

which the effect of an incremental addition of mineral filler versus cohesion is plotted. The optimum filler content is the value that gives the highest cohesion value. The shape of the curve will show the sensitivity of the system to changes in mineral filler. This will help in determining the range of mineral filler that will give acceptable laboratory results.

2.5.4.1.2 STRIPPING. Two tests can be used to evaluate the potential for stripping: Wet Stripping Test (ISSA TM 114) and the Boiling Test (ISSA TM 149). The Wet Stripping Test is performed on 60°C (140°F) cured cohesion specimens that are boiled in water for 3 minutes to determine the asphalt adhesion to the aggregate. A coating retention of 90 percent or greater is considered satisfactory, with 75 to 90 percent being marginal and less than 75 percent unsatisfactory. The Boiling Test is similar to the Wet Stripping Test. Both tests can also be used as an early compatibility indicator test.

2.5.4.2 DETERMINATION OF OPTIMUM ASPHALT CONTENT. There are several procedures used to determine the optimum asphalt cement content. One way is to use ISSA test procedures, and another is to use a modified Marshall procedure. A few states also specify requirements for Hveem stability.

2.5.4.2.1 ISSA PROCEDURE. The optimum asphalt content is determined from ISSA procedures by graphically combining the results of a wet track abrasion test (WTAT) and a loaded wheel test (LWT). Figure 3 (a, b, and c) shows how the optimum asphalt content along with an acceptable range can be determined by graphically combining WTAT and LWT data. The minimum and maximum asphalt content should fall within the range usually provided in the specification. The ISSA recommends that residual asphalt content be within a range of 5.5 to 9.5 percent.

2.5.4.2.1.1 WET TRACK ABRASION TEST (ASTM D 3910/ISSA TB 100). This test determines the abrasion resistance of micro-surfacing mixture relative to asphalt content and is one of two ISSA tests used for determining optimum asphalt content. This test simulates wet abrasive conditions such as vehicle cornering and braking. A prepared and cured sample of mixture 6 millimeters thick x 280 millimeters in diameter that has been

soaked for periods of either 1 hour or 6 days is immersed in a 25⁰C (77⁰F) water pan and is wet abraded by a rotating weighted (2.3 kilogram) rubber hose for 5 minutes. The abraded specimen is dried to 60⁰C (140⁰F) and weighed. Maximum allowed weight losses for 1-hour and 6-day soaks are 0.54 kilogram/meter² and 0.8 kilogram/meter², respectively. Asphalt contents that result in these weight losses are considered the minimum asphalt contents. The WTAT on a 6-day soaked sample is generally not required. However, due to the increased severity of the 6-days soak, it is preferred by some laboratories and user agencies for predicting the performance of the system.

2.5.4.2.1.2 THE LOADED WHEEL TEST (ISSA TM 109). This test is used to determine the maximum asphalt content to avoid asphalt flushing in micro-surfacing systems. This is accomplished by specifying and measuring fine sand that adheres to the sample subjected to simulated wheel loadings. The ISSA recommends a maximum sand adhesion value of 0.54 kilogram/meter² for heavy traffic loadings. If the sand adhesion is below this maximum value mixture bleeding should not occur. In this test a 50 millimeter wide x 375 millimeter long specimen of desired thickness (generally 25 percent thicker than the coarsest particle) is fastened to the mounting plate and is compacted with 100, 57 kilogram cycles at 25⁰C (77⁰F). At the end of compaction the specimen is washed, dried at 60⁰C (140⁰F) to a constant weight. A measured quantity of sand is then placed on the sample, and the loaded wheel test is repeated for a specified (usually 100) number of cycles. The specimen is then removed and weighed. The increase in weight due to sand adhesion is noted.

2.5.4.2 MARSHALL PROCEDURE (modified CRD-C 649 or ASTM D1559). The Marshall hot mix asphalt mixture criteria can be used to determine the optimum asphalt content. Since these are cold polymer-modified emulsion systems, the stability and flow test procedures have been modified to allow for air and low temperature drying (at least 3 days of air curing, 18-20 hours of drying in an oven at 60⁰C (140⁰F) before compaction at 135⁰C (275⁰F)). The mixes are usually compacted with 50 blows per side. Under this procedure several test specimens are prepared for combinations of aggregate and asphalt content. The asphalt contents are selected to provide voids in total mix (VTM) of

about 4.5 to 5.5 percent. The compacted test specimens are tested for the bulk specific gravity (ASTM D 2726), stability, and flow values. Finally, the optimum asphalt cement content is determined using results from these tests. For thin micro-surfacing applications, the stability is not considered a primary factor in determining the optimum asphalt cement content. The surface characteristics of some aggregates may require adjustments in the VTM requirement to achieve the desired flow values.

2.5.4.3 DESIGN LIMITATIONS.

2.5.4.3.1 ISSA DESIGN. Torque values are measured in the laboratory under specific conditions (there has been no correlation established with pavement performance in the field). The mixing and wet cohesion test should be performed at various moisture contents, relative humidities, and temperatures to simulate the expected field conditions. In addition, it has been reported that some aggregates that met ISSA torque standards for 60 minutes have failed to meet the torque values for 30 minutes. Some laboratories also use a subjective analysis to determine torque. The sample is examined after the torque is applied, and should it fail, the torque value is determined from a visual examination of the condition of the sample. However, this analysis would appear to negate the objectivity of the cohesion test. This indicates an area where the industry should reexamine their procedures for cohesion test and consider the effect of various aggregates on test results. WTAT was correlated to field performance for only 6 millimeter thickness and 0/4 gradations. Accordingly, values of 0.54 kilogram/meter² may not be appropriate for other thicknesses and aggregate gradations. Further tests are needed to verify or establish new values. Also, some limestones meet the WTAT standard for 1-hour soak periods but fail to meet maximum abrasion loss when a sample with a 6-day soak is tested. While WTAT on a 6-day soak specimen is generally used for information only, the industry may wish to review and adjust their current design standards. The reproducibility of the loaded wheel test is questionable. The arm that moves the wheel does not stay horizontal, but rather moves up and down during the test. This changes the pressure on the sample. The arm should be modified to stay horizontal. At the present time, the weights used to apply pressure are bags of lead shot. These bags may shift

during the test and can affect the applied pressure. The bags should be replaced by plates that can be attached to the machine. Sample preparation has been shown to affect the LWT results by a factor of as much as two. The test specimen can flush if water levels are not carefully controlled. This condition will affect the sand adhesion. Current laboratory procedures for sample preparation should be improved so that samples can be more consistently molded. For some aggregates, LWT has shown to permit excessive amounts of binder resulting in unacceptable mixtures. This is true particularly for applications in high shear areas such as intersections. Performance data indicates that mixtures produced with these aggregates using a lower binder content (than would have been permitted by LWT) have performed well in extending the pavement service life. The specific gravity specification is very subjective due to sampling procedure. The entire LWT specimen is weighed wet and dry to obtain specific gravity. After compaction the same test is repeated. The problem is only 50 to 60 percent of the specimen is compacted. Variations in the specific gravities of samples can also skew LWT results.

2.5.4.3.2 MARSHALL DESIGN. The applicability of this HMA test for micro-surfacing is questionable. The Marshall series uses large specimens of varying asphalt contents which are dried, reheated to 135EC, and compacted to low void content. Micro-surfacing mixtures neither reach these temperatures nor do they compact to low design voids. Field observation has noted air voids of 10 to 15 percent after 1 to 2 years of placement. There is a need to correlate the voids measured during the design using the Marshall method with the actual field voids. One materials laboratory that has developed a cold Marshall test procedure to estimate field voids is currently correlating the field voids with the voids obtained by the modified HMA procedure. The HMA samples are prepared by compacting in a mold. The question whether the microsurfacing samples should be compacted or screened into the sample mold remains to be answered. Also, for reliable results, the sample has to be cured in a uniformly distributed film throughout the thickness of the lift.

2.5.5 SURFACE PREPARATION. The pavement surface should have all loose material removed prior to application of the micro-surface. Any structurally deficient pavement

areas must be repaired. Cracks wider than 3 millimeters (1/8 inch) or with vegetation should be cleaned and sealed prior to application of the micro-surface.

2.5.6 APPLICATION. A tack coat should be applied to the pavement surface prior to application of the micro-surfacing. Immediately prior to application, the pavement surface should be wetted with a water fogging. This fogging should leave the surface damp but with no free water. The minimum thickness of application should at least exceed the maximum nominal size of the aggregate in the mixture (usually 1-1/4 to 1-1/2 times). This relates to minimum thicknesses of from 10 to 15 millimeters (3/8 to slightly over 1/2 inch). Where wheel ruts exceed 6 millimeters (1/4 inch) in depth, a separate rut filling layer should be placed prior to the complete overlay. The emulsion is generally heated to within 27 to 49EC (80 to 120EF) prior to mixing. Micro-surfacing applications are generally designed to be opened to traffic within 1 hour after placement. Temperature and humidity are the controlling factors for curing micro-surfacing placement. As the temperature increases and the humidity decreases, the cure time decreases. Construction of a test section is very important for micro-surfacing due to changes in field conditions from lab conditions. Micro-surfacing is a quick-set system. Therefore, changes or variations in field conditions may require moisture, additive, or basic mix design changes to meet field conditions. Where possible, placement should be accomplished utilizing “nurse trucks” to allow for continuous placement. “Nurse trucks” are vehicles that are intended to carry aggregate, emulsion, and water to the application vehicle, whereby, application of the micro-surfacing can be a continuous operation. Whenever placement of the micro-surfacing is stopped, the spreader box must be lifted and cleaned and the transverse joint squared. Paper strips or metal flashing can be used to improve transverse joints. Longitudinal joints should be constructed with a 50 millimeter (2 inch) overlap to assure complete coverage and to reduce rigid development. The use of an operator to control the rate of material flow along with careful control of the placement vehicle’s speed allows for accurate placement of the microsurfacing.

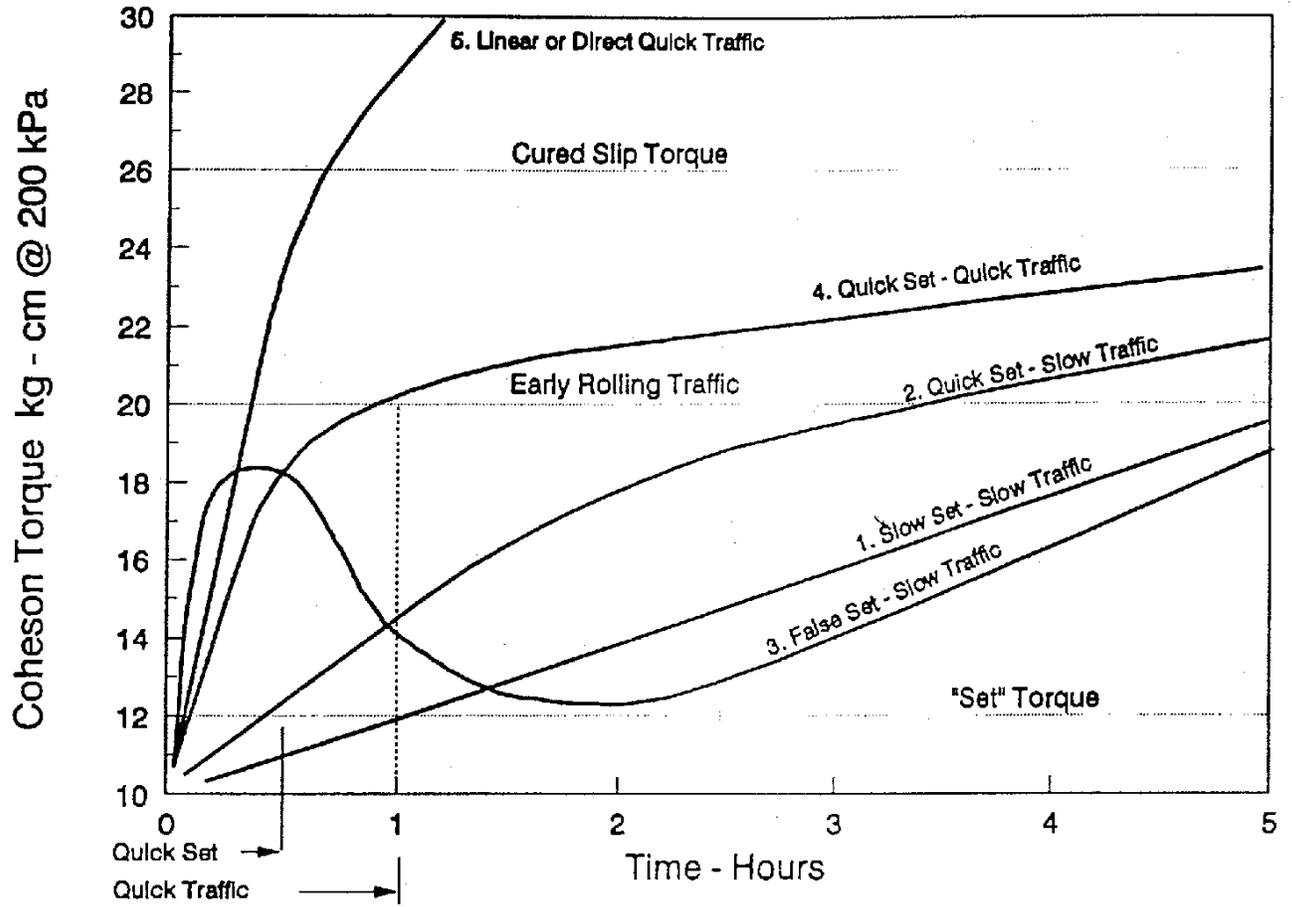


Figure 1
Classification of mix systems by cohesion test curves

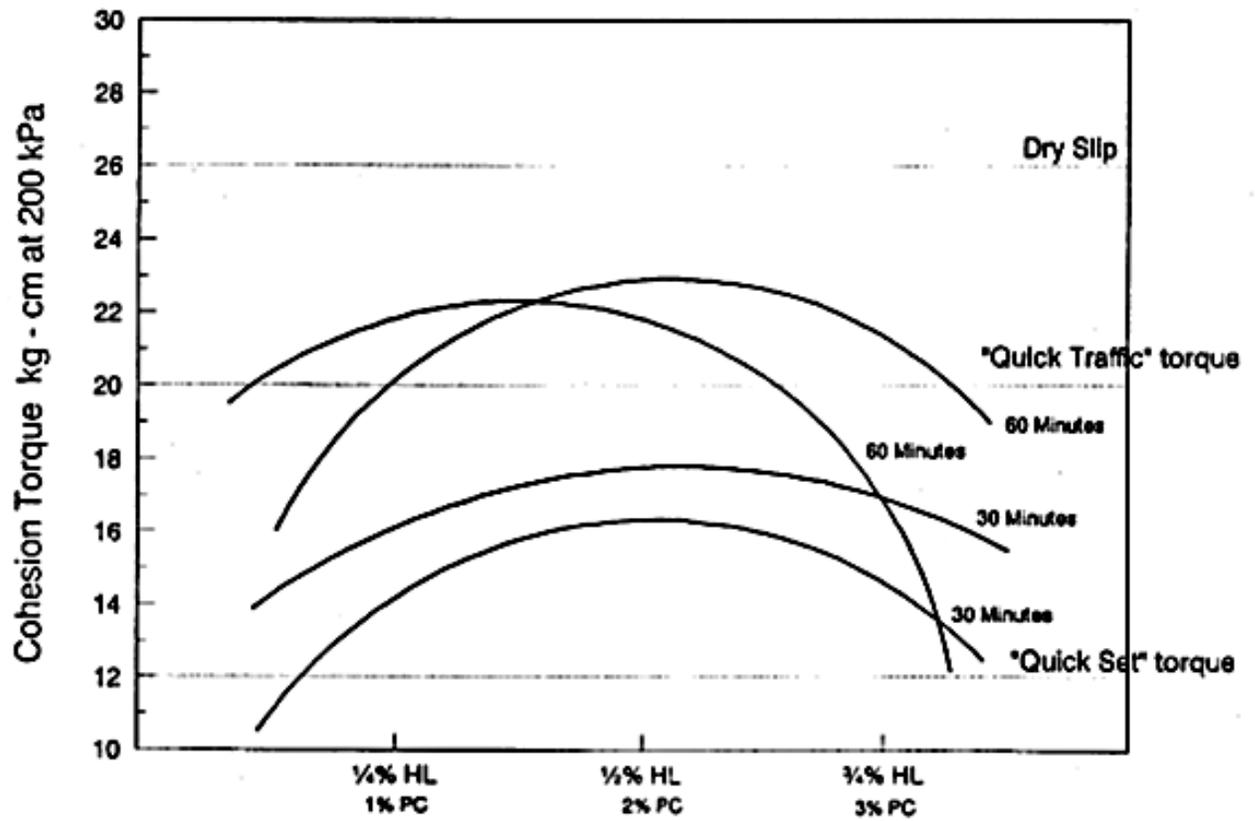
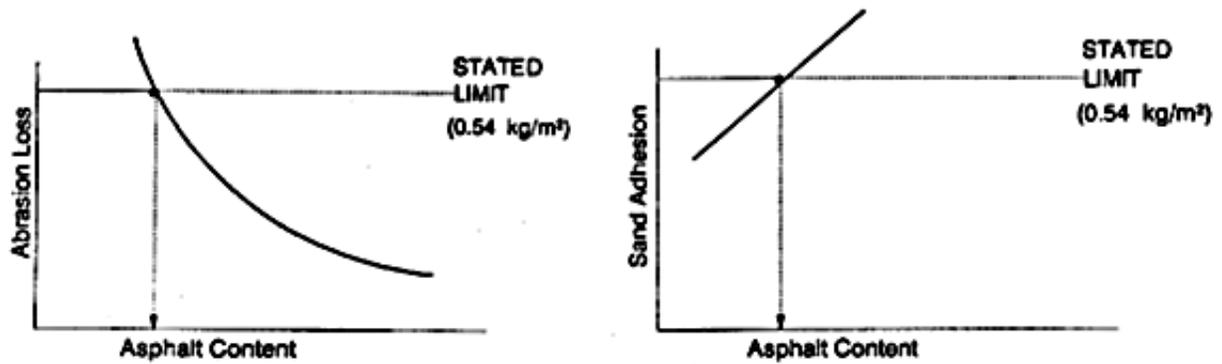
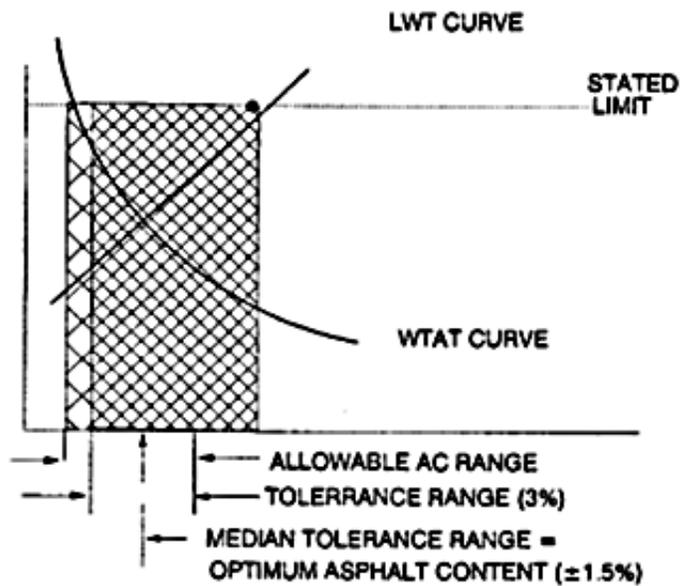


Figure 2
Mineral filler content optimization "Benedict Curve"



(a) Minimum asphalt content by wet track abrasion test

(b) Maximum asphalt content by loaded wheel test



(c) Combined WTAT and LWT curves

Figure 3
Determination of optimum asphalt content