RECOMMENDED PERFORMANCE GUIDELINES

Fifth Edition (Electronic) - Revised 20 November 2017

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SECTION 1

AEMA: AN OVERVIEW

Simply stated, the **Asphalt Emulsion Manufacturers Association (AEMA)** exists to promote the increase and more efficient use of asphalt emulsions. Since 1973, the Association has served as a forum for discussion, a clearinghouse of information, and a platform of action for the asphalt emulsion industry. Through its meetings, seminars, and publications, AEMA has helped to bring state of the art asphalt emulsion technology to all parts of the world.

The Asphalt Emulsion Manufacturers Association is an excellent network for the information exchange and technology transfer among professionals in the highway industry. Although the Association does not maintain a technical staff, it is able to address concerns of a technical nature by calling upon the tremendous bank of expertise that exists throughout its membership.

A cornerstone of AEMA's technology transfer is the International Technical Committee (ITC). Charged with developing technical activities, programs, and publications, in response to and in anticipation of market and production requirements, the ITC functions with several standing committees and several more sub-committees with specific areas of technical and program responsibilities. This volume is one of the responsibilities of the ITC.

Throughout the year, AEMA members participate in a wide range of local, regional, national, and international seminars and conferences to promote the industry and recent improvements in technology.

1.1 How to Use this Volume

This fourth edition of AEMA's Recommended Performance Guidelines for using Asphalt Emulsions (Electronic) has been updated and greatly expanded and is included in this publication. Several new Guides are now available to the highway professional.

AEMA Guides reference documents from ASTM, ARRA, and ISSA. Each of these associations updates their own publications on a regular basis. Therefore, AEMA encourages the reader to obtain the most recent versions of these important documents.

Some of these documents are included in this volume and were current at the time of publication. Due to the delay from final editing to printing, some of these may have been superseded. As an example, ASTM must publish new standards each year as about 30% of the documents are new, have been withdrawn, or have had substantial changes.

These documents should be used as companions to the AEMA's **A Basic Asphalt Emulsion Manual.**

1.2 Acknowledgements

This fourth edition of AEMA's *Recommended Performance Guidelines for Using Asphalt Emulsions* would not have been possible without the dedication and generosity of time and talent from the AEMA member companies, their individual representatives, and the International Technical Committee of AEMA.

In addition, several interested groups have made contributions to this volume. The **Asphalt Recycling and Reclaiming Association (ARRA)** provided the sections on pavement recycling.

The **International Slurry Surfacing Association (ISSA)** provided the sections on Slurry Sealing and Micro surfacing.

Many AEMA member companies also maintain membership in one or more of these associations as well as standards writing organizations such as The **American Society for Testing and Materials (ASTM)**. You are encouraged to contact these associations for more information on their respective activities.

ARRA
800 Roosevelt Road, Building C-312
Glen Ellyn, IL 60137
Phone: 630-942-6578
Fax: 630-790-3095

ISSA
800 Roosevelt Road, Building C-312
Glen Ellyn, IL 60137
Phone: 630-942-6577
Fax: 630-790-3095

ASTM
1916 Race Street
Philadelphia, PA 19103-1187
Phone: 215-299-5400
Fax: 215-977 -9679

SECTION 2

ASPHALT EMULSION THEORY

2.1 Overview

Asphalt emulsions, used in road construction and maintenance, may be defined as a homogeneous mixture of minute asphalt droplets suspended in a continuous water phase. These types of emulsions are usually termed oil-in- water (o/w) emulsions. Their preparation involves the use of a high speed, high shear mechanical device, such as a colloid mill. The colloid mill breaks down molten asphalt into minute droplets in the presence of water and a chemical, surface active emulsifier. The emulsifier imparts its properties to the dispersed asphalt and is most influential in maintaining stable asphalt droplet suspension.

Asphalt emulsions are classified into three categories; anionic, cationic, and nonionic. In practice, the first two types are ordinarily used in roadway construction and maintenance. The anionic and cationic classes refer to the electrical charges surrounding the asphalt particles. This identification system stems from one of the basic laws of electricity; like charges repel one another and unlike charges attract. When two poles (an anode and a cathode) are immersed in a liquid and an electric current is passed through, the anode becomes positively charged and the cathode becomes negatively charged.

If a current is passed through an emulsion containing negatively charged particles of asphalt they will migrate to the anode. Hence, it is referred to an anionic.

Conversely, positively charged particles will move to the cathode and is referred to as cationic. With non ionic emulsions, the asphalt particles are neutral and, therefore, do not migrate to either pole.

The polarity of the asphalt emulsion is determined by the type of the emulsifying agent used. If the surfactant, often called the emulsifier, inherently possesses a negative charge, the asphalt droplets bear a negative charge. If the surfactant inherently possesses a positive charge, the asphalt droplets bear a positive charge. In nonionic emulsions the asphalt particles have a neutral charge.

The three primary chemical components of emulsion, asphalt, water, and emulsifier, joined together by the mechanical influence of a colloid mill, are the necessary ingredients in the chemistry and related production of paving asphalt emulsions. Other additives may be incorporated to fulfill a specific purpose.

2.2 Asphalt

Asphalt cement is the basic ingredient of an asphalt emulsion. It makes up 50 to 75% of the emulsion, although in most cases, the range is from 55 to 70%. Asphalt chemistry is a complex subject, and there is no need to examine all of the properties of asphalt cement. Only those that affect emulsions are discussed. Some properties of the asphalt cement significantly affect those of the finished emulsion. There is not an exact correlation, however, between the properties and the ease with which the asphalt can be emulsified. Although hardness of base asphalt cements may vary, most emulsions are made with asphalts in the 100 to 250 penetration range. On occasion, climatic conditions may dictate that a harder or softer base asphalt be used. In any case, compatibility of the emulsifying agent with the asphalt cement is essential for production of a stable emulsion.

Asphalt is a colloid composed of several fractions, the major ones being asphaltenes and maltenes. The colloidal makeup of the asphalt depends on the chemical nature and ratio of these fractions in relationship to each other. The varying chemical and physical characteristics of asphalt are primarily due to inherent variations in crude oil sources and refining practices.

The asphaltenes are the dispersed phase in the asphalt whereas the maltenes are the continuous phase. Asphaltenes are insoluble in n-pentane and have a fairly high molecular weight. The maltene fraction is composed of sub-fractions of oil and resins.

The asphaltenes are thought to furnish hardness while the maltenes are believed to endow the adhesive and ductile properties of the asphalt. The oils and resins present have an influence on the viscosity, or flow properties, of the asphalt. The complex interaction of the different fractions makes it almost impossible to predict accurately the behavior of an asphalt to be emulsified. Asphalts, even from the same refinery, vary in behavior. This is confirmed by the differences in the emulsions manufactured from the asphalts through tests such as: viscosity, pump stability (do not break down while pumping), and general stability (do not break down during storage or while handling).

Several systems of asphalt analysis are in use today to separate and evaluate the fractions. There is no absolute agreement among technologists as to how each fraction affects field performance. Nor is there total agreement about the ease with which an asphalt cement can be emulsified.

Asphalt emulsion manufacturers determine their own formulations and develop production techniques to achieve optimum results with the asphalt cement and emulsifying chemicals available.

2.3 Water

The second largest ingredient in an asphalt emulsion is water. Its contribution to the desired properties of the finished product cannot be minimized. Water may contain minerals or other matter that helps or hurts the production of stable asphalt emulsions. Accordingly, water considered pure for drinking might not be pure for use in asphalt emulsion.

Water wets and dissolves. It adheres to other substances. And it moderates chemical reactions. Those are all important factors that can be favorable to the production of a satisfactory asphalt emulsion.

Water found in nature may be unfit because of impurities, either in solution or colloidal suspension. Of particular concern is the presence of calcium and magnesium ions. These ions benefit the formation of a stable cationic emulsion. In fact, calcium chloride is often added to cationic emulsions to enhance storage stability.

These same ions, however, can be harmful in anionic emulsions. That is because water insoluble calcium and magnesium salts are formed from the reaction with water soluble sodium and potassium salts normally used as organic emulsifiers.

In a like manner, carbonate and bicarbonate ions can help produce an anionic emulsion because of their buffering effect. But they probably would suppress a stable cationic emulsion. That is because of their reaction with the water soluble amine hydrochlorides which are often used as a cationic emulsifier.

Water containing particulate matter should not be used in asphalt emulsion production. It can be especially harmful in cationic emulsions. The usually negatively charged particles
quickly adsorb the cationic emulsifying agents. The result is an imbalance of the emulsion components that can adversely affect emulsification and performance.

2.4 Emulsifying Agents (Surfactants)

Asphalt emulsion properties depend greatly upon the chemical used as the emulsifier. That chemical is a surface active agent, commonly called a surfactant and is the determining factor as to whether the emulsion will be classified as anionic, cationic, or nonionic. The emulsifier also keeps the asphalt droplets in stable suspension and permits the asphalt to be deposited onto the aggregate at the proper time.

By broad definition surface active chemicals are water soluble substances whose presence in solution markedly changes the properties of the solvent and the surfaces they contact. They are categorized according to the manner in which they dissociate or ionize in water and are characterized, structurally, by possessing a molecular balance of a long lipophilic, hydrocarbon tail and a polar, hydrophilic head. Surface active agents owe their physiochemical behavior to their property of being adsorbed at the interface between liquids and gases or liquid and solid phases. They tend to concentrate in an oriented manner, at the interface, in such a way that, almost entirely, they turn a majority of their hydrophilic groups toward the more polar phase and a majority of their lipophilic groups away from the more polar phase and perhaps even into a non polar medium. The surface active molecule or ion, in a sense, acts as sort of a bridge between two phases and makes any transition between them less abrupt.

Basically, there are three types of chemical surface active agents which are classified according to their dissociation characteristics in water. They are:

1. Anionic Surfactants-where the electrovalent and polar hydrocarbon group is part of the negatively charged ion, when the compound ionizes:

ANIONIC

$CH_3 (CH_2)_{16} COO^- Na^+$

2. Nonionic Surfactants — Where the hydrophilic group is covalent and polar and which dissolves without ionization:

NONIONIC

$CH_3 (CH_2)_{16} COO (CH_2CH_2O) x H$

3. Cationic Surfactants — Where the electrovalent and polar hydrocarbon group is part of the positively charged ion when the compound ionized:

CATIONIC

$CH_3 (CH_2)_{17} NH_3^+ CL^-$

Alternately called surface active chemical or surfactant, the emulsifier is the single most important component in any paving asphalt, oil-in-water emulsion formulation. To be an effective emulsifier for asphalt, a surfactant must be water soluble and must possess a proper balance between the hydrophilic and lipophilic properties inherently found in each true surfactant-type chemical. The emulsifier, when used in combination with an acceptable asphalt, good quality water and adequate mechanical input, is the major factor which influences initial emulsification, emulsion stability and ultimate field application performance. A wide range of chemical emulsifiers are available.

Each manufacturer has its own procedure for using surfactants in asphalt emulsion production. In most cases, the surfactant is combined with the water before introduction into the colloid mill. However, it may be combined with the asphalt cement just before it goes into the colloid mill.

The rate at which the asphalt emulsion is deposited onto an aggregate surface as asphalt cement is controlled, largely, by the specific type and concentration of the emulsifying agent being used. This chemically controlled feature of asphalt emulsions relates to the availability of three cationic and non-cationic emulsion grades: rapid, medium and slow setting as designated in ASTM D977 and D2397 and AASHTO M-140, M-208 and M-316.

Factors which affect the setting rate or rate of asphalt deposition (RAD) of an asphalt emulsion:

- Water Absorption — The rate that water is absorbed by the aggregate and old pavement or base, or worn pavement speeds the setting time by absorbing water from the emulsion.

- Weather Conditions — Temperature, humidity, and wind velocity all have a bearing on rate of asphalt deposition onto an aggregate surface since they affect water evaporation rate and emulsifier migration and water release characteristics.
- Mechanical Forces — Forces brought to bear by rolling and by traffic. Roller pressure, to some extent, forces the water from the mix and helps attainment of mix cohesion, cure and stability.
- Surface Area — Size distribution, dirty aggregate and excessive fines may accelerate the rate at which asphalt is deposited onto the aggregate (break time).
- Surface Charge — The intensity of the negative surface charge on aggregates may affect the rate of asphalt deposition onto an aggregate surface from cationic asphalt emulsions. High aggregate surface charge causes more rapid deposition.
- Asphalt emulsion and Aggregate Temperature — Cool emulsion and aggregate temperature usually retards setting (rate of asphalt deposition) time. Warm or hot asphalt emulsion and aggregate temperature accelerates RAD.
- Type and Amount of Emulsifier — The emulsifier used in the manufacture of the asphalt emulsion and the amount used can affect rate of asphalt deposition.
- The above factors must be considered in determining working time after the asphalt emulsion has been sprayed or mixed with the aggregate in the field.

2.5 References:

- **A Basic Asphalt Emulsion Manual**, Asphalt Emulsion Manufacturers Association.
- *Asphalt-lts Composition. Properties*, and Uses. Ralph N. Traxler 1961
- A*sphalt-Science and Technology*. Edwin J. Barth 1962
- *Bituminous Materials-Asphalts*, Vol. 2, Part 1. Arnold J. Hoiberg 1965
- • *The Chemistry of Asphalt Emulsion*. TRB. Jack N. Dybalski 1976

SECTION 3

SAFETY & HANDLING OF ASPHALT EMULSIONS

There are several characteristics that distinguish asphalt emulsions from other forms of bituminous paving materials, asphalt cements and cutbacks. The biggest single difference is the presence of water in asphalt emulsions. Most asphalt emulsions contain between 30 to 40% water, depending on the grade. The asphalt cements and cutbacks on the other hand cannot tolerate the presence of water or moisture.

The water constituent of emulsions is basic to many of the properties of these materials, both advantageous and otherwise. One of the prime advantages is safety. Emulsions are liquid at ambient temperatures and therefore require much less heat than asphalt cements when being handled and worked. Depending on the grade of product and the type of job, asphalt emulsions are typically used at temperatures between ambient and 185° F (85° C), while asphalt cements require much higher temperatures. Asphalt cutbacks, like emulsions are liquids at ambient temperature, but have the disadvantage of being flammable because of the petroleum solvents present.

From a safety standpoint, the asphalt emulsions have the best of two worlds. They may be used at comparatively low temperatures thus reducing the danger of people being badly burned when inadvertently splattered or drenched. Because the medium used in asphalt emulsions is mostly water, they are nonflammable and therefore are more difficult to flash or burn when overheated.

Asphalt emulsions, although inherently safer than most other forms of asphalt, like all construction products must be handled with reasonable care. The use of protective clothing (long sleeves, rubber gloves, goggles, etc.) will protect the skin from accidental contact. In the event that the skin is splashed with emulsion, the area should be flushed well with water to remove most of the unbroken emulsion. Any remaining residue can be removed by the use of a suitable hand cleaner or baby oil. If the eyes are part of the affected area, flush well with water and consult a physician.

In case of a spill, the best method is to contain the spill with an absorbent solid, such as sand or dirt. The resulting mix may then be picked up and disposed of in accordance with local regulations.

AEMA recommends the following additional precautions in the handling of asphalt emulsion:

1. Do not heat asphalt emulsion to temperatures in excess of 185° F (85° C).

2. Do not subject the asphalt emulsion or the air above it to an open flame, heat or strong oxidants. Adequate ventilation is required.
3. Avoid breathing hot fumes, vapors, and mist.
4. Obtain a copy of supplier's Material Safety Data Sheet (MSDS). Read the MSDS carefully and follow it.
5. Read and understand the operation manual for any equipment used with asphalt emulsions.
6. Instruct all personnel working with asphalt emulsions in proper operational and
7. material safety procedures.

3.1 Handling

Because asphalt emulsions contain water, they tend to behave like water. They will freeze at 32° F (0° C) and will boil at 212° F (100° C). When ambient temperatures are around the freezing point or below 39.2° F (4° C), care must be taken to protect the material. If the temperature of the asphalt emulsion is allowed to reach the freezing point, it will usually be damaged enough to render it useless as a workable material. Even after warming to a high temperature, the thawed material will in most cases be broken, the asphalt phase being separated from the water-phase.

One way of handling this problem, is not to use asphalt emulsion during the cold months. However, with proper handling, a certain amount of winter work is possible with emulsions. Keeping the material warm and not allowing it to freeze is the key.

Asphalt emulsions can be damaged by overheating. If the material is heated to the boiling point of water, 212° F (100° C), the emulsion will start to break, just as with freezing.

Asphalt emulsions are limited then, to temperatures between 39.2° F (4° C) and 212° F (100° C). In practice, it should seldom, if ever be necessary to heat the asphalt emulsion above 185° F (85° C).for any type of a field job. Should heating be necessary, the use of mild heat while gently agitating the material is recommended.

Another important factor in the handling of asphalt emulsion is to recognize the incompatibility of the two different types, anionic and cationic. The two types cannot be mixed. Any storage tanks, transport vessels, or lines handling the one type must be completely cleaned before introducing the other type.

Refer to AEMA's **A Basic Asphalt Emulsion Manual** for further information regarding the storage and transportation of incompatible asphalt emulsion types.

Mild heating of lines, pumps, and valves may be necessary at times when the asphalt emulsion has set up or hardened in these small restricted areas. This is especially true at lower temperatures, but sometimes is necessary even in warm weather.

While transporting asphalt emulsion in bulk, the transport tank should be as full as possible. This will avoid sloshing the asphalt emulsion around within the tank while moving. Transport tanks with baffle plates should be used if available.

Do not pump asphalt emulsions excessively. The high viscosity types may tend to lose viscosity if pumped too often or continually.

Pumps used for asphalt emulsion should have extra clearance tolerance between the gears 0.015 to 0.020 in. (0.38 to 0.51 mm), and may be of the positive displacement or centrifugal type. A frozen pump may be broken loose by gently heating from the outside. Refer to SECTION 23 ASPHALT EMULSION EQUIPMENT PUMPS for further information.

Some grades of asphalt emulsions are designed to be mixed or diluted with water. In those grades that are dilutable, the water should be added to asphalt emulsion, never asphalt emulsion to water. For the best field performance, the temperature of the water added should be as near the temperature of the asphalt emulsion as possible. Also, the water should be potable and free of rust and other contaminants. The asphalt emulsion should not be handled in a manner which will cause foaming and incorporate air bubbles. This can cause the asphalt emulsion to break. Special care should be taken while loading or unloading. Bottom loading facilities are recommended.

The various grades and types of asphalt emulsion are designed for different jobs, aggregates, methods, etc. Asphalt emulsions can vary widely and some require handling techniques that may differ from others. Always check with your asphalt emulsion supplier to find the best way to handle the particular grade or type being used.

In recent years, there has appeared in the market a variety of asphalt emulsions that have been modified with polymer, rubber, elastomers or other modifiers. These materials may or may not require different or special handling techniques. No really general recommendations can be made since there is such a wide variety of materials. Each supplier of the particular product is in the best position to recommend how to handle its own asphalt emulsion. Check with your AEMA supplier.

3.2 Sample Conditioning for Testing

Both ASTM and AASHTO recognize the importance of proper sample handling to achieve valid test results. They recognize that all asphalt emulsions are made hot typically 180° to 200° F (82° to 93° C), some grades are stored hot typically 150° to 180° F (66° to 82° C), and that some of these hot stored grades are subsequently transported and applied at temperatures above 140° F (60° C). Hot samples collected in the field usually arrive at the laboratory at ambient temperature. How should these samples be handled? The language in ASTM D244 and AASHTO T-59 is significant and similar, with AASHTO stating:

All asphalt emulsions with viscosity requirements of 50° C (122° F) should be heated to 122 $\pm$ 5° F (50° $\pm$ 3° C) in a 160° F (68° C) water bath or oven. The container should be vented to relieve pressure. After the sample reaches 122 ± 5° F (50° ± 3° C), stir the sample to achieve homogeneity.

The above statement recognizes that the viscous grades of asphalt emulsion, those tested for viscosity at 122° F (50° C), generally give low, false viscosity values if manipulated or handled in the laboratory at ambient temperatures. The key to this sample-conditioning step is that if the sample is NOT stirred or agitated prior to heating to 122° F (50° C), it will give a more realistic laboratory viscosity like that experienced at the jobsite. This recovery of the jobsite viscosity is quite independent of the duration of ambient temperature storage of the sample.

SECTION 4

SINGLE AND MULTIPLE CHIP SEALS USING ASPHALT EMULSIONS

4.1 Scope

This guideline has been prepared for the benefit of those engaged in chip seal construction, to highlight items that are essential for achieving consistent, high quality results. It will present information on rapid setting (RS or CRS), medium setting (MS or CMS), and high float asphalt emulsions, cover aggregates, design practices that indicate the quantities of asphalt emulsion and cover aggregate to be applied, relevant construction equipment, and construction procedures that are required for successful single and multiple chip seals.

This section has been written as a guide only, and should be so employed. User specifications based on this guide should be adapted to job conditions, local usages and anticipated performance requirements.

4.2 Definitions

A single chip seal wearing surface typically consists of a uniform application of a rapid setting asphalt emulsion (RS, HFRS, or CRS) to a prepared surface followed by uniform application of cover aggregate which is then rolled.

A multiple chip seal continues this construction procedure by adding alternate uniform applications of asphalt emulsion and cover aggregate, followed by rolling each application of cover stone. Subsequently, a double chip seal consists of two alternate uniform applications of asphalt emulsion and cover aggregate, a triple chip seal consists of three alternate uniform applications of these materials, etc. For multiple chip seals, the size of the cover aggregate for each successive layer is normally about one-half that of the immediately preceding layer.

Chip seals are quite often referred to as seal coats when they are applied to an existing paved surface, and as surface treatments when they are applied to a prepared consolidated gravel, crushed stone, water bound macadam, stabilized soil, or similar base.

4.3 Applicable Documents

4.3.1 ASTM Documents

- C29 *Test Method for Unit Weight and Voids in Aggregate*
- C131 *Resistance to Degradation of Small-Size Course Aggregate by Abrasion and Impact in the Los Angeles Machine*
- D977 *Specification for Emulsified Asphalt*
- D1139 *Specification for Aggregate for Single or Multiple Bituminous Surface Treatments*
- D1369 *Practice for Quantities of Materials for Bituminous Surface Treatments*
- D2397 *Specification for Cationic Emulsified Asphalt*
- D2995 *Practice for Determining Application Rate of Bituminous Distributors*
- D7000 *Standard Test Method for Sweep Test of Bituminous Emulsion Surface Treatments Samples*

4.3.2 AEMA Documents

A Basic Asphalt Emulsion Manual

4.4 Asphalt Emulsions

The asphalt emulsions employed for chip seals are typically either anionic rapid setting (RS), cationic rapid setting (CRS) or high float rapid setting (HFRS) emulsions. ASTM specifications for anionic (RS, HFRS) asphalt emulsions are listed in D977 and for cationic (CRS) asphalt emulsions in D2397. Each of the rapid-setting asphalt emulsions may be modified with a polymer additive. ASTM does not have published specifications for polymer modified asphalt emulsions, and most specifying agencies have developed their own specifications for them. AASHTO M316 does address cationic polymer modified asphalts typically used for chip sealing. Polymer-modified asphalt emulsions are generally used for chip seal of pavements that are subject to higher traffic volumes. The polymer modified asphalt emulsions offer a more resilient surface course and tend to reduce chip or aggregate loss due to traffic and environmental conditions. Adjustments may also be made to the asphalt used in the emulsion based on climatic conditions.

Rapid setting asphalt emulsions should be selected where the chip seal will be exposed to traffic immediately after construction. By breaking or setting quickly, the asphalt cement in the asphalt emulsion is able to develop a strong bond with the cover aggregate, providing the chip seal with more resistance to the disintegrating forces of traffic. Fast traffic should never be allowed on newly constructed chip seals.

Even though rapid setting asphalt emulsions are most commonly used for chip seals, there may be certain applications where medium setting asphalt emulsions provide better performance. Graded aggregate seals (section 4.29) most often use medium-setting high float (HFMS-1 or HFMS-2) asphalt emulsion. Medium setting asphalt emulsions may also work better with cover aggregate that is “dirty” or contains larger amounts of fine particles than desirable.

4.4.1 Cover Aggregates

There are four very important properties of cover aggregates; toughness or hardness, gradation or sieve analysis, particle shape, and voids in the loose weight condition. In addition, cover stone should be clean and free from coatings of dust or other foreign material, preferably less than 1.5 percent passing No. 200 (0.075mm) sieve by the wash test.

4.4.2 Hardness

A Los Angeles (LA) abrasion rating of 25 maximum is sometimes stipulated for heavier traffic (more than 1,000 vehicles per day (vpd)) while an L.A. rating up to 40 may be accepted for light traffic (under 500 vpd). However, locally available aggregates tend to be employed as cover materials regardless of the Los Angeles abrasion value. The advantage of a Los Angeles abrasion rating of 26 or less is that this usually ensures a tough aggregate with much less tendency to break up or wear away under the influence of traffic and climate.

4.4.3 Gradation

ASTM D1139 provides the gradation requirements for cover aggregates for single and multiple chip seals. The National Association of Australian Road Authorities specification requires cover aggregates that are more nearly one-size than those referred to in ASTM D1139. The Australian specification calls for 95% of the aggregate to be retained on two adjacent sieves in the standard series, and a maximum of 0.5% minus the No. 200 (0.075mm) sieve. Because of the consistent excellence of chip seals in the State of Victoria, Australia, this target cover aggregate specification should be approximated or equaled wherever possible. These single-size cover aggregates are seldom available in North America and cover stone referred to in ASTM D1139 is generally used. Many state and local agencies also have developed their own aggregate gradation requirements to better utilize local materials.

Figure 4-1 Average Least Dimension Illustrates the Average Least Dimension (ALD) of cover aggregate particles and their ultimate positioning after considerable traffic (the least dimension of each particle is vertical).

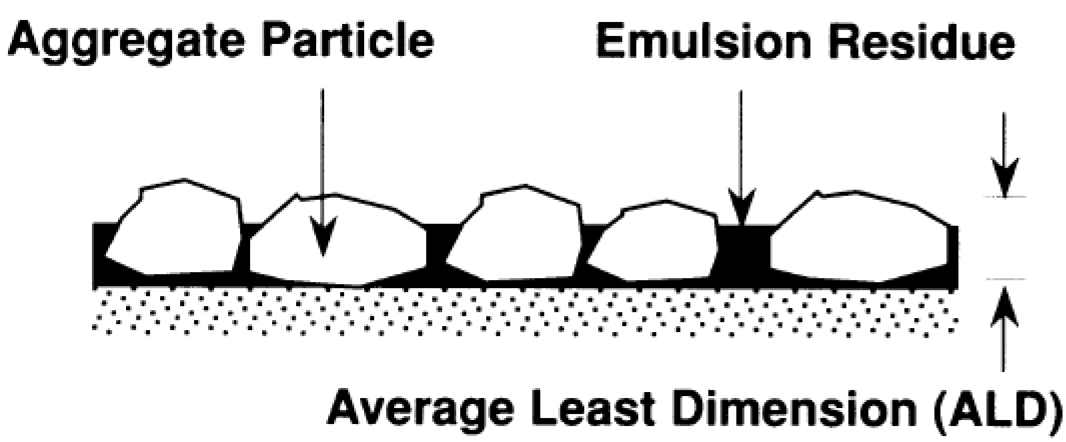


Figure 4-1 Average Least Dimension

4.4.4 Shape

The third important characteristic of cover aggregate is particle shape, which should preferably approach that of a cube or tetrahedron (pyramid). However, as illustrated by **Figure 4-1 Average Least Dimension**, most aggregate particles are thinner in one dimension than in the other two, and under traffic all cover aggregate particles tend eventually to lie on their flattest sides, which is their most stable position. Therefore, the average thickness of a chip seal is given by the average of the smallest dimension of a representative sample of cover aggregate particles, which is called their Average Least Dimension (ALD). Elongated particles, having a ratio of maximum to minimum dimensions greater than 4 to 1, should be limited to not more than 25%. Flat and elongated particles of larger cover aggregate (3/8" and larger) can measured using ASTM D 4791. The flakiness index can also be used to characterize the shape of the aggregate similar to flat and elongated particles. No ASTM standard exists for the flakiness index, but many state and federal agencies have published their own specification for this test.

4.4.5 Voids

The voids in the cover stone is needed for one method of chip seal design and requires the use of ASTM C29 for determining the loose unit weight of the cover aggregate. Knowing the loose unit weight and the bulk specific gravity of the aggregate, the voids in the cover stone in the loose weight condition can be calculated.

4.5 Compatibility of Asphalt Emulsion and Aggregate

Compatibility or affinity between an asphalt emulsion and an aggregate can be variable. If there is any doubt as to whether an anionic or cationic asphalt emulsion would be preferable with a given cover stone, your AEMA asphalt emulsion supplier should be consulted. ASTM D7000 may be used to help determine the chip or aggregate loss and compatibility of the emulsion using field environmental conditions. AASHTO T 59 contains several tests that can be run to measure the ability of the asphalt emulsion to coat the aggregate as well as get an indication about the compatibility of the asphalt emulsion and the aggregate. Some states have also developed their own test methods to check compatibility and coating of the emulsion and the aggregate.

4.6 Chip Seal Design

4.6.1 General

There are two approaches to the design of chip seals. One approach is for organizations that do not have access to a laboratory, and are primarily interested in approximate quantities of asphalt emulsion and cover aggregate to be applied.

The second approach measures the physical properties of the actual construction materials and develops a scientific basis for aggregate and asphalt emulsion application. This approach will be precise and minimize both the risk of product failure and the use of unnecessary materials.

4.6.2 Background for Chip Seal Design

Any method of design for chip seals must be able to provide an answer to the following three questions:

1. How much asphalt emulsion will be applied in gal/yd² (L/m²) measured at 60°F (15.6°C)?
2. How many lb (kg) of cover aggregate will be applied per yd² (m²)?
3. What grade of asphalt emulsion should be selected?

CRS-2, HFRS-2, RS-2, and polymer modified versions of these types of asphalt emulsions are typically used. They work well with all sizes of cover aggregate and for highly crowned or sloping surfaces. The high viscosity of these asphalt emulsions minimizes the chance of having the asphalt emulsion run off the pavement surface. The -2h grades of the above asphalt emulsions may be used in warmer climates to provide a harder asphalt residue which should reduce the chance of bleeding of the asphalt through the cover aggregate and to improve chip retention.

CRS-1, RS-1, and their polymer modified versions may be able to be used on flat surfaces or with smaller sized cover aggregate (less than ¼") as the chance for run off should be decreased.

Consult your local AEMA asphalt emulsion supplier for selection criteria.

4.6.2.1 Other Considerations

When designing a chip seal, each of the following items should be examined and assessed. Whether the design is being done on a formal or very casual basis, more success will be achieved by focusing on and checking off each item before construction is permitted to begin.

- Traffic Volume — The optimum amount of asphalt binder to be applied can be increased by 40% as the traffic volume decreases from more than 2000 to less than 100 vehicles per day.
- Voids in the Cover Stone — Between different cover aggregates this can easily range from 0.16 to 0.20 of the volume of a chip seal, and can result in a difference in optimum asphalt requirements of 25 percent.
- ASTM Bulk Specific Gravity of Cover Stone — With all other factors equal, if the ASTM bulk specific gravity of a cover aggregate is higher than normal, more lb/yd² (kg/m²) must be applied, and vice-versa.
- Aggregate Waste — Because of unevenness of spread and loss due to whip-off by traffic, more cover aggregate must be placed than will remain in a chip seal.
- The excess cover stone that must be applied for this reason can range from 2 to 10% depending on the efficiency of the chip spreader being employed.
- Percent Residual Asphalt — The asphalt emulsion requirement for a chip seal is based on the amount of residual asphalt in the emulsion. Asphalt emulsions for chip seal usually contain from about 60 to 70 percent of residual asphalt. Therefore, the same optimum residual asphalt content in a chip seal, 17% more

asphalt emulsion with a residue of 60 percent should be applied than an emulsion with 70 percent of asphalt residue.

- Surface Texture of the Existing Pavement — The texture of a paved surface to which a chip seal is to be applied, can range from black due to some flushing or bleeding which can subtract as much as 0.06 gal/yd² (0.27L/m²) from the normal asphalt binder requirement for a chip seal, to a dry raveled surface which can require up to an additional 0.09 gal/yd² (0.40L/m²). Therefore, the adjustment in asphalt emulsion application in terms of residual asphalt due to the wide difference in texture of the surface on which a chip seal is to be constructed, can range from 0 to 0.15 gal/yd² (0 to 0.7L/m²).

It should be clear that the ranges in quantities of asphalt emulsion and cover stone associated with the above items, can very easily make the difference between a poor, mediocre, and a highly successful chip seal. They also emphasize the need for a formal chip seal design in which each of these items is evaluated. A good design also points out the dangers in the common absence of any but the most casual and even complete lack of attention to the design of chip seals.

4.7 Single Chip Seal Design Without Access to a Laboratory

For organizations that do not have access to a laboratory for the precise design of chip seals, **Table 6-3 Quantities of Asphalt and Aggregate for Single Surface Treatments** in AEMA's **A Basic Asphalt Emulsion Manual** or ASTM D1369, provides a useful guide to the quantities of asphalt emulsion in gal/yd² (L/m²) and cover stone in lb/yd² (kg/m²) that should be applied for a single chip seal.

It should be clearly recognized that **Table 6-3 Quantities of Asphalt and Aggregate for Single Surface Treatments** provides guidance for selecting the quantities of asphalt emulsion and cover aggregate for average circumstances. It does not provide a precise method of design for the wide range of conditions that can occur on chip seal projects. For example, **Table 6-3 Quantities of Asphalt and Aggregate for Single Surface Treatments** does not specifically make provision for the wide differences in traffic volume, ALD, voids in the cover stone, cover aggregate wastage loss, surface texture to which a chip seal is to be applied, or residual asphalt content of the asphalt emulsion, that can occur from project to project. Each of these conditions can have a major influence on the quantities of cover stone and asphalt binder that should be applied per unit area.

Consequently, while many organizations will probably continue to employ empirical guidance like **Table 6-3 Quantities of Asphalt and Aggregate for Single Surface Treatments** for establishing the quantities of asphalt emulsion and cover stone to be applied per unit area, or no tables at all, they should not be surprised when the resulting chip seals provide indifferent performance and have short service lives.

To improve chances of success, a short test section can be constructed to check application rates of both asphalt emulsion and cover aggregate. Make sure you have sufficient cover aggregate cover the asphalt emulsion without excessive aggregate left on the surface as well as sufficient asphalt emulsion application rate so that the asphalt emulsion thickness is approximately 100% of the average chip height. Application rates can be adjusted if necessary and short test sections constructed to get dialed in before proceeding to longer sections.

4.8 Multiple Chip Seal Design without Access to a Laboratory

The aggregate for each successive layer of a multiple chip seal should be approximately one-half the size of the aggregate for the immediately preceding layer.

On this basis, organizations that do not have access to a laboratory for the precise design of chip seals, **Table 6-4 Correction for Surface Condition** and **Table 6-5 Quantities of Asphalt and Aggregate for Double Surface Treatment** in AEMA's **A Basic Asphalt Emulsion Manual** or ASTM D1369, provides a useful guide to the quantities of asphalt emulsion in gal/yd² (L/m²) and cover stone in lb/yd² (kg/m²) that should be applied for a multiple chip seal.

Again, **Table 6-4 Correction for Surface Condition** and **Table 6-5 Quantities of Asphalt and Aggregate for Double Surface Treatment** provide guidance for selecting the quantities of asphalt emulsion and cover aggregate for more or less average circumstances. They do not provide a precise method of design for the wide range of conditions that can occur on chip seal projects. (See **Figure 4-2 Effect of Aggregate Particle Shape on Materials Quantities**).

4.9 Formal Chip Seal Design

The most widely used chip seal design method in the United States was developed by Norman McLeod in the late 1960's and the method outlined *in A General Method of Design for Seal Coats and Surface Treatments* in the Proceedings of the Association of Asphalt Paving Technologists, Volume 38. St. Paul, MN, 1969. In the McLeod method, a series of calculations are made to determine the optimum application rates of both aggregate and asphalt emulsion. The aggregate application rate is calculated based on the aggregate gradation, shape, and specific gravity. The asphalt emulsion application rate is calculated from the aggregate gradation, absorption and shape, traffic volume, existing pavement condition, and the residual asphalt content of the emulsion. A modified McLeod method has been used in some of the northern states to apply slightly more asphalt emulsion to minimize the chance of snow plow damage.

The asphalt emulsion supplier should be consulted for a formal single or multiple chip seal design. The supplier has knowledge of local aggregate characteristics and construction practice. The supplier is also in the best situation to judge asphalt emulsion compatibility and formulation. Aggregates proposed for use on a chip seal project should be delivered to the asphalt emulsion supplier. Other useful information includes traffic count and road surface condition.

An inspection of the proposed roadway by the supplier may be recommended.

Figure 4-2 Effect of Aggregate Particle Shape on Materials Quantities Illustrates the effect of aggregate particle shape on materials quantities. Both aggregates are 0.5 inch as measured by sieve analysis. One is cubicle, the other is flat and elongated. Voids filled are 70% for both aggregates.

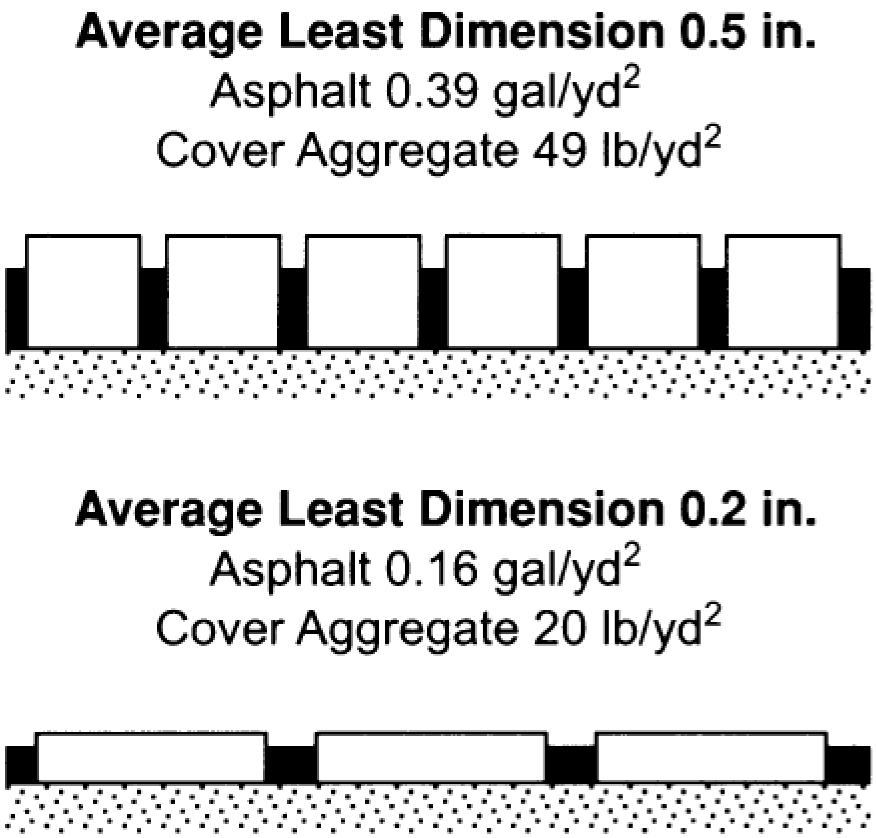


Figure 4-2 Effect of Aggregate Particle Shape on Materials Quantities

4.10 Basic Construction Equipment

The basic equipment for constructing a chip seal should include:

1. Asphalt distributor
2. Cover aggregate spreader, preferably of the mechanical self-propelled type
3. Rollers, preferably pneumatic-tired
4. Rotary power broom and other cleaning equipment
5. Broom drag
6. Cover aggregate haul trucks equipped with special hitches for attachment to aggregate spreaders

4.10.1 Asphalt Emulsion Distributor

It is the principal function of the distributor to apply asphalt emulsion uniformly in both transverse and longitudinal directions at the specified rate in gal/yd^2 (L/m^2). Failure to do so can result in streaking in which too much and too little asphalt alternate every few inches across the road surface. Streaking usually results from incorrect positioning of the nozzles in the spray bar, from different nozzle sizes in the spray bar, from incorrect spray bar height, from damaged or nicked spray nozzles, by forcing more or less than the optimum quantity of asphalt emulsion through each spray nozzle, or from attempting to spray asphalt emulsion at too low a temperature so that it cannot fan out properly from the spray nozzles, and even by inability of the control mechanism to fully open the spray nozzles in one or more sections of the spray bar.

To avoid streaking, each nozzle in the spray bar of the distributor should be turned to make the constant angle with the longitudinal axis of the spray bar that is recommended by the manufacturer. All nozzles in the spray bar should be of the same size. The spray bar height should provide double or triple overlap of the asphalt emulsion being applied by the spray nozzles as recommended by the manufacturer. The distributor should be able to spray asphalt emulsion within ±7.5 percent of the average application rate in the longitudinal direction and within ±10.0 percent of the average rate of application for any 4-inch width in the transverse direction. A very simple and practical method for checking the rate of application of asphalt emulsion in both the longitudinal and transverse directions is provided by ASTM D2995.

For satisfactory application of the asphalt emulsion, uniform pressure must be maintained in the spray bar. The optimum pressure discharges the asphalt emulsion at a constant rate through each spray nozzle, (e.g., 4 gal/min (15.1L/min)). Only at this constant rate of discharge does the asphalt emulsion fan out uniformly from each spray nozzle. Therefore, different rates of application of asphalt emulsion in gal/yd^2 (L/m^2) should be achieved by changing the forward speed of the distributor and not by changing the discharge rate in gal/min (L/min) from each spray nozzle.

Important accessory equipment for each distributor includes an accurate gauge, 6 in. (150mm) in diameter or larger, to indicate pressure in the spray bar, an accurate tachometer to show pump speed in r/min, an accurate thermometer for registering the temperature of the asphalt emulsion in the distributor, a calibrated dipstick to enable gallons (liters) of asphalt emulsion per inch (millimeter) of depth to be read at any time, and a bitumeter that has been calibrated to accurately measure the distance traveled and the speed in ft/min (m/min) when spraying.

4.10.2 Cover Aggregate Spreaders

Cover aggregate spreaders may consist of tailgate spreaders, but to obtain a continuous and uniform rate of cover aggregate application, and to keep up with the asphalt distributor, they should preferably be of the mechanical self-propelled type.

Before use on any given job, a mechanical self-propelled chip spreader should be calibrated for the particular cover aggregate to be applied. The forward speed of the chip spreader during calibration should approximate the speed required to remain close to the distributor. The object of calibration therefore, is the gate opening at this speed that results in the application of cover stone by the chip seal spreader at the rate specified.

Calibrating the aggregate spreader avoids the application of either too little or too much cover aggregate, either of which can be costly. Too little cover aggregate can result in shortened service life, while too much represents a waste of cover stone. Furthermore, there is a shortage of good quality cover aggregates in some areas. Consequently, by applying the correct quantity of cover stone per yd^2 (m^2) a vanishing valuable natural resource is being conserved.

4.10.3 Rollers

The objective of the rolling operation is to press the cover stone firmly into the asphalt emulsion. This improves particle embedment, promotes more thorough wetting and better adhesion between asphalt emulsion and cover aggregate, and achieves better cover stone interlock. For single chip seals, rollers should be of the pneumatic-tire type. No existing surface is entirely smooth, and because of their flexibility, pneumatic tires can reach down into small depressions and press the cover stone into the asphalt emulsion. Steel wheel rollers bridge over these depressions. Steel wheel rollers also tend to crush cover aggregate particles.

For multiple chip seals, while most rolling should be done with pneumatic tire rollers, at least one pass should preferably be made with a steel wheel roller immediately before the next layer is to be placed, and also on the final layer. This orients the cover stone particles into a flatter surface, which is desirable when constructing multiple chip seals.

For an average chip seal construction operation, a minimum of three rollers should be used on chip seal projects. Two rollers should be kept close to the chip spreader at all times so as to make the first pass of the roller over the cover aggregate before the asphalt emulsion breaks, while the third roller does the back-rolling.

4.10.4 Rotary Power Broom

A powerful rotary broom is needed to thoroughly clean the existing surface before a chip seal is applied.

A layer of dust tends to accumulate near the edges of an existing surface which can prevent good bond between the new chip seal and the old surface. For this reason this layer of dust should be carefully removed with a power broom.

By light brooming, the powered rotary broom should also be used to remove excess cover stone from a new chip seal preferably during the coolness of early morning immediately following the construction of the chip seal.

4.10.5 Broom Drag

The use of a broom drag immediately following the chip spreader is generally frowned upon. Nevertheless, even the most skillfully operated chip spreaders leave occasional areas with insufficient cover aggregate and others with an excess. With some chip spreaders there is considerable unevenness of spread. Consequently, there is often need for a carefully operated broom drag to provide more uniform distribution of the cover stone. To obtain more evenness of spread, broom dragging may be particularly beneficial on the first layer of cover stone for a double surface treatment.

It needs to be emphatically stressed however, that the broom drag operation must avoid turning over any of the cover aggregate particles exposing their black undersides. These black surfaces stick to the wheels of traffic and initiate a snowballing effect by tearing out other stone particles to the detriment of the new chip seal. On any project where this is occurring in spite of careful broom drag operations, the broom dragging should be stopped immediately.

4.10.6 Cover Aggregate Trucks

To avoid costly delays in chip seal construction operations due to lack of cover stone an adequate number of dump trucks should be provided.

Each truck should be equipped with a suitable hitch for connection to the chip spreader. The trucks should be designed to avoid contact between the truck body and the chip spreader at all times and the truck body should be modified if necessary to empty cleanly and completely into the hopper of a self-propelled chip spreader. Spillage of cover aggregate onto the road surface when the truck is emptying into this hopper should not be tolerated.

4.11 Construction Operations

The sequence of construction operations is as follows:

1. Adequate preparation, repair, and thorough cleaning of the surface that is to receive the chip seal. Because they are invariably quite porous, new patches made with pre-mix material should preferably be made several weeks ahead of the chip seal.
2. Consideration of temperature and weather
3. Spraying the asphalt emulsion
4. Applying the cover aggregate
5. Rolling
6. Broom dragging if necessary to achieve more uniform cover aggregate distribution
7. Brooming off excess cover stone
8. Repeating this sequence of operations for each layer of multiple chip seal

4.12 General Considerations

It cannot be overemphasized that poor chip seals often result from poor construction practice in spite of the excellent quality of the asphalt emulsion and cover aggregate, and the competent design procedures employed.

Some chip seals lose much or most of the cover aggregate during the first winter. When the particles of cover aggregate thrown onto the shoulder are examined, very often only a very small area of each particle has been blackened by asphalt. This provides evidence of lack of sufficient embedment during construction, which could result from a number of causes:

- The chip seal was constructed during cool weather late in the year. Therefore, the one month of warm weather traffic required to reorient them onto their flattest sides and properly embed the cover stone particles into the asphalt binder was not available before winter arrived.
- Not enough asphalt emulsion was applied.
- There was a long delay between the application of the asphalt emulsion and the application of the cover stone so that the asphalt emulsion had broken before the cover aggregate was applied.
- The asphalt emulsion being used was too fast breaking. The asphalt emulsion broke before the cover aggregate was applied in spite of well-coordinated chip seal construction operations.
- The rolling operation was inadequate, or the rollers may not have been ballasted, or were delayed so that the first roller pass was not made before the asphalt emulsion had broken.
- The skin of hard penetration grade asphalt that forms on the surface of an asphalt emulsion when it breaks, tends to prevent the development of adequate early adhesion between asphalt emulsion and cover aggregate when the cover stone is applied after the asphalt emulsion has started to break. Consequently, adequate rolling of chip seals made with asphalt emulsions should be crowded as closely to the chip spreader as possible, so that the first roller pass over the cover stone is made before the asphalt emulsion breaks.

4.12.1 Preparation of a Granular or Stabilized Base

The granular or stabilized base should be scarified if necessary, bladed, watered, and rolled to provide a surface that is uniform, firm, smooth, and that conforms to specified profile and cross section.

Immediately after this preliminary preparation, it should be primed with 0.2 to 0.5gal/yd² (0.9 to 2.3L/m²) of a suitable asphalt primer. Priming will be facilitated if the surface is damp, but the use of calcium chloride can hinder penetration of the primer. The grade of primer selected and the quantity to be applied should be completely absorbed into the surface in 24 hours, and depends very largely on the porosity of the surface.

If the primed surface is to be exposed to traffic for a short period of time, it should be protected by an immediate application of 6 to 10Ib/yd² (3.2 to 5.4kg/m²) of clean coarse sand.

The priming operation should be completed far enough ahead of the chip seal to enable the asphalt primer to cure. Depending upon local conditions and the season of the year, this could be from two or three days to two weeks.

Immediately before applying the chip seal, the primed surface should be broomed with a rotary power broom to remove all loose and foreign material. Hardened patches of mud or clay may have to be removed with a pick and shovel.

4.12.2 Preparation of a Paved Surface

The paved surface should be made as uniform as possible before a chip seal is applied. Consequently, all rich patches should be removed or pretreated, and all holes, depressions, and other defective or distressed areas should be repaired. It cannot be overemphasized that unless a chip seal is constructed on a uniform surface, the appearance of the chip seal after several weeks of traffic will not be uniform.

New patches that have been made on the surface will be porous, and may absorb some of the asphalt emulsion applied for the chip seal. These should be sprayed with up to 0.1gal/yd² (0.45L/m²) of SS-1h or CSS-1h emulsion that has been diluted 50 percent (1 + 1) with water, and covered with from 6 to 10Ib/yd² (3.2 to 5.4kg/m²) of clean coarse sand, for example bank sand, and opened to traffic for two weeks before chip sealing.

If the old pavement is noticeably porous, it may absorb some of the asphalt emulsion applied for a chip seal. A simple quick test for porosity of an existing surface is to apply to it a couple of drops of lubricating oil from the dipstick of an automobile. If the surface is porous it will absorb the oil almost immediately. If it is non-porous most of the oil will remain on the surface after 10 minutes. If the existing surface is porous, it should be sprayed with 0.1gal/yd² (0.45L/m²) of SS-1h or CSS-1h asphalt emulsion that has been diluted 50 percent with water and covered with from 6 to 10Ib/yd² (3.2 to 5.4kg/m²) of clean coarse sand. An asphalt emulsion sand slurry seal can be substituted for the SS-1h or CSS-1h asphalt emulsion and sand. In some cases, the application rate of the emulsion may be need to be increased to account for the increased absorption of the emulsion into the pavement.

If the old surface is severely pocked, see **Table 6-3 Quantities of Asphalt and Aggregate for Single Surface Treatments** in AEMA's **A Basic Asphalt Emulsion Manual**), it is probably so variable that it should be made uniform before a chip seal is applied. Again, the remedy is either 0.1gal/yd² (0.45L/m²) of SS-1h or CSS-1h asphalt emulsion diluted 50 percent (1 + 1) with water and covered with 6 to 10Ib/yd² (3.2 to 5.4kg/m²) of clean coarse sand, or an asphalt emulsion slurry seal. In some cases, the application rate of the asphalt emulsion may need to be increased to account for the increased texture of the pavement.

The purpose of each of these treatments is to obtain a uniform surface on which a chip seal is to be constructed. Each treatment should result in a uniform surface with a textural rating of smooth.

Immediately before any of these treatments is applied, and before a chip seal is constructed, the existing surface should be thoroughly broomed with a rotary broom to remove all dust and other foreign material. Hardened patches of mud or clay may have to be removed with a pick and shovel.

4.12.3 Temperature and Weather Restraints

The temperature of the surface on which a single chip seal is to be constructed should be not less than 50° F (10°C) and rising, and should be not less than 40° F (4°C) and rising for a double chip seal.

In addition, there should be a weather forecast with no rain expected for a minimum period of 24 hours following the construction of the chip seal.

4.12.4 Spraying the Asphalt Emulsion

Five very important items that can be easily checked that will help ensure a successful application of the asphalt emulsion are:

1. Alignment of the nozzles in the spray bar
2. That all spray nozzles are of the same size, and are not nicked or otherwise damaged
3. That every spray nozzle is free from even partial clogging, is clean, and can spray normally
4. Height of spray bar above the road surface
5. Application temperature of the asphalt emulsion. The recommended ranges are:

RS-1 80 to 185°F (27 to 85°C)
RS-2 125 to 185°F (52 to 85°C)
HFRS-2 125 to 185°F (52 to 85°C)
CRS-1 125 to 185°F (52 to 85°C)
CRS-2 140 to 185°F (60 to 85°C)

Unless the distributor has been calibrated for its ability to spray the specified quantity of asphalt emulsion uniformly over every 0.1yd² (m²) of surface, this should be checked. It is not enough to determine that the total gallons applied to a measured section of road surface is correct. This tells nothing about the uniformity of application transversely across the sprayed width.

When necessary adjustments have been made, the distributor should be able to make a uniform application of asphalt emulsion at the rate specified. Before spraying begins, a line should be placed along one edge of the road as a guide. This line may consist of string or even suitably spaced small rocks. Existing pavement striping may also be used as a reference. To protect concrete curbs in urban areas a removable shield may be attached to the pertinent end of the spray bar.

The distributor should not be permitted to start spraying until the chip spreader and loaded trucks are in line and ready to apply the cover stone, and rollers are ready torol l the cover stone immediately after it has been spread. Otherwise, the asphalt emulsion may break before the cover stone has been applied, or before the first pass of the roller over the spread aggregate has been made.

The asphalt emulsion should preferably be sprayed full width to avoid the need for a longitudinal joint in the center of the road that can be unsightly due to either too much or too little asphalt and can also be a location for distress and even failure within the chip seal. When this is not possible an inside strip of uncovered asphalt emulsion from 3 to 4in. (75 to 100mm) wide should be left when constructing the first half, to provide center joint overlap when the second half of the chip seal is placed. For a double surface treatment, the center joint on the second layer should be displaced at least 6 in. (150mm) from the center joint in the first layer.

To obtain smooth, well-constructed transverse joints, the distributor should always begin and preferably stop spraying on a strip of Kraft or building paper placed across the lane under construction at right angles to the direction of traffic to prevent double application of asphalt emulsion and aggregate at the joint, creating a bump or uneven surface.

4.12.5 Applying the Cover Aggregate

The gate opening and forward speed of the chip spreader, which should preferably be the same as the forward speed of the asphalt distributor should be adjusted to apply the number of pounds of cover aggregate per square yard (kg/m^2) indicated by the design requirement.

Truckloads of cover aggregate should be in position before any asphalt emulsion is applied. When spraying of asphalt emulsion begins, the chip spreader should follow within a distance of 50 to 150ft (15 to 50m). This distance is needed for a layer of asphalt emulsion of more uniform thickness to develop under the influence of gravity.

A self-propelled chip spreader should pull the truck, which should be in neutral gear.

Use of a tachometer assists in maintaining a uniform forward speed of the chip spreader. The trucks supplying the chip spreader should stagger their wheel paths, to reduce the chance of damaging the newly applied chip seal. If the trucks vary their wheel paths, they will also act as additional rollers for the newly applied chip seal, which is beneficial for a good project.

If speed of the chip spreader is too fast, a wave of asphalt emulsion may form just ahead of where the cover aggregate is applied. This should be avoided. Slowing down the chip spreader should resolve this problem.

Oversize cover stone particles and other foreign material can interfere with the uniform application of the cover aggregate by partially clogging the gate opening of the chip spreader. This can result in streaking, and should not be tolerated. Most of these problems can be avoided by proper stockpile management and using a skilled loader operator.

The cover aggregate should be preferably damp when applied, but should never be wet. Less than 2% moisture is desirable.

When cover aggregate is spilled on to the chip seal it should be removed with hand shovels. In small areas where not enough cover stone has been applied, broadcasting cover aggregate with hand shovels from a truck can be employed to make up the deficiency.

4.12.6 Rolling

Rolling should begin as soon as possible after the cover aggregate has been applied, and one pass of a roller should be made before the asphalt emulsion breaks.

On chip seal projects of average size, two pneumatic-tired rollers should be kept as close to the spreader as possible at all times, and should make one or two initial passes over the cover aggregate before the asphalt emulsion breaks. A third roller should apply the several roller passes required for back rolling.

Rolling should proceed from the outer edge to the center, with each pass overlapping the previous pass by one-half. Care should be taken that this is done as quickly as possible, to make sure the asphalt emulsion is not broken.

4.12.7 Removing Surplus Cover Aggregate

When designing the quantity of cover aggregate to be applied, some allowance must be made for loss of cover aggregate due to whip-off and unevenness of spread. Consequently, the quantity of cover aggregate applied exceeds by 2 to 10 percent the amount that will remain in the chip seal. Since this surplus aggregate can be thrown into the air by traffic and cause motor vehicle damage, it should be removed. Removal can be done by light brooming with a power broom as soon as possible, as long as it does not damage the chip seal. This is typically done during the cool morning after construction, when the asphalt binder is reasonably hard. Care must be taken to avoid turning over any of the cover aggregate particles embedded in asphalt. With quicker breaking systems, the brooming may be done on the same day to reduce chip loss due to traffic. This can be tested by brooming the surface to check for good bonding of the chip to the asphalt emulsion.

4.12.8 Constructing Multiple Chip Seals

For the construction of multiple chip seals, the same sequence of operations is continued that has just been described for single chip seals, with the exception that one pass with a steel-wheeled roller should preferably be made over each layer before the next layer is applied, and over the surface of the final layer.

All layers should be constructed the same day, or as soon thereafter as possible. The center joint in each layer of a multiple chip seal should be displaced at least 6 in. (150mm) from the center joints in the other layers. The distributor should be driven in opposite directions on successive layers. If there is any lack of uniformity of asphalt emulsion distribution from the spray bars, this procedure will ordinarily avoid the same fault occurring at the same location in superimposed layers.

4.12.9 Traffic Control for Newly Constructed Chip Seals

Traffic control by flagmen, barriers, or pilot vehicle is required to protect workers, construction equipment, and motor vehicles, and to avoid damage to the chip seal as construction proceeds and during the critical period when the finished chip seal is first opened to traffic.

Preferably, all traffic should be kept off chip seals during their construction. This includes the construction equipment, which should be routed to the worksite from the direction opposite to that in which construction is progressing.

Newly constructed chip seals tend to be rather weak for two reasons:

1. Hanson, a New Zealand engineer who made the first authoritative study of chip seals, observed that the voids in the cover aggregate with which he was working were approximately 30 percent after rolling, but under warm weather traffic the voids eventually decreased to about 20 percent. Consequently, newly constructed chip seals are weak because at 30 percent voids the cover aggregate interlock is only partly developed.
2. An asphalt emulsion contains from 30 to 40 percent water, and some time is required after spraying for this water to leave the emulsion. As its water content decreases, the residual asphalt remaining becomes stronger and stronger with increasing ability to hold the cover aggregate in place against the dislodging tendencies of traffic.

During this weak period immediately following construction of a chip seal, fast moving traffic should not be permitted because it tends to tear out cover aggregate particles.

While traffic speeds can be partially controlled by barricades and flagmen, the most effective means is the assignment of a pilot vehicle to convoy traffic over the new chip seal at speeds that are low enough to avoid damaging it.

The length of time during which a newly constructed chip seal must be protected against high speed traffic depends upon existing conditions. It can vary from a few hours in hot dry weather, to one or more days in humid, cool, or wet weather.

4.12.10 Graded Aggregate Seals

For low volume roads, graded cover aggregates can be used in place of the normally more expensive one-size cover stone specified for standard chip seals. The aggregates should typically all be passing a 5/8in. (16.0mm) or 1/2in. (12.5mm) sieve, with from 60 to 70 percent passing a No. 4 (4.75mm) sieve, with preferably not more than 6 percent passing a No. 200 (0.075mm) sieve, and have a minimum sand equivalent of 45. The resulting seals tend to be several superimposed aggregate particles in thickness.

To allow for percolation into the graded layer, low viscosity High Float Medium Setting Asphalt Emulsions (HFMS-1 and HFMS-2) are recommended for graded aggregate seals. They may contain from 0 to 10 percent of a petroleum solvent, which results in a softer distillation residue. These asphalt emulsions normally appear to develop a weak gel structure immediately after spraying which gives them greater resistance to flow on a banked or crowned surface.

A typical HFMS graded aggregate seal would require the application of a high float asphalt emulsion at the rate of 0.50 to 0.80gal/yd² (2.3 to 3.6L/m²) to which 30 to 40Ib/yd² (16 to 22kg/m²) of graded cover aggregate would be applied.

The speed of the aggregate spreader should be slow enough to avoid the formation of a wave or roll of HFMS asphalt emulsion of width greater than about 1 in. (25mm) along the front of the layer of graded cover aggregate being applied. Otherwise, the aggregate tends to jump over this wave or roll, and this in turn can result in a ripple (bump) or series of ripples in the surface of the finished seal.

Self-propelled chip spreaders are designed to apply approximately single-size cover stone which is not susceptible to noticeable segregation. When graded cover aggregates are used, a system of baffles or augers should be added to the front hopper to prevent marked segregation of the aggregate into a series of alternating zones or sections of coarse and fine aggregate within the hopper itself, which can result in similar segregation of the graded cover aggregate in longitudinal streaks of coarse and fine cover aggregate in the finished seal.

After curing, any excess cover aggregate may be removed from the seal by light sweeping with a powered rotary broom.

4.13 Do’s and Don’ts

A number of items will help to insure a successful chip seal project:

1. Never permit anionic and cationic asphalt emulsions to be mixed because this will cause each asphalt emulsion to break, leaving tanks or other equipment partially filled with semi-solid asphalt, and a difficult cleaning job.
2. Thoroughly wash out equipment with an approved product in which an anionic asphalt emulsion has been used before using it for a cationic asphalt emulsion and vice versa. Make sure to drain out additional product before using the equipment to avoid contaminating the asphalt emulsion.
3. At the end of each day, flush out equipment with an approved product for the pumping and spraying system on the asphalt distributor. This will avoid clogging, binding, or seizure if the asphalt emulsion otherwise left in this system should break. Make sure to drain out approved product before filling the distributor with asphalt emulsion to avoid contaminating the asphalt emulsion.
4. Do not dilute a rapid setting HFRS, RS, or CRS asphalt emulsions with water. It is likely to break.
5. Do not allow asphalt emulsion to either freeze or boil — it will break.
6. When pumping asphalt emulsions, keep the end of the discharge pipe submerged in the asphalt emulsion to avoid entrapment of air and foaming. Foaming and excessive air may also cause an asphalt emulsion to break.
7. Avoid tight fitting pumps when pumping asphalt emulsion. They may bind and

seize due to breaking of the emulsion as well as affecting the properties of the asphalt emulsion.

8. Avoid excessive pumping or handling of asphalt emulsions, because this can result in a reduction of their viscosity and could adversely affect the performance of the asphalt emulsion in the field.
9. Have a clear mental image of what an excellent chip seal looks like as a target for achievement.
10. For chip seals, tailor rapid setting asphalt emulsion formulations (when possible) to break after the first pass of a roller has been made immediately behind the chip spreader, which in turn should follow from 50 to 150ft (15 to 50m) after the distributor.
11. A lack of uniformity of texture in an old asphalt surface that is to be chip sealed will result in a lack of uniformity in the finished chip seal. Therefore, rich patches or flushed and bleeding areas should be repaired before a chip seal is applied. If an old pavement is dry and raveling and has a variable surface texture, it should be sprayed with 0.1gal/yd² (0.45L/m²) of SS-1 or CSS-1 asphalt emulsion that has been diluted 50 percent with water, covered with 6 to 10Ib/yd² (3.2 to 5.4kg/m²) of clean coarse sand, and exposed to traffic for two weeks, before a chip seal is applied. This will provide the old pavement with a more consistent surface texture, on which a more uniform chip seal can be constructed.
12. Since they tend to be porous and could absorb a portion of the asphalt emulsion applied, new patches on an old pavement should be placed several weeks before a chip seal is constructed, so as to obtain compaction and closing up by traffic.
13. The quantity of cover aggregate to be applied per unit area for a chip seal depends on the aggregate's Average Least Dimension, the void space between the cover stone particles, its ASTM bulk specific gravity and the allowance for loss due to whip-off and unevenness of spread.
14. The quantity of asphalt emulsion to be applied per unit area for a chip seal depends upon the Average Least Dimension of the cover aggregate, the volume of void space between the cover stone particles, the traffic volume anticipated, the texture of the surface on which the chip seal is to be placed, and the percent residual asphalt in the asphalt emulsion.
15. Any asphalt emulsion application is optimum for only one cover aggregate particle size. This is a strong argument for cover stone as nearly one size as possible.
16. Chip spreaders should be calibrated on each project to apply uniformly the quantity of cover aggregate per unit area that has been stipulated, and the asphalt distributor should have been calibrated to spray uniformly the specified quantity of asphalt emulsion per unit area.
17. Before starting to spray asphalt emulsion on any chip seal project, the nozzles in the spray bar should be checked for angle to the spray bar, clogging, damage, and size. The spray bar height should be adjusted and then maintained either by a special mechanism for automatic adjustment, or by chaining or otherwise tying the frame to the axle.
18. Do not proceed with the construction of an asphalt emulsion chip seal if rain is forecast within two hours after completion of the chip seal.

19. The asphalt distributor should not be permitted to start spraying until the chip spreader and loaded trucks are in line and ready to apply the cover stone, and pneumatic-tire rollers are ready to begin rolling the cover aggregate as soon as it has been spread. Otherwise, the asphalt emulsion may break before the cover stone is applied, or before the first pass of a roller over the newly spread cover aggregate has been made.
20. When constructing a chip seal in half-road widths a strip of uncovered asphalt emulsion 3 to 4in. (75 to 100mm) wide should be left along the inside edge when spraying the first half-width, for overlap when spraying the second half-width.
21. To obtain satisfactory transverse joints free from bumps or of flushing and bleeding, the asphalt distributor should start spraying and should preferably stop spraying on a strip of Kraft or building paper placed across the construction lane at right angles to the direction of traffic.
22. For approximately a 50% increase in cost, a double chip seal can be constructed that will ordinarily provide three times the service life of a single chip seal.
23. When constructing a multiple chip seal, to avoid superimposing the same fault at the same location in consecutive layers, the asphalt distributor should be driven in the opposite direction on successive courses.
24. To minimize the damage of flying cover stone particles to motor vehicles, excess cover aggregate should be broomed from a newly constructed chip seal by light sweeping with a rotary power broom as soon as it can be done without damaging the chip seal. Typically, this is done during the cool part of the morning following construction, when the asphalt binder is hardest.
25. To avoid damage by high speed traffic to a newly opened chip seal, control of traffic during this initial critical period is required. The most effective method is convoying traffic over the new chip seal with a pilot vehicle at a speed not exceeding 20 mph (30km/h).

SECTION 5

SANDWICH SEALS USING ASPHALT EMULSIONS

5.1 Scope

This guideline has been prepared for those engaged in chip seal construction who would like to use current equipment to expand the techniques for use in higher traffic and higher stress situations.

Before reading this section, familiarize yourself with **SECTION 4 SINGLE AND MULTIPLE CHIP SEALS USING ASPHALT EMULSIONS** and **SECTION 4 TESTING** of the AEMA's **A Basic Asphalt Emulsion Manual**. Related topics and definitions will not be duplicated here. The same recommendations as to equipment calibration, uniformity of construction practice, soundness and absence of dust in the aggregate, rolling, weather, and traffic control are equally important to the successful use of sandwich seals.

This guide will highlight the materials, application rates, and construction practices unique to sandwich seals.

5.2 Definitions

A Sandwich Seal consists of the uniform application of one course of aggregate to a prepared surface, followed by the application of an asphalt emulsion, which is then followed by the uniform application of a second course of smaller aggregate, which is then rolled.

5.3 Asphalt Emulsion

Sandwich seals are generally constructed with rapid setting high viscosity asphalt emulsions RS-2, HFRS-2, and CRS-2 (ASTM D997 and D2397).

5.3.1 Polymer Modified Asphalt Emulsion

Polymer-modified asphalt emulsions (RS-2P, HFRS-2P, CRS-2P) can be used, and are reported to give improved chip retention and better service life.

For best results, it is good practice to consult your asphalt emulsion supplier, and be guided by their recommendations for any sandwich seal project.

5.4 Aggregates

Aggregates have several characteristics which must be considered with respect to sandwich seals. The ideal aggregates will be a uniform size, fractured, hard, and free from dust or other foreign materials.

Hard aggregates indicate a resistance to breakage and wear. This provides the proper surface texture for longer duration. Uniformly sized aggregates make sandwich seal design easier and more accurate, reduce segregation problems, minimize construction errors, and provide a uniform wearing surface.

Suggested sizes for aggregates are given in **Table 5-1 Suggested Quantities for Sandwich Seals**.

5.5 Construction Techniques

5.5.1 Preparation of Road Surface

Any road repairs should be allowed to cure prior to the sandwich seal. The road surface should be thoroughly cleaned by brooming just prior to construction.

5.5.2 Application of 1st Aggregate

The first aggregate should be spread uniformly over the road surface so as to achieve 60 to 80% coverage. For high traffic roadways or in areas with bleeding, flushing, or excessive crack sealing / filling, rolling of the uncovered aggregate will help orient and seat the large aggregate.

5.5.3 Application of Asphalt Emulsion

The selected asphalt emulsion should be uniformly applied to the uncovered aggregate with a calibrated distributor. The application rate should be based on the preliminary design quantities; incorporating adjustments deemed necessary due to surface condition and traffic.

5.5.4 Application of 2nd Aggregate

The second aggregate should be uniformly spread over the asphalt emulsion to achieve complete coverage of the void space remaining after the application of the first aggregate.

5.5.5 Rolling

The aggregate should be seated with pneumatic rollers. Multiple passes with two or three rollers will ensure consistent operations.

5.5.6 Traffic Control

Traffic speed should be controlled over the freshly applied sandwich seal. This may be accomplished by means of a pilot vehicle. The vehicle should not track the same path with each pass, but rather guide traffic over the entire road surface as much as possible. When a pilot vehicle is not available, care should be taken to slow traffic until the aggregate is firmly seated.

5.5.7 Brooming

A light brooming may be necessary to remove any excess aggregate. Care should be taken not to damage the seal.

5.6 Advantages of Sandwich Seals

There are several advantages to the use of sandwich seals in a comprehensive maintenance program.

1. The use of larger aggregates allows more relative wear before the surface characteristics become unacceptable.
2. Large aggregate also allows better water drainage due to higher surface voids.
3. The smaller aggregates help to key the large aggregate with firm lateral support. This also dissipates the tire stress at the surface layer.
4. Large aggregates allow the use of a generous application of asphalt emulsions which provide a thicker film of asphalt to protect the surface and fill small cracks.
5. Large aggregates and generous asphalt emulsion applications reduce the effect of construction variations.
6. Sandwich seals have proven to be effective on flushed or bleeding surfaces.
7. Sandwich seals reduce minor surface irregularities.
8. The spider effect of crack sealers/fillers appearing through a conventional chip seal is reduced.

Table 5-1 Suggested Quantities for Sandwich Seals

Sandwich Seal Layer	Emulsion App Rate (gal/yd²)	Aggregate Cut (Sieve Size)		Aggregate App Rate (lb/yd²)
		Passing	Retained	
1st	0.55	5/8"	½"	17 to 22
1st	0.50	½"	No 4	13 to 17
2nd	0.55	3/8"	No 4	11 to 15
2nd	0.45 to 0.55	No 4	No 8	7 to 11

SECTION 6

SCRUB SEALS USING ASPHALT EMULSIONS

6.1 Scope

This guideline has been prepared for the benefit of those engaged in scrub seal construction, to highlight items that are essential for achieving consistent, high quality results. Asphalt Emulsions used in scrub seal applications are generally of the medium to slow setting type, anionic, cationic, or non-ionic, such as MS-2, CMS-2, SS-1, SS-1H, CSS-1, CSS-1H and specialty asphalt emulsions developed specifically for scrub sealing. They may or may not be polymer modified. Scrub seals can use a wide range of cover aggregates, which are generally sands or fine crushed aggregates, cinders or chip seal aggregates up to 3/8" (9.5mm). Quantities of asphalt emulsion and cover aggregate to be applied, and relevant construction equipment and construction procedures that are required for successful scrub seals are outlined.

This section has been written as a guide only and should be so employed. User specifications based on this guide should be adapted to job conditions, local usages and anticipated performance requirements.

6.2 Definitions

A scrub seal wearing surface consists of a uniform application of a medium to slow setting asphalt emulsion to a prepared surface followed by an asphalt emulsion scrub broom which sweeps the asphalt emulsion into pores and cracks in the pavement surface. This application is then followed by a uniform application of cover aggregate which is may be 'scrubbed' or rolled into the asphalt emulsion binder with a second aggregate scrub broom (the second broom should only be used with aggregates ¼" (6mm) or smaller). The use of brooms results in a surface treatment which seals surface cracks and binds the cover aggregate intimately with the pavement. Desired surface texture is controlled by selection of cover aggregate.

Where other seals (chip, scrub, slurry, micro surfacing) or paving mixes are subsequently placed over a polymer modified scrub seal, the scrub seal acts as a stress absorbing membrane interlayer or SAMI.

Scrub seals that use very fine aggregates or cinders greatly reduce potential for windshield damage from loose scrub seal aggregate due to the use of scrub brooms and the subsequent well bound aggregate, when compared to traditional chip seal applications. However, when using larger aggregate, larger than ¼" (6mm), care must be taken to keep traffic speeds low until the excess aggregate is removed, typically the morning after application.

• **Dense Surface**—Tight, relatively non-absorbent smooth-textured surface.
• **Open Surface**—Open, relatively porous and absorbent, rough textured surface. This type of surface will require a higher rate of application to compensate for the asphalt emulsion which flows into the large voids and cracks. Most scrub sealed surfaces are open surfaces.

6.3 Applicable Documents

6.3.1 ASTM Documents

- D70 *Test Method for Specific Gravity of Semi-Solid Bituminous Materials*
- D140 *Sampling Bituminous Materials*
- D244 *Standard Methods of Testing Emulsified Asphalts*
- D2170 *Test Method for Kinematic Viscosity of Asphalts*
- D 2171 *Test Method for Viscosity of Asphalts by vacuum Capillary Viscometer*
- D2995 *Practice for Determining Application Rate of Bituminous Distributors*
- C29 *Test Method for Unit Weight and Voids in Aggregate*
- D1139 *Specification for Aggregate for Single or Multiple Bituminous Surface Treatments*

6.3.2 AEMA Documents

A Basic Asphalt Emulsion Manual (BAEM)

6.4 Materials

6.4.1 Asphalt Emulsions

The asphalt emulsions employed for scrub seals should be medium to slow setting anionic or cationic MS-2, CMS-2, SS-1, SS-1H, CSS-1, CSS-1H; ASTM specifications for anionic (SS) asphalt emulsions are listed in D977 and for cationic (CSS) asphalt emulsions in D2397. Suppliers of other specialty asphalt emulsions for scrub sealing should supply specifications for these emulsions. Asphalt emulsions for scrub sealing may be modified with a polymer additive. Polymer-modified asphalt emulsions are generally used for scrub sealing of pavements for a tough, resilient surface, and to minimize future maintenance.

6.4.2 Cover Aggregates

Because scrub seal asphalt emulsions are medium to slow setting, aggregates which may not be desirable (excess fines) for other asphalt emulsion sealing applications often produce an excellent scrub seal.

6.4.2.1 Aggregate Gradation

Aggregates for scrub seal applications are generally 96-100% passing the No. 4 (4.75mm) or ¼ inch (6.30mm) sieve and 2-8% passing the No. 200 (0.075mm) sieve. Larger aggregate, up to 3/8" (9.5mm), can be used successfully on more open or porous surfaces where higher asphalt emulsion application rates are necessary to fill cracks and voids. The Asphalt emulsion supplier and local agencies can offer information on locally available aggregates which have been used successfully in scrub seal applications. Where washed aggregates are used it is very important that they be 'surface dry' at time of application. Excess moisture in fine aggregate for scrub seals can result in a washboard surface under traffic. Moisture content should be specified to be not more than 1.5% by weight of aggregate.

6.4.2.2 Compatibility of Asphalt Emulsion and Aggregate

Compatibility or affinity between an asphalt emulsion and an aggregate can be variable. If there is any doubt as to whether an anionic, cationic or non-ionic asphalt emulsion would be preferable with a given cover aggregate, your AEMA emulsion supplier should be consulted. A Sweep Test, ASTM D-7000, or Aggregate Coating Test, ASTM D6998, may be performed to give an indication of asphalt emulsion-aggregate compatibility.

6.5 Construction Equipment

The basic equipment for constructing a scrub seal should include:

1. Asphalt distributor
2. Asphalt Emulsion scrub broom
3. Cover aggregate spreader, preferably of the mechanical self-propelled type
4. Aggregate scrub broom
5. Rollers, preferably pneumatic-tired
6. Rotary power broom and other cleaning equipment
7. Cover aggregate haul trucks equipped with special hitches for attachment to aggregate spreaders

6.5.1 Asphalt Emulsion Distributor

It is the principal function of the distributor to apply asphalt emulsion uniformly in both transverse and longitudinal directions at the specified rate in gal/yd² (L/m²). Failure to do so can result in streaking in which too much and too little asphalt alternate every few inches (centimeters) across the road surface.

Streaking usually results from incorrect positioning of the nozzles in the spray bar, different nozzle sizes in the spray bar, incorrect spray bar height, damaged or nicked spray nozzles, forcing more or less than the optimum quantity of asphalt emulsion through each spray nozzle, attempting to spray asphalt emulsion that is too high in viscosity or at too low a temperature so that it cannot fan out properly from the spray nozzles, and even by inability of the control mechanism to fully open the spray nozzles in one or more sections of the spray bar.

To avoid streaking, the scrub seal emulsion's viscosity should be within the given specification. Each nozzle in the spray bar of the asphalt distributor should be turned to make the constant angle with the longitudinal axis of the spray bar that is recommended by the manufacturer. All nozzles in the spray bar should be of the same size. The spray bar height should provide double or triple overlap of the asphalt emulsion being applied by the spray nozzles as recommended by the manufacturer. The distributor should be able to spray asphalt emulsion within ±7.5 percent of the average application rate in the longitudinal direction and within ±10.0 percent of the average rate of application for any 4-inch (100mm) width in the transverse direction. A very simple and practical method for checking the rate of application of asphalt emulsion in both the longitudinal and transverse directions is provided by ASTM D2995.

For satisfactory application of asphalt emulsion uniform pressure must be maintained in the spray bar. The optimum pressure discharges asphalt emulsion at a constant rate through each spray nozzle, (e.g., 4gal/min (15.1L/min)). Only at this constant rate of discharge does the asphalt emulsion fan out uniformly from each spray nozzle. Therefore, different rates of application of asphalt emulsion in gal/yd² (L/m²) should be achieved by changing the forward speed of the distributor and not by changing the discharge rate in gal/min (L/min) from each spray nozzle.

Important accessory equipment for each distributor includes an accurate gauge, 6 in. (150mm) in diameter or larger, to indicate pressure in the spray bar, an accurate tachometer to show pump speed in r/min, an accurate thermometer for registering the temperature of the asphalt emulsion in the distributor, a calibrated dipstick to enable gallons (liters) of asphalt binder per inch (millimeter) of depth to be read at any time, and a bitumeter that has been calibrated to accurately measure the distance traveled and the speed in ft/min (m/min) when spraying.

6.5.2 Asphalt Emulsion Scrub Broom

An asphalt emulsion scrub broom is specially designed to sweep the asphalt emulsion into cracks and surface pores manufactured in accordance with **6.7.2 Asphalt Emulsion Scrub Brooms**. Note that additional weight may be added via sand bags, etc. during use if the scrub broom is not making uniform contact with the surface to be sealed.

6.5.3 Cover Aggregate Spreaders

Cover aggregate spreaders may consist of tailgate spreaders, but to obtain a continuous and uniform rate of cover aggregate application, and to keep up with the asphalt distributor, they should preferably be of the mechanical self-propelled type.

Before use on any given job, a mechanical self-propelled aggregate spreader should be calibrated for the particular cover aggregate to be applied. The forward speed of the aggregate spreader during calibration should approximate the speed required to remain close to the distributor. The object of calibration therefore, is the gate opening at this speed that results in the application of cover aggregate by the scrub seal spreader at the rate specified.

Calibrating the aggregate spreader avoids the application of either too little or too much cover aggregate, either of which can be costly. Too little cover aggregate can result in shortened service life, while too much represents a waste of cover aggregate that over a state or province can amount to a loss of many thousands of dollars per annum. Excess cover aggregate can also act as a wedge and pop out imbedded aggregate resulting in additional loss of aggregate. Furthermore, there is a shortage of good quality cover aggregates in some areas. Consequently, by applying the correct quantity of cover aggregate per yd^2 (m^2) a vanishing valuable natural resource is being conserved.

6.5.4 Aggregate Scrub Broom

An aggregate scrub broom may be manufactured in accordance with **6.7.1 Aggregate Scrub Brooms.** Note that additional weight may need to be added to broom during use to ensure uniform contact of broom with aggregate surface.

6.5.5 Rollers

The objective of the rolling operation is to press the cover aggregate firmly into the asphalt emulsion. This improves particle embedment, promotes more thorough wetting and better adhesion between asphalt emulsion and cover aggregate, and achieves better cover aggregate interlock. For single scrub seals, rollers should be of the pneumatic-tire type. No existing surface is entirely smooth, and because of their flexibility, pneumatic tires can reach down into small depressions and press the cover aggregate into the asphalt emulsion. Steel wheel rollers bridge over these depressions. Steel wheel rollers also tend to crush cover aggregate particles.

For an average scrub seal construction operation, a minimum of two rollers should be used.

6.5.6 Rotary Power Broom

A powerful rotary broom is needed to thoroughly clean the existing surface before a scrub seal is applied.

A layer of dust tends to accumulate near the edges of an existing surface which can prevent good bond between the new scrub seal and the old surface. For this reason this layer of dust should be carefully removed with a power broom.

By light brooming, the powered rotary broom should also be used to remove excess cover aggregate from a new scrub seal preferably during the coolness of early morning immediately following the construction of the scrub seal.

6.5.7 Cover Aggregate Trucks

To avoid costly delays in scrub seal construction operations due to lack of cover aggregate an adequate number of dump trucks should be provided.

Each truck should be equipped with a suitable hitch for connection to the aggregate spreader. The trucks should be designed to avoid contact between the truck body and the aggregate spreader at all times and the truck body should be modified if necessary to empty cleanly and completely into the hopper of a self-propelled aggregate spreader. Spillage of cover aggregate onto the road surface when the truck is emptying into the hopper should not be tolerated. The trucks should also vary their back up to chip spreader to not follow the same path. By not following in the same path, the trucks will reduce the darkening of the new surface in that path and will also act as an additional roller on the newly applied surface.

6.6 Construction Operations

The sequence of construction operations is as follows:

1. Adequate preparation, repair, and thorough cleaning of the surface that is to receive the scrub seal. Because they are invariably quite porous, new patches made with pre-mix material should preferably be made several weeks ahead of the scrub seal.
2. Consideration of temperature and weather
3. Spraying the asphalt emulsion
4. Brooming the asphalt emulsion
5. Applying the cover aggregate
6. Brooming the aggregate to achieve a uniform cover aggregate distribution
7. Rolling cover aggregate into scrub seal
8. Sweeping off excess cover aggregate

6.6.1 General Considerations

It cannot be overemphasized that poor scrub seals may result from poor construction practice in spite of the excellent quality of the asphalt emulsion and cover aggregate.

Application rates of both asphalt emulsion and aggregate sufficient to accommodate the degree of oxidation and porosity of the existing surface and the characteristics of the cover aggregate (dense, porous, high in fines, etc.) should be established with the assistance of the asphalt emulsion supplier and an experienced contractor.

6.6.2 Preparation of a Granular or Stabilized Base

The granular or stabilized base should be scarified if necessary, bladed, watered, and rolled to provide a surface that is uniform, firm, smooth, and that conforms to specified profile and cross section.

Immediately after this preliminary preparation, it may be primed with 0.2 to 0.5gal/yd^2 (0.9 to 2.3L/m^2) of a suitable asphalt primer. Priming will be facilitated if the surface is damp, but the use of calcium chloride can hinder penetration of the primer. The grade of primer selected and the quantity to be applied should be completely absorbed into the surface in 24 hours, and depends very largely on the porosity of the surface. In many instances, priming is not required prior to scrub sealing. The recommendation of the asphalt emulsion manufacturer should be taken into consideration.

If a primed surface is to be exposed to traffic for some time, it should be protected by an immediate application of 6 to 10lb/yd² (3.2 to 5.4kg/m²) of clean coarse sand. The priming operation should be completed far enough ahead of the scrub seal to enable the asphalt primer to cure. Depending upon local conditions and the season of the year, this could be from two or three days to two weeks.

Immediately before applying the scrub seal, the primed surface should be broomed with a rotary power broom to remove all loose and foreign material. Hardened patches of mud or clay may have to be removed with a pick and shovel.

6.6.3 Preparation of a Paved Surface

The paved surface should be made as uniform as possible before a scrub seal is applied. In order to prevent subsequent bleeding, all rich patches should be removed, and all holes, depressions, and other defective or distressed areas should be repaired. It cannot be overemphasized that unless a scrub seal is constructed on a uniform surface, the appearance of the scrub seal after several weeks of traffic will not be uniform.

New patches that have been made on the surface will be porous, and may absorb some of the asphalt emulsion applied for the scrub seal. These should be sprayed with 0.1gal/yd² (0.45L/m²) of SS-1h or CSS-1h asphalt emulsion that has been diluted 50 percent (1 + 1) with water, and covered with 6 to 10lb/yd² (3.2 to 5.4kg/m²) of clean coarse sand, for example bank sand, and opened to traffic for two weeks before scrub sealing.

If the old pavement is noticeably porous, it may absorb some of the asphalt emulsion applied for a scrub seal. A simple quick test for porosity of an existing surface is to apply to it a couple of drops of lubricating oil from the dipstick of an automobile. If the surface is porous it will absorb the oil almost immediately. If it is non-porous most of the oil will remain on the surface after 10 minutes. If the existing surface is porous, the application rate should be established to accommodate this porosity as well as to bind the cover aggregate.

Severely pocked (AEMA BAEM Table VI-3) surfaces, also require consideration in establishing the optimum asphalt emulsion application rate.

Scrub seals are designed to accommodate these kinds of surface imperfections and should result in a well sealed and reasonably uniform surface.

Immediately before a scrub seal is constructed, the existing surface should be thoroughly broomed with a rotary broom to re-move all dust and other foreign material. Hardened patches of mud or clay may have to be removed with a pick and shovel.

6.6.4 Temperature and Weather Restraints

The temperature of the surface on which a single scrub seal is to be constructed should be not less than 50°F (10°C) and rising, although some specialized products have been developed for use through a wider range of temperatures. Check with the emulsion supplier for recommended temperature ranges.

A weather forecast that no rain is expected for a minimum period of 24 hours is essential.

6.6.5 Spraying the Asphalt Emulsion

Five very important items that can be easily checked are:

1. Alignment of the nozzles in the spray bar
2. That all spray nozzles are of the same size, and are not nicked or otherwise damaged
3. That every spray nozzle is free from even partial clogging, is clean, and can spray normally
4. Height of spray bar above the road surface
5. Recommended application temperature for emulsion is 125 to 185°F (52 to 85°C).

Unless the distributor has been calibrated for its ability to spray the specified quantity of asphalt emulsion uniformly over every 0.1 yd^2 (m^2) of surface, this should be checked. It is not enough to determine that the total gallons applied to a measured section of road surface is correct. This tells nothing about the uniformity of application transversely across the sprayed width.

When necessary adjustments have been made, the distributor should be able to make a uniform application of asphalt emulsion at the rate specified. Before spraying begins, a line should be placed along one edge of the road as a guide. This line may consist of string or even suitably spaced small rocks. To protect concrete curbs in urban areas a removable shield may be attached to the pertinent end of the spray bar.

The distributor should not be permitted to start spraying until the asphalt emulsion broom, aggregate spreader, aggregate broom, loaded trucks and rollers are in line and ready to proceed.

The asphalt emulsion should preferably be sprayed full width. Best practices are to leave an inside strip of uncovered asphalt emulsion 3 to 4 in. (75 to 100mm) wide should be left when constructing the first half, to provide center joint overlap when the second half of the scrub seal is placed. To obtain smooth, well-constructed transverse joints, the distributor should always begin and preferably stop spraying on a strip of Kraft or building paper placed across the lane under construction at right angles to the direction of traffic.

6.6.6 Scrubbing the Asphalt Emulsion

The tractor or distributor pulled Asphalt emulsion scrub broom should follow immediately behind the distributor scrubbing the asphalt emulsion into the cracks and voids. Weight may be added to the scrub broom to assure adequate and uniform filling of cracks and voids with asphalt emulsion.

6.6.7 Applying the Cover Aggregate

The gate openings of aggregate spreader should be adjusted to produce the desired application rate.

Truckloads of cover aggregate should be in position before any asphalt emulsion is applied. When scrubbing of asphalt emulsion begins, the aggregate spreader should follow within a distance of 50 to 150ft (15 to 50m). This distance is needed for a layer of asphalt emulsion of more uniform thickness to develop under the influence of gravity.

A self-propelled aggregate spreader should pull the truck, which should be in neutral gear.

Use of a tachometer assists in maintaining a uniform forward speed of the aggregate spreader.

Oversize cover aggregate particles and other foreign material can interfere with the uniform application of the cover aggregate by partially clogging the gate opening of the aggregate spreader. This can result in streaking and should not be tolerated.

Note: The cover aggregate may be damp when applied, but should never be wet.

When cover aggregate is spilled on to the scrub seal it should be removed with hand shovels. In small areas where not enough cover aggregate has been applied, broadcasting cover aggregate with hand shovels from a truck can be employed to make up the deficiency.

6.6.8 Scrubbing the Cover Aggregate

When scrubbing fine aggregates (¼" (6mm) and smaller) a tractor pulled cover aggregate (sand) broom shall immediately follow the aggregate spreader. For aggregates larger than ¼" (6mm), no secondary broom should be used because damage to the seal will result. Weight may be added to the sand broom to assure uniform and adequate scrubbing of the sand cover aggregate into the asphalt emulsion.

6.6.9 Rolling

Rolling should begin as soon as possible after the cover aggregate has been Scrubbed or applied, and one pass of a roller should be made before the asphalt emulsion breaks.

On scrub seal projects of average size, two pneumatic-tired rollers should make one or two initial passes over the cover aggregate before the asphalt emulsion breaks. A third pass should be made after the asphalt emulsion has broken for uniform seating of the cover aggregate particles. Aggregate trucks will also assist with rolling the cover aggregate into the pavement. These trucks should be staggered to optimize rolling patterns on the pavement.

Rolling should proceed from the outer edge to the center, with each pass overlapping the previous pass by one-half.

6.6.10 Removing Surplus Cover Aggregate

When specifying the quantity of cover aggregate to be applied, some allowance must be made for loss of cover aggregate due to whip-off and unevenness of spread. consequently, the quantity of cover aggregate applied exceeds by 2 to 10 percent of the amount that will remain in the scrub seal. This surplus aggregate may be removed by light brooming with a power broom during the cool morning after construction, when the asphalt binder is reasonably hard. Care must be taken to avoid turning over any of the cover aggregate particles embedded in asphalt.

6.6.11 A Helpful Check List for a Successful Scrub Seal Project:

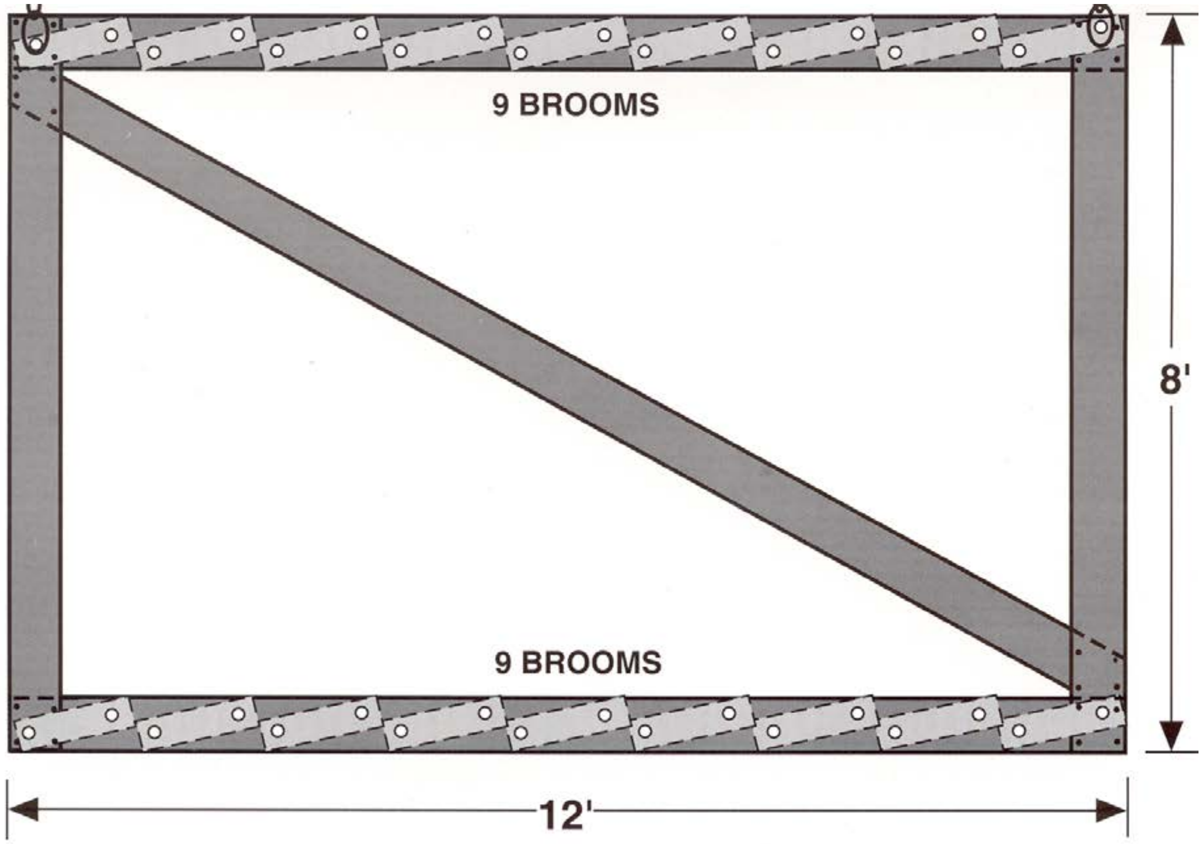
A number of items will help to insure a successful scrub seal project:

1. Never permit anionic and cationic asphalt emulsions to be mixed because this will cause each asphalt emulsion to break, leaving tanks or other equipment partially filled with semi-solid asphalt, and a difficult cleaning job.
2. Thoroughly wash out, with approved product, any equipment in which an anionic asphalt emulsion has been used before using it for a cationic asphalt emulsion and vice versa.
3. At the end of each day, flush out, with approved product, the pumping and spraying system on the asphalt distributor. This will avoid clogging, binding, or seizure if the asphalt emulsion otherwise left in this system should break.
4. Do not allow asphalt emulsion to either freeze or boil — it will break.
5. When pumping asphalt emulsions, keep the end of the discharge pipe submerged in emulsion to avoid entrapment of air and foaming. This may also cause emulsion to break.
6. Avoid tight fitting pumps when pumping asphalt emulsion. They may bind and seize due to breaking of the asphalt emulsion.
7. Avoid excessive pumping or handling of asphalt emulsions, because this can result in a reduction of their viscosity.
8. Have a clear mental image of what an excellent scrub seal looks like as a target for achievement.
9. For scrub seals, tailor more rapid setting asphalt emulsions to break after the first pass of a roller has been made immediately behind the aggregate spreader, which in turn should follow 50 to 150ft (15 to 50m) after the distributor.
10. A lack of uniformity of texture in an old asphalt surface that is to be scrub sealed will result in a lack of uniformity in the finished scrub seal. Therefore, rich patches or flushed and bleeding areas may be repaired before a scrub seal is applied.

11. Since they tend to be porous and could absorb a portion of the asphalt emulsion applied, new patches on an old pavement should be placed several weeks before a scrub seal is constructed, so as to obtain compaction and closing up by traffic.
12. The quantity of cover aggregate to be applied per unit area for a scrub seal depends on the aggregate gradation and nominal size.
13. The quantity of asphalt emulsion to be applied per unit area for a scrub seal depends upon the gradation of the cover aggregate, the texture of the surface on which the scrub seal is to be placed, and the percent residual asphalt in the asphalt emulsion.
14. Aggregate spreaders should be calibrated on each project to apply uniformly the quantity of cover aggregate per unit area that has been stipulated, and the asphalt distributor should have been calibrated to spray uniformly the specified quantity of asphalt emulsion per unit area.
15. Before starting to spray asphalt emulsion on any scrub seal project, the nozzles in the spray bar should be checked for angle to the spray bar, clogging, damage, and size. The spray bar height should be adjusted and maintained either by a special mechanism for automatic adjustment, or by chaining or otherwise tying the frame to the axle.
16. Do not proceed with the construction of an asphalt emulsion scrub seal if rain is impending within four hours after completion of the scrub seal.
17. The asphalt distributor should not be permitted to start spraying until the brooms, aggregate spreader and loaded trucks are in line and ready to apply the cover aggregate, and pneumatic-tire rollers are ready to begin rolling the cover aggregate as soon as it has been spread.
18. When constructing a scrub seal in half-road widths a strip of uncovered asphalt emulsion 3 to 4in. (75 to 100mm) wide should be left along the inside edge when spraying the first half-width, for overlap when spraying the second half width.
19. To obtain satisfactory transverse joints free from the common faults of bumps or flushing and bleeding, the asphalt distributor should start spraying and should preferably stop spraying on a strip of Kraft or building paper placed across the construction lane at right angles to the direction of traffic.
20. To avoid damage by high speed traffic to a newly opened scrub seal, control of traffic during this initial critical period is required. The most effective method is convoying traffic over the new scrub seal with a half-ton (half-tonne) truck at a speed not exceeding 20 mph (30km/h).

6.7 Aggregate and Asphalt Emulsion Scrub Brooms

6.7.1 Aggregate Scrub Brooms



2 - 2 x 6 x 8 ft
2 - 2 x 6 x 12 ft
1 - 2 x 6 x 14 ft
18 - Street Broom
3½"W x 6"H x 16"L

62 - 5/16 nuts
62 - 5/16 flat washers
62 - 5/16 lock washers
62 - 5/16 x 5 in. carriage bolts
2 - 3/8" x 2' chain w/ hooks
2 - 3/8" x 6' bolts w/ nuts, locks, and washers

 = Street Broom w/ nylon bristles

 = 3/8" Chain with hooks

6.7.2 Asphalt Emulsion Scrub Brooms

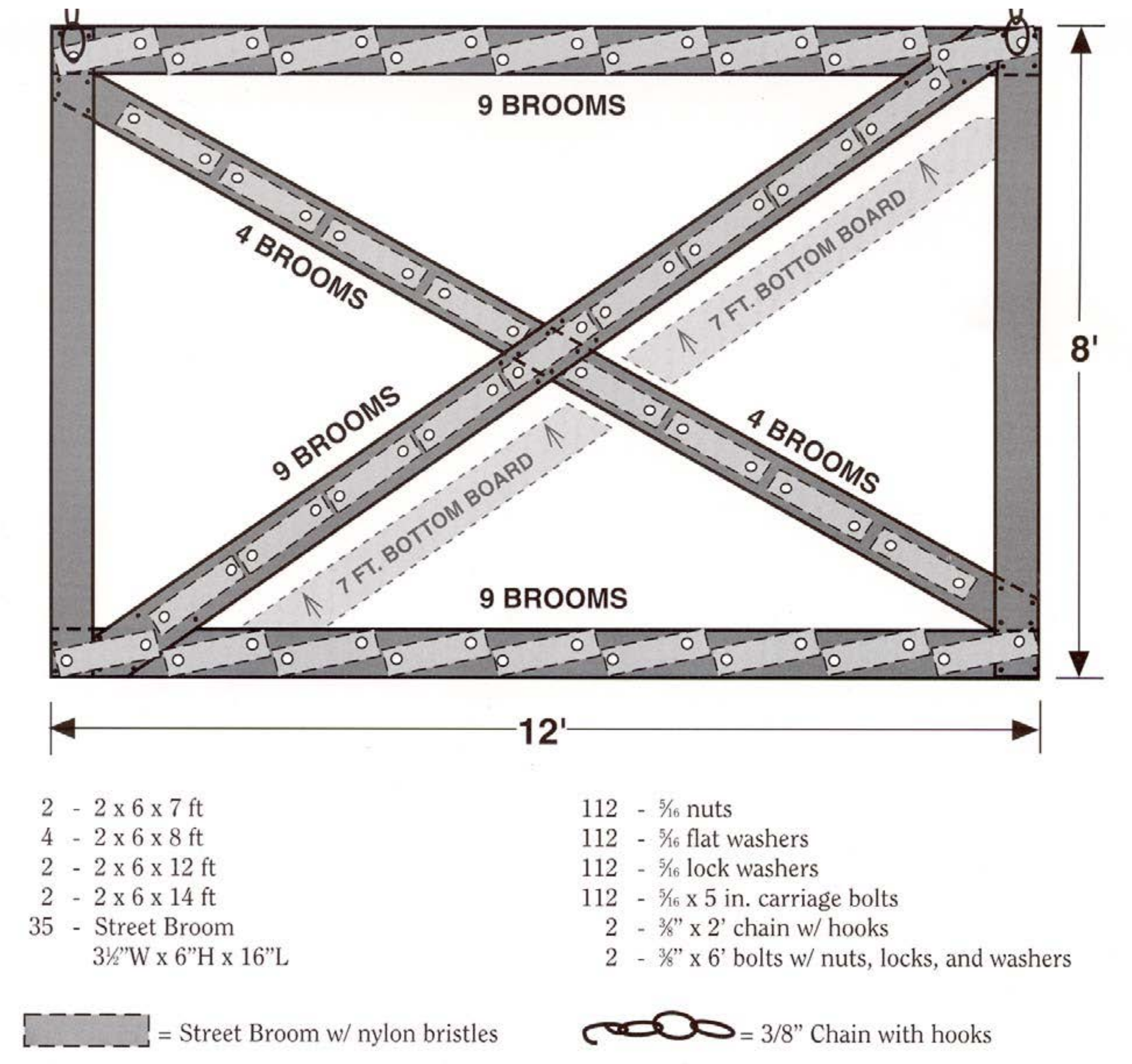


Figure 6-2 Asphalt Emulsion Scrub Brooms

SECTION 7

RECOMMENDED PERFORMANCE GUIDELINES FOR EMULSIFIED ASPHALT SLURRY SEAL

International Slurry Surfacing Association
800 Roosevelt Road, Building C-312
Glen Ellyn, IL 60137
Phone: 630-942-6577
www.slurry.org

A105 (Revised)

February 2010

NOTICE

It is not intended or recommended that this guideline be used as a verbatim specification. It should be used as an outline, helping user agencies establish their particular project specification. Users should understand that almost all geographical areas vary as to the availability of materials. An effort should be made to determine what materials are reasonably available, keeping in mind system compatibility and specific job requirements. Contact ISSA for answers to questions and for a list of ISSA member contractors and companies.

7.1 Scope

The intent of this guideline is to aid in the design, testing methods, quality control, measurement and payment procedures for the application of Emulsified Asphalt Slurry Seal Surfacing.

7.2 Description

The slurry seal shall consist of a mixture of an approved emulsified asphalt, mineral aggregate, water, and specified additives, proportioned, mixed and uniformly spread over a properly prepared surface as directed by the Buyer's Authorized Representative (B.A.R.). The slurry seal shall be applied as a homogeneous mat, adhere firmly to the prepared surface, and have a skid-resistant texture throughout its service life.

7.3 Applicable Specifications

7.3.1 General

There are agencies and testing methods listed in the appendix (see **7.14 Appendix A: Agencies and Test Methods**) which form a part of this guideline.

It is not normally required to run all tests on every project. A compilation of results from the listed tests should be indicative of system performance. Failure to meet specification for an individual test does not necessarily disqualify the system. If, for example, the system to be used on the project has a record of good performance, individual requirements for testing may be waived. Agency and testing methods are listed in the appendix (see Appendix A) and form a part of this guideline.

7.4 Materials

7.4.1 Emulsified Asphalt

The emulsified asphalt, and emulsified asphalt residue, shall meet the requirements of AASHTO M 140 or ASTM D 977 for SS-1 or SS-1h. For CSS-1, CSS-1h, or CQS-1h, it shall meet the requirements of AASHTO M 208 or ASTM D 2397. Each load of emulsified asphalt shall be accompanied with a Certificate of Analysis/Compliance to indicate that the emulsion meets the specifications.

7.4.1.1 Quality Tests

Each load of emulsified asphalt shall be accompanied with a Certificate of Analysis/ Compliance to assure that it is the same as that used in the mix design.

Table 7-1 Quality Test Methods

AASHTO Test Method	ASTM Test Method	Purpose	Specification
TEST ON EMULSION			
AASHTO T59	ASTM D244	Residue After Distillation	60% Minimum
TEST ON RESIDUE			
AASHTO T49	ASTM 2397	Penetration of Residue	40-90[1]

NOTES: 1. Climate conditions should be considered when establishing this band.

7.4.2 Aggregate

7.4.2.1 General

The mineral aggregate used shall be the type and grade specified for the particular use of the slurry seal. The aggregate shall be manufactured crushed stone such as granite, slag, limestone, chat, or other high-quality aggregate, or combination thereof. To assure the material is totally crushed, 100 percent of the parent aggregate will be larger than the largest stone in the gradation to be used.

7.4.2.2 Quality Tests

When tested according to the following tests shown in **Table 7-2 Quality Test Numbers**, the aggregate will meet these requirements.

Table 7-2 Quality Test Numbers

AASHTO Test No.	ASTM Test No.	Quality	Specification
AASHTO T176	ASTM D2419	Sand Equivalent	45 Minimum
AASHTO T104	ASTM C88	Soundness	15% Maximum using Na_2SO_4 or 25% Maximum using $MgSO_4$
AASHTO T96	ASTM C131	Abrasion Resistance	35% Maximum

The abrasion test is to be run on the aggregate before it is crushed.

7.4.2.3 Grading

When tested in accordance to AASHTO T27 (ASTM C136) and AASHTO T11 (ASTM C117), the target (mix design) aggregate gradation (including the mineral filter) shall be within one of the following bands (or of one currently recognized by your local paving authority) as shown in **Table 7-3 Grading Percents**.

The gradation of the aggregate stockpile shall not vary by more than the stockpile tolerance from the mix design gradation (indicated in the table above) while also remaining within the specification gradation band. The percentage of aggregate passing any two successive sieves shall not change from one end of the specified range to the other end.

The aggregate will be accepted at the job location or stockpile based on five gradation tests sampled according to AASHTO T 2 (ASTM D 75). If the average of the five tests is within the stockpile tolerance from the mix design gradation, the material will be accepted. If the average of those test results is out of specification or tolerance, the contractor will be given the choice to either remove the material or blend additional aggregate with the stockpile material to bring it into compliance. Materials used in blending must meet the required aggregate quality test specifications in Section 4.2.2 before blending and must be blended in a manner to produce a consistent gradation. Aggregate blending may require a new mix design.

Screening shall be required at the stockpile if there are any problems created by oversized materials in the mix.

Type I. This aggregate gradation is used to fill surface voids, address moderate surface distresses, and provide protection from the elements. The fineness of this mixture provides the ability for some crack penetration.
Type II. This aggregate gradation is used to fill surface voids, address more severe surface distresses, seal, and provide a durable wearing surface.

Type III. This aggregate gradation provides maximum skid resistance and an improved wearing surface.

Table 7-3 Grading Percent

Sieve Size	Type 1 Percent Passing	Type 2 Percent Passing	Type 3 Percent Passing	Stockpile Tolerance
3/8 (9.5 mm)	100	100	100	
# 4 (4.75 mm)	100	90-100	70-90	± 5%
# 8 (2.36 mm)	90-100	65-90	45-70	± 5%
# 16 (1.18 mm)	65-90	45-70	28-50	± 5%
# 30 (600 µm)	40-65	30-50	19-34	± 5%
# 50 (330 µm)	25-42	18-30	12-25	± 4%
#100 (150 µm)	15-30	10-21	7-18	± 3%
#200 (75 µm)	10-20	5-15	5-15	± 2%

7.4.3 Mineral Filler

Mineral filler may be used to improve mixture consistency and to adjust mixture breaking and curing properties. Portland cement, hydrated lime, limestone dust, fly ash, or other approved filler meeting the requirements of ASTM D 242 shall be used if required by the mix design. Typical use levels are normally 0.0 - 3.0 percent and may be considered part of the aggregate gradation.

7.4.4 Water

The water shall be free of harmful salts and contaminants. If the quality of the water is in question, it should be submitted to the laboratory with the other raw materials for the mix design.

7.4.5 Additives

Additives may be used to accelerate or retard the break/set of the slurry seal. Appropriate additives, and their applicable use range, should be approved by the laboratory as part of the mix design.

7.5 Laboratory Evaluation

7.5.1 General

Before work begins, the contractor shall submit a signed mix design covering the specific materials to be used on the project. This design will be performed by a laboratory that has experience in designing Emulsified Asphalt Slurry Seal Surfacing. After the mix design has been approved, no substitution will be permitted unless approved by the B.A.R. ISSA can provide a list of laboratories experienced in testing slurry seal materials for mix designs.

7.5.2 Mix Design

The contractor shall submit to the B.A.R. for approval a complete mix design prepared and certified by the laboratory. Compatibility of the aggregate, emulsion, mineral filler, and other additives shall be evaluated in the mix design. The mix design shall be completed using materials consistent with those supplied by the contractor for the project.

Recommended tests and values are shown in **Table 7-4 Mix Design Tests.**

Table 7-4 Mix Design Tests

ISSA Test No.	Description	Specification
TB 106	Slurry Seal Consistency	2 cm to 3 cm
TB 139	Wet Cohesion 30 Minutes Minimum (Set) [1] Wet Cohesion 60 Minutes Minimum	12 kg-cm Minimum 20 kg-cm Minimum
TB 109	Excess Asphalt by LWT Sand Adhesion [2]	50 g/ft2 Maximum (538 g/m2)
TB 114	Wet Stripping	Pass (90% Minimum)
TB 100	Wet-Track Abrasion Loss, One-Hour Soak	75 g/ft² (807 g/m²)
TB 113	Mix Time1	Controllable to 180" Minimum

Note 1 = For Quick Traffic only
Note 2 = For Heavy Traffic Only

The Wet Track Abrasion Test is performed under laboratory conditions as a component of the mix design process. The purpose of this test is to determine the minimum asphalt content required in a slurry seal system. The Wet Track Abrasion Test is not recommended as a field quality control or acceptance test. ISSA TB 136 describes potential causes for inconsistent results of the Wet Track Abrasion Test.

The mixing test is used to predict the time the material can be mixed before it begins to break. It can be a good reference check to verify consistent sources of material. The laboratory should verify that mix and set times are appropriate for the climatic conditions expected during the project.

The laboratory shall also report the quantitative effects of moisture content on the unit weight of the aggregate (bulking effect) according to AASHTO T19 (ASTM C29). The report must clearly show the proportions of aggregate, mineral filler (if used) and emulsified asphalt based on the dry weight of the aggregate.

The percentages of each individual material required shall be shown in the laboratory report. Based on field conditions, adjustments within the specific ranges of the mix design may be required.

The B.A.R. shall approve the mix design and all slurry seal materials and methods prior to use. The component materials shall be within the following limits as shown in **Table 7-5 Component Limits**.

Table 7-5 Component Limits

Component Materials (Based on dry weight of aggregate)	Limits
Residual Asphalt	Type I: 10 - 16% Type II: 7.5 - 13.5% Type III: 6.5 - 12%
Mineral Filler	0 - 3.0%
Additives	As Needed
Water	As needed to achieve proper mix consistency

7.5.3 Mix Tolerances

Tolerances for individual materials as well as the slurry seal mixture are as follows:

a. After the residual asphalt content is determined, a variation ±1% by weight of dry aggregate will be permitted.
b. The slurry consistency, as determined according to ISSA TB No. 106, shall not vary more than ± 0.2” (± 0.5 cm) from the job mix formula after field adjustments.
c. The rate of application shall not vary more than ± 2 lb/yd2 (± 1.1 kg/m2) when the surface texture does not vary significantly.

7.6 Equipment

7.6.1 General

All equipment, tools, and machines used in performance of this work shall be maintained in satisfactory working condition at all times.

7.6.2 Mixing Equipment

The machine shall be specifically designed and manufactured to apply slurry seal. The material shall be mixed by an automatic-sequenced, self-propelled, slurry seal mixing machine of either truck-mounted or continuous-run design. Continuous-run machines are those that are equipped to self-load materials while continuing to apply slurry seal. Either type machine shall be able to accurately deliver and proportion the mix components through a mixer and to discharge the mixed product on a continuous-flow basis. Sufficient storage capacity for all mix components is required to maintain an adequate supply to the proportioning controls.

The B.A.R. should decide which type of equipment best suits the specific project. In some cases, truck-mounted machines may be more suited, i.e. cul-de-sacs, small narrow roadways, parking lots, etc. On some projects, continuous-run equipment may be chosen due to the continuity of mix and the reduction of start-up joints. Generally, truck-mounted machines or continuous-run machines may be used on similar projects.

If continuous-run equipment is used, the machine shall provide the operator with full control of the forward and reverse speeds during application of the slurry seal. It shall be equipped with a self-loading device and opposite-side driver stations. The self-loading device, opposite-side driver stations, and forward and reverse speed controls shall be of original-equipment manufacturer design.

7.6.3 Proportioning Devices

Individual volume or weight controls for proportioning mix components shall be provided and properly labeled. These proportioning devices are used in material calibration to determine the material output at any time.

7.6.4 Spreading Equipment

The mixture shall be placed uniformly by means of a spreader box attached to the paver and mechanically equipped, if necessary, to agitate and spread the material evenly throughout the box. With some quick-set systems, mechanical agitation may extend mix time. The slurry seal mixture shall have the proper consistency as it enters the spreader box. Spraying of additional water into the spreader box will not be permitted.

A front seal shall be utilized to ensure no loss of the mixture at the road contact point. The rear seal shall act as final strike-off and shall be adjustable. The spreader box and rear seal shall be designed and operated to provide uniform mix consistency behind the box. The spreader box shall have suitable means to side shift to compensate for variations in the pavement width. A burlap drag or other approved screed may be attached to the rear of the spreader box to provide a highly textured uniform surface. A drag stiffened by hardened slurry is ineffective and should be replaced immediately.

7.6.5 Auxiliary Equipment

Suitable surface preparation equipment, traffic control equipment, hand tools, and other support and safety equipment necessary to perform the work shall be provided by the contractor.

7.7 Calibration

Each mixing unit to be used in performance of the work shall be calibrated in the presence of the B.A.R. prior to the start of the project. Previous calibration documentation covering the exact materials to be used may be acceptable, provided the calibration was performed during the previous 60 days. The documentation shall include an individual calibration of each material at various settings, which can be related to the machine's metering devices. Any equipment replacement affecting material proportioning requires that the machine be recalibrated. No machine will be allowed to work on the project until the calibration has been accepted. ISSA Inspector's Manual describes a method of machine calibration. ISSA contractors and/or machine manufacturers may also provide methods of machine calibration.

7.8 Weather Limitations

The slurry seal shall not be applied if either the pavement or air temperature is below 50oF (10oC) and falling, but may be applied when both pavement and air temperatures are above 45oF (7oC) and rising. No slurry seal shall be applied when there is the possibility of freezing temperatures at the project location within 24 hours after application. The mixture shall not be applied when weather conditions prolong opening to traffic beyond a reasonable time.

7.9 Notification and Traffic Control

7.9.1 Notification

Homeowners and businesses affected by the paving shall be notified at least one day in advance of the surfacing. Should work not occur on the specified day, a new notification will be distributed. The notification shall be posted in written form, stating the time and date that the surfacing will take place. If necessary, signage alerting traffic to the intended project should be posted.

7.9.2 Traffic Control

Traffic control devices shall be in accordance with agency requirements and, if necessary, conform to the requirements of the Manual on Uniform Traffic Control Devices. Opening to traffic does not constitute acceptance of the work.

In areas that are subject to an increased rate of sharp-turning vehicles, additional time may be required for a more complete cure of the slurry seal mat to prevent damage. Tire marks may be evident in these areas after opening but typically diminish over time with rolling traffic.

7.10 Surface Preparation

7.10.1 General

Prior to applying the slurry seal, loose material, oil spots, vegetation, and other objectionable material shall be removed. Any standard cleaning method will be acceptable. If water is used, cracks shall be allowed to dry thoroughly before slurry surfacing. Manholes, valve boxes, drop inlets and other service entrances shall be protected from the slurry seal by a suitable method. The B.A.R. shall approve the surface preparation prior to surfacing.

7.10.2 Tack Coat

Normally, tack coat is not required unless the surface to be covered is extremely dry and raveled or is concrete or brick. If required, the emulsified asphalt should be SS, CSS, or the slurry seal emulsion. Consult with the slurry seal emulsion supplier to determine dilution stability. The tack coat may consist of one part emulsified asphalt/three parts water and should be applied with a standard distributor. The distributor shall be capable of applying the dilution evenly at a rate of 0.05-0.15 gal/yd2 (0.23-0.68 l/m2). The tack coat shall be allowed to cure sufficiently before the application of slurry seal. If a tack coat is to be required, it must be noted in the project plans.

7.10.3 Cracks

It is recommended to treat cracks wider than 0.25” (0.64cm) in the pavement surface with an approved crack sealer prior to application of the slurry seal.

7.11 Application

7.11.1 General

If required, it is recommended that a test strip be placed in conditions similar to those expected to be encountered during the project.

The surface may be wetted with water ahead of the spreader box. The rate of application of the water spray shall be adjusted during the day to suit temperature, surface texture, humidity, and dryness of the pavement. Pooling or standing water shall be avoided.

The slurry seal shall be of the desired consistency upon exiting the mixer. A sufficient amount of material shall be carried in all parts of the spreader box at all times so that complete coverage is achieved. Overloading of the spreader shall be avoided.

No lumping, balling, or unmixed aggregate shall be permitted.

Significant streaks, such as those caused by oversized aggregate or broken mix, shall not be left in the finished surface. If excessive streaking occurs, the job will be stopped until the cause of the problem has been corrected. Some situations may require screening the aggregate prior to loading it into the units going from the stockpile area to the jobsite.

7.11.2 Rate of Application

The slurry seal mixture shall be of the proper consistency at all times so as to provide the application rate required by the surface condition. The average application rate shall be in accordance with the information in **Table 7-6 Application Rates**.

Table 7-6 Application Rates

Aggregate Type	Location	Suggested Application Rate
Type I	Park Areas Urban and Residential Streets Airport Runways	8 - 12 lb/yd² (4.3 – 6.5 kg/m²)
Type II	Urban and Residential Streets Airport Runways	8 - 12 lb/yd² (4.3 – 6.5 kg/m²)
Type III	Primary and Interstate Routes	18 - 30 lb/yd² (9.8 – 16.3 kg/m²)

Suggested application rates are based upon the weight of dry aggregate in the mixture. Application rates are affected by the unit weight and gradation of the aggregate and the demand of the surface to which the slurry seal is being applied.

7.11.3 Joints

No excess buildup, uncovered areas, or unsightly appearance shall be permitted on longitudinal or transverse joints. The contractor shall provide suitable equipment to produce a minimum number of longitudinal joints throughout the project. When possible, a longitudinal joint shall not be placed in a wheel path. Less than full box width passes will be used only as required. If less than full box width passes are used, they shall not be the last pass of any paved area. A maximum of 6” (15.2 cm) shall be allowed for overlap of longitudinal joints.

7.11.4 Mixture

The slurry seal shall possess sufficient stability so that premature breaking of the material in the spreader box does not occur. The mixture shall be homogeneous during and following mixing and spreading. It shall be free of excess liquids which create segregation of the aggregate. Spraying of additional water into the spreader box will not be permitted.

7.11.5 Handwork

Areas which cannot be accessed by the mixing machine shall be surfaced using hand squeegees to provide complete and uniform coverage. If necessary, the area to be handworked shall be lightly dampened prior to mix placement. Handwork shall exhibit the same finish as that applied by the spreader box and shall be completed prior to final surfacing.

7.11.6 Lines

Care shall be taken to apply straight lines along curbs, shoulders, and intersections. No run-off on these areas will be permitted. Roofing felt or heavy plastic may be used to begin or end a pull cleanly. This also provides for easy removal of excess slurry.

7.11.7 Rolling

Rolling is usually not necessary for slurry seal on roadways. Airports and parking areas should be rolled by a self-propelled, 10-ton (maximum) pneumatic tire roller equipped with a water spray system. All tires should be inflated per manufacturer’s specifications. Rolling shall not start until the slurry has cured sufficiently to avoid damage by the roller. Areas which require rolling shall receive a minimum of two (2) full coverage passes.

7.11.8 Clean-up

All utility access areas, gutters and intersections, shall have the slurry seal removed as specified by the B.A.R. The contractor shall remove any debris associated with the performance of the work on a daily basis.

7.12 Quality Control

7.12.1 Inspection

Inspectors assigned to projects must be familiar with the materials, equipment and application of slurry seal. Local conditions and specific project requirements should be considered when determining the parameters of field inspection.

Proper mix consistency should be one of the major areas of inspector concern. If mixes are too dry, streaking, lumping and roughness will be present in the mat surface. Mixes applied too wet will flow excessively and not hold straight lane lines. Excessive liquids may also cause an asphalt-rich surface with segregation.

7.12.2 Materials

To account for aggregate bulking, it is the responsibility of the contractor to check stockpile moisture content and to set the machine accordingly. At the B.A.R.'s discretion, material tests may be run on representative samples of the aggregate and emulsion. Tests will be run at the expense of the buyer. The buyer must notify the contractor immediately if any test fails to meet the specifications.

7.12.3 Slurry Seal

If required, representative samples of the slurry seal may be taken directly from the slurry unit(s). Consistency (ISSA TB No. 106) and residual asphalt content (ASTM D2172) tests may be run on the samples. Please note that the consistency test may not be applicable to certain Quick-Set and Quick-Traffic systems because of erratic results due to setting characteristics. If this test is run, it must be performed immediately after the sample is taken. Tests will be run at the expense of the buyer. The buyer must notify the contractor immediately if any test fails to meet specifications.

Data obtained from the proportioning devices on the slurry seal unit may be used to determine individual material quantities and application rate.

7.12.4 Non-Compliance

If any two successive tests fail on the stockpile aggregate, the job shall be stopped. If any two successive tests on the mix from the same machine fail, the use of the machine shall be suspended. It will be the responsibility of the contractor, at his expense, to prove to the B.A.R. that the problems have been corrected.

7.13 Payment

The slurry seal shall be measured and paid for by the unit area or weight of aggregate and the weight of emulsion used on the work completed and accepted by the buyer. If paid by the weight of the aggregate and emulsified asphalt, the contractor shall submit to the B.A.R. certified delivery tickets which show quantities of each material delivered to the job site and used on the project. Payment shall be full compensation for all preparation, mixing and application of materials, and for all labor, equipment, tools, testing, cleaning, and incidentals necessary to complete the job as specified herein.

7.14 Appendix A: Agencies and Test Methods

7.14.1 Agencies

American Association of State Highway and Transportation Officials (AASHTO)

American Society for Testing and Materials (ASTM)

[International Slurry Surfacing Association (ISSA)]

7.14.2 Test Methods

Table 7-7 Aggregate and Mineral Filler

AASHTO Test No.	ASTM Test No.	Test
AASHTO T2	ASTM D75	Sampling Mineral Aggregates
AASHTO T27	ASTM C136	Sieve Analysis of Aggregates
AASHTO T11	ASTM C117	Materials Finer than No. 200 in Mineral Aggregates
AASHTO 176	ASTM D2419	Sand Equivalent Value of Soils and Fine Aggregate
AASHTO T19	ASTM C29	Unit Weight of Aggregate
AASHTO T96	ASTM C131	Resistance to Abrasion of Small Size Coarse Aggregate by Use of the Los Angeles Machine
AASHTO T104	ASTM C88	Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
AASHTO M-17	ASTM D242	Mineral Filler for Bituminous Paving Mixtures

Table 7-8 Emulsified Asphalt

AASHTO Test No.	ASTM Test No.	Test
AASHTO T40	ASTM D140	Sampling Bituminous Materials
AASHTO T59	ASTM D244	Test Methods and Practices for Emulsified Asphalt
AASHTO M140	ASTM D977	Specification for Emulsified Asphalt
AASHTO M208	ASTM D2397	Specification for Cationic Emulsified Asphalt

Table 7-9 Residue from Emulsion

AASHTO Test No.	ASTM Test No.	Test
AASHTO T59	ASTM D244	Residue by Evaporation
AASHTO T49	ASTM C2397	Penetration 3.5 oz (100 gm) at 5 Seconds 77°F (25°C)

Table 7-10 Slurry Seal System

ISSA Test Method	Test
T100	Test Method for Wet Track Abrasion of Slurry Surfaces
T101	Guide for Sampling Slurry Mix for Extraction Test
TB106	Measurement of Slurry Seal Consistency
TB109	Test Method for Measurement of Excess Asphalt in Bituminous Mixtures by Use of a Loaded-Wheel Tester
TB111	Outline Guide Design Procedure for Slurry Seal
TB112	Method of Estimate Slurry Seal Spread Rates and To Measure Pavement Macro texture
TB113	Trial mix Procedure for Slurry Seal Design
T114	Wet Stripping Test for Cured Slurry Seal Mixes
T115	Wet Stripping Test for Cured Slurry Seal Mixes
T139	Method of Classified Emulsified Asphalt, Aggregate Mixtures by Modified Cohesion Test Measurement of Set and Cure Characteristics
A105	Design, Testing, and Construction of Slurry Seal

NOTES:

ASTM D 3910, Standard Practice for Design, Testing, and Construction of Slurry Seal, is a combined reference of the ISSA Test Bulletins listed above.
ASTM D 2172, Standard Test Methods for Quantitative Extraction of Bitumen From Bituminous Paving Mixtures, is referenced in Section 12.3.

7.15 Appendix B: Instructions To The Writer

This specification is written as a guideline and should be used as such. It is not intended to be copied verbatim. The writer should thoroughly read the guideline and determine what is and is not applicable. Feel free to contact the **ISSA** for answers to any questions and also for a list of **ISSA** member contractors and companies who could assist.

This specification is written to cover a conventional slurry seal system. It is not applicable to micro surfacing. Consult the **ISSA** for information on modified systems.

7.15.1 Technical Notes

7.15.1.1 Slurry Seal

To be sure all the water is removed from the slurry before running, ASTM D2172, ASTM D95 or ASTM D1461 should be run. Some laboratories have modified ASTM D95 to permit removing of the water and bitumen at the same time.

7.15.1.2 Emulsified Asphalt

The cement mixing test determines the emulsion mix-ability. However, this is best determined by the laboratory using the job materials rather than cement. Also, many emulsions designed especially for slurry seal will not pass the cement mixing test, yet give good results in the field.

7.15.1.3 General

It is recommended a 100 percent crushed material be used for airfields and major roadways. The use of natural, non-angular sand will give poor results. If materials are to be blended, be sure the contractor provides suitable means. Wet materials are difficult to blend. Materials with a great difference in unit weights are hard to blend.

Where blended materials are used, stockpile sampling and testing should be increased.

7.15.1.4 Grading

Select only one gradation. Experience has taught that it is better to limit the top sieve of each gradation (No. 8 - Type I; No. 4 - Type II; 3/8 - Type III) to 98 to 100 percent passing to improve surface appearance. The following is additional information on the three gradations:

Type I. This aggregate blend is used to fill surface voids and correct moderate surface conditions. It gives an approximate application rate of 8 to 12 lb/yd² (4.3 to 6.5 kg/m²) and a theoretical asphalt content of 10 to 16 percent based on dry aggregate weight. The fineness of this design provides it with the ability for crack penetration. A typical example of this type of slurry surface would be on areas where only protection from the elements is desired. If Type I gradation is used for streets, it is recommended that maximum poundage be required.

Type II. This aggregate blend is used when it is desired to fill surface voids, to correct severe surface conditions, and to provide sealing and a wearing surface. It gives an approximate application rate of 12 to 20[1] lb/yd² (5.4 to 9.8kg/m²) and a theoretical asphalt content of 7.5 to 13.5 percent based on the dry aggregate weight.
A typical example of this type of slurry surface would be on pavements with a medium textured surface which would require this size aggregate to fill in the cracks and provide a minimum wearing surface. Another example would be placing a general slurry on flexible base, stabilized base, or soil cement as a sealer prior to final paving.

1. For aggregates of ASG#2.65

Type III. This aggregate blend is used to give maximum skid resistance and an improved wearing surface. It is applied at a rate of 15 to 22lb/yd² (8.1 to 12.0 kg/m²) or more and a theoretical asphalt content of 6.5 to 12.0 percent based on dry aggregate weight. A typical example of this type of slurry surface is as the first or second course of a multiple-course slurry treatment on flexible base, stabilized base, or soil cement. Another example of this type of slurry surface would be on pavements that have highly textured surfaces and require this size aggregate to fill in the voids and provide an improved wearing surface.

7.15.1.5 Mineral Filler

Mineral filler is required with most aggregates. Its use is normally 0.5 to 2.0 percent and is considered part of the aggregate. Mineral filler is primarily used to improve the homogeneity of the slurry seal.

7.15.1.6 Additives

There are many types of additives being tried and used in slurry seal for slurry break and set control. Any additives used should be approved by the laboratory as part of the mix design. The slurry equipment should have 1) accurate means to meter the product into the mix and 2) instrumentation to measure the amount of material that has been added during any particular period.

7.15.1.7 Laboratory Report

ISSA T109, the Loaded Wheel Test for Excessive Asphalt, is most applicable when the slurry seal is to be placed in areas receiving high volumes of traffic. For jobs where the slurry is only being placed on low volume areas, the test could be deleted.

ISSA TB136 describes some of the items to watch for when performing the Wet-Track Abrasion Test.

ISSA TB139 describes a method to classify emulsified asphalt/aggregate mixture systems as to set and cure characteristics by a Modified Cohesion Tester.

ISSA Operation Bulletin 128 describes a method to determine the bulk effect of aggregate and how it relates to machine calibration.

7.15.1.8 Slurry Mixing Equipment

Counters, flow meters or totalizer meters are the most common instruments used on machines. They should be kept in good working order.

7.15.1.9 Slurry Spreading Equipment

Some spreader boxes are equipped with one or more sets of augers to improve the distribution of the slurry seal in the spreader box. In some quick-set systems, these augers also keep the mix from breaking. The important thing is to have the slurry seal the proper consistency as it leaves the mixer and to not to add any water to the mix afterwards. Any type drag pulled behind the spreader box that has been stiffened by hardened slurry or asphalt is ineffective.

7.15.1.10 Calibration

ISSA Inspector's Manual describes a method of machine calibration. ISSA contractors and/or machine manufacturers have proven methods of machine calibration which can be provided.

7.15.1.11 Verification

The consistency test is sometimes difficult to evaluate in the field, especially if the slurry is setting quickly. If run in the field, it must be performed immediately after the sample is taken. One method used to measure consistency is to take a stick and draw a line through the slurry immediately behind the spreader box. If the line stays, the slurry is at the proper consistency. If it fills up, the mix is not correct.

Keeping the proper consistency should be one of the major areas of inspector concern.

An improper mix will cause a number of problems. If mixes are too dry, streaking, lumping and roughness will be present in the mat. Mixes applied too wet will run excessively, not hold straight lane lines, and cause an asphalt-rich surface with segregation evident in the mat.

7.15.1.12 Tack Coat

When slurry is being placed over a brick, concrete, or other highly absorbent or polished surface, a one-part emulsion/three-part water tack coat of the same asphalt emulsion (if possible) type and grade as specified for the slurry is recommended. This can be applied with an asphalt distributor. The normal application rate is 0.05 to 0.10gal/yd^2 (0.23 to 0.45l/m^2) of the diluted emulsion.

7.15.1.13 Lines

Many contractors use 15-lb (6.8-kg) black roofing paper to start and stop at intersections. This insures a straight line and leaves something to hold the excess slurry for easy removal.

SECTION 8

CAPE SEALS USING ASPHALT EMULSIONS

8.1 Scope

This performance guide covers materials, equipment and construction procedures for the Cape Seal surface treatment for pavements. It is written as a guide for assistance in preparing specifications and placing Cape Seals.

8.2 Description

Definition — A Cape Seal is a multiple surface treatment that consists of the application of an asphalt emulsion chip seal followed by the application of asphalt emulsion slurry seal or micro surfacing.

This pavement treatment method was originally developed in South Africa in the late 1950's by the Cape of Good Hope Provincial Administration for which it was named.

Function – Cape Seals are designed to provide:

1. An economical initial asphalt bound pavement layer over granular bases where stage construction is planned.
2. An economical surface course over new asphalt emulsion sand or dense-graded bases or cold recycled surfaces.
3. To seal existing pavements to retard the entrance of air and moisture and to prevent raveling.
4. Provide a skid resistant driving surface when appropriate aggregate is used.
5. Provide a highly durable surface treatment. The slurry/micro bonds the chips to prevent loss and the chips prevent undue traffic abrasion and erosion of the slurry.

8.3 Applicable Documents

The following standards form a part of this performance guide and reference should be made to them.

AEMA — Asphalt Emulsion Manufacturers Association
ASTM — American Society for Testing and Materials
ISSA — International Slurry Surfacing Association

8.3.1 ASTM Standards

- C29 *Test Method for Unit Weight and Voids in Aggregate*C88 *Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate*

- T*est Method for Materials finer than No. 200 (0.075mm) in Mineral Aggregates by Washing*
- C127 *Test Method for Specific Gravity and Absorption of Coarse Aggregate*
- C128 *Test Method for Specific Gravity and Absorption of fine Aggregate*
- C131 *Resistance to Degradation of Small-Size Course Aggregate by Abrasion and Impact in the Los Angeles Machine*
- C136 *Method for Sieve Analysis of fine and Coarse Aggregates*
- C183 *Practice for Sampling Hydraulic Cement*
- D2419 *Test Method for Sand Equivalent Values of Soils and fine Aggregate*
- D5 *Test Method for Penetration of Bituminous Materials*
- D75 *Practice for Sampling Aggregates*
- D113 *Test Method for Ductility of Bituminous Materials*
- D140 *Practice for Sampling Bituminous Materials*
- D242 *Specification for Mineral filler for Bituminous Paving*
- D244 *Test Methods for Emulsified Asphalts*
- D448 *Classification for Sizes of Aggregate for Road and Bridge Construction*
- D546 *Test Method for Sieve Analysis of Mineral filler for Road and Paving Materials*
- D977 *Specification for Emulsified Asphalt*
- D1139 *Specification for Aggregate for Single or Multiple Bituminous Surface Treatments*
- D2172 *Test for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures*
- D2397 *Specification for Cationic Emulsified Asphalt*
- D2995 *Practice for Determining Application Rate of Bituminous Distributors*
- D3910 *Practices for Design, Testing, and Construction of Slurry Seal*
- D6372 *Practices for Design, Testing, and Construction of Micro Surfacing*

8.3.2 ISSA Documents

- A105 *Recommended Performance Guidelines for Emulsified Asphalt Slurry Seal Surfaces*
- A143 *Recommended Performance Guidelines for Micro Surfacing*
- TB101 *Guide for Sampling of the Slurry Mix for Extraction Test*
- TB 102 *Mixing, Setting and Water Resistance Test to Identify "Quick-Set" Emulsified Asphalts*
- TB 116 *Specifications for Quick-Set Emulsified Asphalt Slurry Seal*
- TB117 *Specifications for Slow-Set Emulsified Asphalt Slurry Seal Systems*
- TB140 *Specifications for Quick-Traffic Emulsified Asphalt Slurry Seal Systems*

8.3.3 AEMA Documents

- *Recommended Performance Guideline (RPG) for Single and Multiple Chip Seals Using Asphalt Emulsions (RPG Chapter 4)*
- *Recommended Performance Guideline(RPG) for Asphalt Emulsion Prime (AEP) (RPG Chapter 10)*
- *Recommended Performance Guideline (RPG) for Tack Coat and Fog Seal Using Asphalt Emulsions (RPG Chapter 11)*

8.4 Asphalt Emulsions

Asphalt emulsions should conform to the requirements of ASTM D977 or ASTM D2397.

The type of asphalt emulsion for the chip seal should be RS-2, RS-2P, HFRS-2, HFRS-2P, CRS-2 or CRS-2P.

The type of asphalt emulsion for the tack coat should be SS-1, SS-1h, CSS-1, or CSS-1h.

The type of asphalt emulsion for the slurry seal should be SS-1, SS-1h, SS-1HP CSS-1, CSS-1h, CSS-1HP, Quick Setting QS-1h, QS-1HP, CQS-1h, CQS-1HP or micro surfacing emulsion.

8.5 Aggregate

8.5.1 Cover Aggregate for the Chip Seal

Cover aggregate for the chip seal should conform to the requirements of ASTM D448 and D1139 and may consist of most hard aggregates such as crushed stone, crushed slag or crushed gravel. **Table 8-1 Cover Aggregate for Chip Seal** shows the aggregate sizes recommended for the chip seal portion of the Cape Seal.

8.5.2 Aggregate for the Slurry Seal/Micro Surfacing Mixes

Aggregate for the slurry seal mixes should conform to the requirements of ASTM D3910/D6372, Type 1, 2, or 3 and may consist of most hard crushed aggregates such as granite, limestone, trap-rock, slag and expanded clays and shale. **Table 8-2 Aggregate for Slurry Seal/Micro Surfacing** shows the aggregate sizes recommended for the slurry seal/micro- portion of the Cape Seal.

NOTE

The Type 1 gradation is preferred where it is desired to have the chips remaining uncovered, i.e., producing a knobby surface texture for skid resistance.

Table 8-1 Cover Aggregate for Chip Seal

ASTM Size D448	Nominal Size Square Openings	Cape Seal Application
8	3/8 in. to No. 8 (9.5 to 2.36mm)	City Streets & Urban County Roads
7	1/2 in. to No. 4 (12.5 to 4.75mm)	State Highways & Rural County Roads
6	3/4 to 3/8 in. (19.0 to 9.5mm)	Untreated Granular Base Courses

Table 8-2 Aggregate for Slurry Seal/Micro Surfacing

ASTM Size D448	Nominal Size Square Opening	Cape Seal Application
8	3/8 in. to No. 8 (9.5 to 2.36mm)	Type 1, 2 or 3
7	1/2 in. to No. 4 (12.5 to 4.75mm)	Type 1, 2 or 3
6	3/4 to 3/8 in. (19.0 to 9.5mm)	Type 1, 2 or 3

8.6 Other Materials

8.6.1 Mineral Filler

Mineral filler for slurry seal/micro mixes should conform to the requirements of ASTM 0242 and should be used if indicated required by the mix design. Mineral fillers may include materials such as portland cement, hydrated lime, limestone dust and fly ash.

8.6.2 Water

All water used should be potable and compatible with the slurry/micro mix.

8.6.3 Additives

Chemical additives may be used to accelerate or retard the break or set of the slurry/micro mix. The contractor should indicate the type of additive to be used and the initial quantity as predetermined by the mix design.

8.7 Cape Seal Design

8.7.1 Chip Seal

Before work commences, the Contractor should submit a seal coat design covering the specific materials to be used on the project. The compatibility or affinity between the proposed asphalt emulsion and cover aggregate (chips) should have been checked with coating and resistance to stripping determined. The selection of asphalt emulsion quantity or application rate, gal/yd^2 (l/m^2), should be based on the suggested design procedures contained in **SECTION 4 SINGLE AND MULTIPLE CHIP SEALS USING ASPHALT EMULSIONS**.

8.7.2 Slurry Seal/Micro Surfacing

Before work commences, the Contractor should submit a mix design covering the specific materials to be used on the project. The design laboratory test report should include evidence that all materials are individually acceptable and are collectively compatible when mixed together to produce the slurry seal or micro surfacing. The mix design procedures should be in accordance with those contained in ASTM D3910 or ASTM D6372 and **SECTION 7 RECOMMENDED PERFORMANCE GUIDELINES FOR EMULSIFIED ASPHALT SLURRY SEAL** or **SECTION 9 RECOMMENDED PERFORMANCE GUIDELINES FOR MICRO SURFACING**.

8.8 Equipment

The basic equipment required for the construction of a Cape Seal should include the following:

- Emulsion distributor.
- Cover aggregate spreader, preferably mechanical self-propelled type.
- Roller, preferably pneumatic tired.
- Rotary power broom, vacuum assisted.
- Truck or trailer mounted slurry mixing/spreading machine, continuous flow mixing type.

- Trucks for hauling cover and slurry/micro aggregates.
- Front end loader for filling trucks or slurry/micro machine.
- Auxiliary equipment such as hand tools and barricades.

8.8.1 Asphalt Emulsion Distributor

The distributor used for applying asphalt emulsion for prime coat, tack coat and chip seal should consist of a fully insulated tank mounted on a truck or trailer propelled by a power unit capable of accurately maintaining the speed required for proper application rates. The distributor should have the following minimum capabilities.

An adequate heating system so as to heat asphalt emulsion uniformly to a temperature up to 185°F (85°C). An approved tachometer-odometer to accurately register speed and distances traveled when spraying.

A pump capable of developing uniform pressures or volumes for asphalt emulsion.

A rear mounted spray-bar capable of vertical and transverse adjustment to provide proper asphalt emulsion application.

8.8.2 Cover Aggregate Spreader

Cover aggregate spreaders may be of the tailgate type but preferred are the mechanical self-propelled type to obtain a more continuous and uniform rate of cover aggregate application.

8.8.3 Rollers

AII rollers should be of the self-propelled type with pneumatic tired preferred, particularly when the surface is uneven or the cover aggregate is soft. A minimum of three rollers is preferred with two rollers staying immediately behind the chip spreader and the third for back rolling.

8.8.4 Rotary Broom

The broom should be a powered rotary type, preferably vacuum assisted unit, which shall be capable of thoroughly cleaning the existing surface prior to chip sealing and removing excess, loose chips before slurry application.

8.8.5 Slurry Mixing Equipment

The slurry mixing equipment should be of the continuous flow type with suitable means of accurately metering each individual material fed into the mixer. The unit should be equipped with approved devices so that the mixer can be accurately calibrated. The mixer should thoroughly blend all materials to produce a homogenous material before leaving the mixer.

8.8.6 Spreading Equipment

The spreading equipment should be a mechanical squeegee type equipped with flexible material in contact with the surface to prevent loss of slurry from the distributing box. There should be a flexible rear strike-off which is adjustable in width and capable of producing a uniform surface its full width.

For quick-setting type slurry systems, the distributing box may need hydraulic powered augers to prevent premature slurry setting and allow uniform spreading.

8.9 Preparation of Existing Surface

When an untreated base course, the surface should be prepared as outlined in **SECTION 10 ASPHALT EMULSION PRIME (AEP)** which would include the following:

1. Grading to insure the surface is free of local high or low spots and potholes and that the base material is evenly distributed and not segregated.
2. Watering to obtain better penetration of the asphalt emulsion priming materials (done some period in advance of priming so surface is damp but not saturated).
3. Application of asphalt emulsion prime using diluted (normally 1 + 1) SS-1 and SS-1h conforming to ASTM D997, CSS-1 and CSS-1h conforming to ASTM D2397 or other asphalt emulsion grades which have exhibited priming capabilities. Typical application rates of diluted emulsion are 0.5 to 1.0gal/yd² (2.3 to 4.5l/m²).
4. Compaction to consolidate loosened base material.
5. The light application, if necessary, of 4 to 6lb/yd² (1.8 to 2.8kg/m²) of a clean sand to allow for some interim use of the base until placement of the chip seal.
6. For a Cape Seal being placed on an already asphalted surface, the surface should be thoroughly cleaned of loose material, dust, mud and vegetation removed and potholes and other failed areas repaired and wider cracks sealed.

8.10 Chip Sealing

The recommended quantities of asphalt emulsion and cover aggregate for the chipping portion of the Cape Seal are given in **Table 8-3 Application Rates for Chip Seal**.

Table 8-3 Application Rates for Chip Seal

ASTM Size D448	Emulsion gal/yd² (l/m²)	Aggregate lb/yd² (kg/m²)
8	0.20 to 0.30 (0.9 to 1.4)	15 to 20 (8 to 11)
7	0.25 to 0.35 (1.1 to 1.6)	20 to 25 (11 to 14)
6	0.35 to 0.45 (1.6 to 2.0)	35 to 45 (20 to 25)

NOTE:

The quantities of asphalt emulsion cover the normal range of conditions that include primed aggregate base, cold recycled mat, and old pavement. The application rates will vary within the ranges indicated dependent on cover aggregate gradations and the existing surface condition. The weight of aggregate shown is based upon a material with a specific gravity of 2.65 and on obtaining a single layer of cover stone (attempt to have none to very few extra chips).

8.10.1 Tack Coat

The tack coat should consist of a mixture of equal parts (1 +1) of asphalt emulsion and water applied at a rate of 0.10 to 0.20gal/yd² (0.5 to 0.9l/m²). Undiluted asphalt emulsions may also be used with the application rates being adjusted accordingly.

8.10.2 Temperature and Weather Requirements

The chip seal shall not be applied when the pavement is moist, or when the weather is, or may be, detrimental. Detrimental weather is defined as rain showers, cool temperatures, moist pavements, threat of rain showers, or other environmental factors which could affect the performance of the chip seal construction. No chip seal shall be applied if either the pavement or air temperature is below 60°F (15.5°C) and falling, but may be applied when both pavement and air temperatures are above 60°F (15.5°C) and rising. Temperature ranges should be adjusted for regional climates. In addition, no rain should be expected for a minimum period of 24 hours.

8.10.3 General Construction Procedures

Normal good practices should be followed for the seal coat construction as outlined in **SECTION 4 SINGLE AND MULTIPLE CHIP SEALS USING ASPHALT EMULSIONS**.

Some of the more important or unique construction procedures required are:

1. The distributor and chip spreaders shall be calibrated to assure the proper amount of binder and aggregate are applied. The calibration shall consist of assuring mechanical and electronic components are set correctly and in good operation order. Distributors should be checked for proper nozzle size. Manufacturers of the equipment can provide detailed instructions for calibration procedures.
2. Immediately after the asphalt emulsion has been applied, it should be covered with chips (spread as close as possible to a single layer).
3. Rolling should begin as soon as possible after the cover aggregate has beenapplied with pneumatic tired units preferred. The rolling should consist of a minimum of 3 passes.

NOTE: After the initial rolling has been completed with pneumatic tired units, further rolling may be carried out with a 5 to 8 ton (4.5 to 7.3 tonne) steel wheeled unit (optional). To avoid excessive chip crushing, only one complete pass should be made.

4. The surface should be clean with the surface broomed prior to the tack coat if needed to remove any excess chips, dirt, and other objectionable matter. Not less than 24 hours after application and the asphalt emulsion for the chip seal has completely broken, the tack coat may be applied.

NOTE: The tack coat may be eliminated if the cover aggregate is clean and not dusty.

8.11 Slurry Sealing / Micro Surfacing

8.11.1 Materials Quantities

The quantities of aggregate and residual asphalt in the slurry mix are given in **Table 8-4 Application Rates for Slurry Seal** and **Table 9-8 Application Rates for Micro Surfacing**.

Table 8-4 Application Rates for Slurry Seal

ASTM Size D448	Emulsion % Dry wt. of Aggregate	Aggregate lb/yd² (kg/m²)
8	16 to 22	Type 1-10 to 15 (5.5 to 8.0)
	14 to 18	Type 2-14 to 18 (7.5 to 10.0)
7	16 to 22	Type 1-12 to 16 (6.5 to 8.5)
	14 to 18	Type 2-14 to 20 (7.5 to 11.0)
6	14 to 18	Type 1-15 to 20 (8.0 to 11.0)
	12 to 16	Type 2-18 to 25 (10.0 to 13.5)

NOTE:

The aggregate quantities actually used will be dependent on the gradation of the chips and the type of surface texture desired (lesser amount for knobby appearance or increased for greater smoothness).

8.11.2 Temperature and Weather Requirements

The slurry seal and micro surfacing should not be applied if the surface temperature is 50°F (12°C) and falling but may be applied if the temperature is above 45°F (7°C) and is rising. No slurry seal or micro surfacing shall be applied if there is the possibility that the slurry or micro could freeze within 24 hours after placement. In addition, no rain should be expected for a minimum period of 24 hours.

8.11.3 General Construction Procedures

Normal good practices should be followed for the slurry seal or micro surfacing construction as outlined in ISSA's **SECTION 7 RECOMMENDED PERFORMANCE GUIDELINES FOR EMULSIFIED ASPHALT SLURRY SEAL** and **SECTION 9 RECOMMENDED PERFORMANCE GUIDELINES FOR MICRO SURFACINIG**. Some of the more important or unique construction procedures required are:

1. Each slurry/micro unit to be used should be calibrated or have been calibrated with the exact materials to be used. Test strips should be placed prior to construction to determine the desired quantity of slurry or micro to be spread and to provide samples of slurry or micro for verification of mix consistency and materials proportioning.
2. Immediately prior to placement of the slurry seal or micro surfacing, the surface should be cleaned by power brooming and, if needed, flushed with a water truck to remove all loose material, dirt, vegetation and other objectionable matter.
3. Not less than seven days nor more than four weeks after the final asphalt emulsion spray, the slurry seal or micro surfacing should be applied.
4. As the slurry or micro is applied, the surface may be lightly sprayed with water (damp but no free water puddles).
5. In areas where traffic is to be very light, the slurry or micro may need to be rolled by a self-propelled 10 ton (9.1 tonne) pneumatic tired roller with a water spray system (rolling optional). The slurry should be given a minimum of five roller passes. The rolling should not begin until there will be no pickup of the slurry or micro by the tires

of the roller but not later than on the first working day following the slurry or micro placement.

6. The Cape Seal should not be opened to traffic until the slurry or micro has cured sufficiently so as to not exhibit pickup by the tires of regular traffic (asphalt emulsion broken and turned from brown to black color).

Table 8-5 Cover Aggregate Grading Requirements

Sieve Size Square Opening in	Sieve Size Square Opening mm	Weight, Percent Passing		
		ASTM Size No. 6	ASTM Size No. 7	ASTM Size No. 8
1.0	25.0	100		
3/4	19.0	90 to 100	100	
1/2	12.5	20 to 55	90 to 100	100
3/8	9.5	0 to 15	40 to 70	85 to 100
No. 4	4.75	0 to 5	0 to15	10 to 30
No. 8	2.36		0 to15	0 to 10
No. 16	1.18			0 to 5

Table 8-6 Slurry or Micro Surfacing Aggregate Grading Requirements

Sieve Size Square Opening in	Sieve Size Square Opening mm	Weight, Percent Passing		
		ISSA Type 1	ISSA Type 2	ISSA Type 3
3/8	9.5	100	100	100
No. 4	4.75	100	90 to 100	70 to 90
No. 8	2.36	90 to 100	65 to 90	45 to 70
No.16	1.18	65 to 90	45 to 75	28 to 50
No.30	0.60	40 to 65	30 to 50	19 to 34
No.50	0.30	25 to 42	18 to 30	12 to 25
No.100	0.150	15 to 30	10 to 21	7 to 18
No. 200	0.075	10 to 20	5 to 15	5 to 15

SECTION 9

RECOMMENDED PERFORMANCE GUIDELINES FOR MICRO SURFACING



International Slurry Surfacing Association
800 Roosevelt Road, Building C-312
Glen Ellyn, IL 60137
Phone: 630-942-6577
www.slurry.org

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NOTICE

It is not intended or recommended that this guideline be used as a verbatim specification. It should be used as an outline, helping user agencies establish their particular project specification. Users should understand that almost all geographical areas vary as to the availability of materials. An effort should be made to determine what materials are reasonably available, keeping in mind system compatibility and specific job requirements. Contact the ISSA for answers to questions and for a list of ISSA member contractors and companies.

9.1 Scope

The intent of this guideline is to aid in the design, testing, quality control, measurement and payment procedures for the application of micro surfacing.

9.2 Description

Micro surfacing shall consist of a mixture of polymer-modified emulsified asphalt, mineral aggregate, water, and additives, proportioned, mixed and uniformly spread over a properly prepared surface as directed by the Buyer's Authorized Representative (B.A.R.). Micro surfacing should be capable of performing in variable thickness cross-sections such as ruts, scratch courses and milled surfaces. After curing and initial traffic consolidation, it should resist further compaction. The micro surfacing shall be applied as a homogeneous mat, adhere firmly to the prepared surface, and have a skid-resistant texture throughout its service life.

Micro surfacing is a quick-traffic system that allows traffic to return shortly after placement. Normally, these systems are required to accept straight, rolling traffic on a 0.5 in (12.7 mm) thick surface within one hour after placement in specific application conditions. Stopping and starting traffic may require additional curing time.

9.3 Specifications

It is normally not required to specify all tests for every project. A compilation of the results from the listed tests should be indicative of system performance. Failure to meet requirements for an individual test does not necessarily disqualify the system. If, for example, the system to be used on the project has a record of good performance, an individual test result may be waived. Agency and testing methods are listed in the appendix (see Appendix A) and form a part of this guideline.

9.4 Materials

9.4.1 Emulsified Asphalt

9.4.1.1 General

The emulsified asphalt shall be polymer modified. The polymer material shall be milled or blended into the asphalt or emulsifier solution prior to the emulsification process. In general, a three percent (3%) polymer solids, based on asphalt weight, is considered minimum.

9.4.1.2 Quality Tests

The emulsified asphalt, and emulsified asphalt residue, shall meet the requirements of AASHTO M 208 or ASTM D 2397 for CQS-1h, with the following exceptions listed in **Table 9-1 Quality Test Methods**.

Table 9-1 Quality Test Methods

AASHTO Test No.	ASTM Test No.	Quality	Specification
T59	D6930	Settlement and Storage of emulsified asphalts (24 hour)	1% Maximum
T59	D244	Residue after Distillation[1]	62% Minimum
T53	D36	Softening Point	135°F (57°C) Minimum
T49	D2397	Penetration at 77°F (25°C)	40 - 90[2]

NOTES: 1. The temperature for this test should be held below 350°F (177°C). Higher temperatures may cause the polymers to break down.
2. Climate conditions should be considered when establishing this band.

The solubility test, if required, should be evaluated on the base asphalt.

Each load of emulsified asphalt shall be accompanied with a Certificate of Analysis/ Compliance to assure that it is the same as that used in the mix design.

9.4.2 Aggregate

9.4.2.1 General

The mineral aggregate used shall be the type specified for the particular application requirements of the micro surfacing. The aggregate shall be a crushed stone such as granite, slag, limestone, chat, or other high-quality aggregate, or combination thereof. To assure the material is 100 percent crushed, the parent aggregate will be larger than the largest stone in the gradation used.

9.4.2.2 Quality Tests

When tested according to the tests in **Table 9-2 Quality Test Numbers**, the aggregate should meet these minimum requirements.

Table 9-2 Quality Test Numbers

AASHTO Test No.	ASTM Test No.	Quality	Specification
T176	D2419	Sand Equivalent	65 Minimum
T104	C88	Soundness	15% Maximum using NA_2SO_4 or 25% Maximum using $MgSO_4$
T96	C131	Abrasion Resistance[1]	30% Maximum

Note 1: The abrasion test is run on the parent aggregate

The abrasion test is to be run on the parent aggregate. The aggregate should meet state-approved polishing values. Proven performance may justify the use of aggregates that may not pass all of the tests shown in **Table 9-2 Quality Test Numbers**.

9.4.2.3 Grading

When tested in accordance with AASHTO T 27 (ASTM C 136) and AASHTO T 11 (ASTM C 117), the mix design aggregate gradation shall be within one of the following bands (or one recognized by the local paving authority) as shown in **Table 9-3 Grading Percent.**

Table 9-3 Grading Percent

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

The gradation of the aggregate stockpile shall not vary by more than the stockpile tolerance from the mix design gradation (indicated in the table above) while also remaining within the specification gradation band. The percentage of aggregate passing any two successive sieves shall not change from one end of the specified range to the other end.

The aggregate will be accepted at the job location or stockpile based on five gradation tests sampled according to AASHTO T 2 (ASTM D 75). If the average of the five tests is within the stockpile tolerance from the mix design gradation, the material will be accepted. If the average of those test results is out of specification or tolerance, the contractor will be given the choice to either remove the material or blend additional aggregate with the stockpile material to bring it into compliance. Materials used in blending must meet the required aggregate quality test specifications in Section 4.2.2 before blending and must be blended in a manner to produce a consistent gradation. Aggregate blending may require a new mix design.

Screening shall be required at the stockpile if there are any problems created by oversized materials in the mix.

Type II. This aggregate gradation is used to fill surface voids, address surface distresses, seal, and provide a durable wearing surface.

Type III. This aggregate gradation provides maximum skid resistance and an improved wearing surface. This type of micro surfacing surface is appropriate for heavily traveled pavements, rut filling, or for placement on highly textured surfaces requiring larger size aggregate to fill voids.

9.4.3 Mineral Filler

Mineral filler may be used to improve mixture consistency and to adjust mixture breaking and curing properties. Portland cement, hydrated lime, limestone dust, fly ash, or other approved filler meeting the requirements of ASTM D 242 shall be used if required by the mix design. Typical use levels are normally 0.0 - 3.0 percent and may be considered part of the aggregate gradation.

9.4.4 Water

The water shall be free of harmful salts and contaminants. If the quality of the water is in question, it should be submitted to the laboratory with the other raw materials for the mix design.

9.4.5 Additives

Additives may be used to accelerate or retard the break/set of the micro surfacing. Appropriate additives, and their applicable use range, should be approved by the laboratory as part of the mix design.

9.5 Laboratory Evaluation

9.5.1 General

Before the work begins, the contractor shall submit a signed mix design covering the specific materials to be used on the project. This design will be performed by a laboratory which has experience in designing micro surfacing. After the mix design has been approved, no material substitution will be permitted unless approved by the B.A.R.

ISSA can provide a list of laboratories experienced in micro surfacing design.

9.5.2 Mix Design

Compatibility of the aggregate, polymer-modified emulsified asphalt, water, mineral filler, and other additives shall be evaluated in the mix design. The mix design shall be completed using materials consistent with those supplied by the contractor for the project. Recommended tests and values are shown in **Table 9-4 Mix Design Tests.**

Table 9-4 Mix Design Tests

ISSA Test Method	Description	Specification
TB-113	Mix Time @ 77°F (25°C)	controllable to 120 seconds minimum
TB-139	**Wet Cohesion** @ 30 Minutes Minimum (Set) @ 60 Minutes Minimum (Traffic)	12kg-cm Minimum 20 kg-cm Minimum or Near Spin
TB-109	Excess Asphalt by LWT Sand Adhesion	50 g/ft² Maximum (538 g/m² Maximum)
TB-114	Wet Stripping	Pass (90% Minimum)
TB-100	**Wet-Track Abrasion Loss** One-hour Soak Six-day Soak	50 g/ft² (538 g/m²) Maximum 75 g/ft² (807 g/m²) Maximum
TB-147	Lateral Displacement Specific Gravity @ 1,000 Cycles (25lbs/11.34kg)	5% Maximum 2.10 Maximum
TB-144	Classification Compatibility	11 Grade Points Minimum (AAA, BAA)

The Wet Track Abrasion Test is performed under laboratory conditions as a component of the mix design process. The purpose of this test is to determine the minimum asphalt content required in a micro surfacing system. The Wet Track Abrasion Test is not recommended as a field quality control or acceptance test. ISSA TB 136 describes potential causes for inconsistent results of the Wet Track Abrasion Test.

The mixing test is used to predict the length of time the material can be mixed before it begins to break. It can be a good reference check to verify consistent sources of material. The laboratory should verify that mix and set times are appropriate for the climatic conditions expected during the project.

The laboratory shall also report the quantitative effects of moisture content on the unit weight of the aggregate (bulking effect) according to AASHTO T19 (ASTM C29).

The percentage of each individual material required shall be shown in the laboratory report. Based on field conditions, adjustments within the specific ranges of the mix design may be required.

The component materials shall be designed within the following limits: (**Table 9-5 Mixing Test Percentages**).

Table 9-5 Mixing Test Percentages

Component Materials (by dry weight of aggregate)	Limits
Residual Asphalt	5.5 to 10.5%
Mineral Filler	0.0 to 3%
Polymer-Based Modifier (based on bitumen weight content)	Minimum of 3% solids
Additives	As needed
Water	As required to produce proper mix consistency

9.6 Equipment

9.6.1 General

All equipment, tools, and machines used in the application of micro surfacing shall be maintained in satisfactory working condition at all times.

9.6.2 Mixing Equipment

The machine shall be specifically designed and manufactured to apply micro surfacing. The material shall be mixed by an automatic-sequenced, self-propelled micro surfacing mixing machine. It shall be a continuous-flow mixing unit that accurately delivers and proportions the mix components through a revolving multi-blade, double-shafted mixer. Sufficient storage capacity for all mix components is required to maintain an adequate supply to the proportioning controls.

When specifying continuous machinery to minimize transverse joints, the specified machine must be capable of loading materials while continuing to apply micro surfacing. The continuous-run machine shall be equipped to provide the operator with full control of the forward and reverse speeds during application. It shall be equipped with opposite-side driver stations to assist in alignment. The self-loading device, opposite-side driver stations, and forward and reverse speed controls shall be of original-equipment-manufacturer design.

9.6.3 Proportioning Devices

Individual volume or weight controls for proportioning mix components shall be provided and properly labeled. These proportioning devices are used in material calibration to determine the material output at any time.

9.6.4 Spreading Equipment

The mixture shall be agitated and spread uniformly in the surfacing box by means of twin-shafted paddles or spiral augers fixed in the spreader box. A front seal shall be provided to insure no loss of the mixture at the road contact point. The rear seal shall act as a 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 and a free flow of material is provided 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.

9.6.4.1 Secondary Strike-off

A secondary strike-off shall be provided to improve surface texture. The secondary strike-off shall be adjustable to match the width of the spreader box and allow for varying pressures to control the surface texture.

9.6.4.2 Rut-Filling Equipment

When project plans require, Micro Surfacing material may be used to fill ruts, utility cuts, depressions in the existing surface, etc. Ruts of 0.5 in (12.7 mm), or greater in depth, shall be filled independently with a rut-filling box, either 5 ft (1.5 m) or 6 ft (1.8 m) in width. Ruts that are in excess of 1.5 in (38.1 mm) in depth may require multiple applications with the rut-filling box to restore the cross-section. When rutting or deformation is less than 0.5 in (12.7mm), a full width scratch course may be applied with the spreader box using a metal or stiff rubber strike-off. Apply at a sufficient rate to level the pavement surface. The leveling course may, or may not, meet the suggested application rate in the table in Section 11.2. All rut-filling and level-up material should cure under traffic for at least twenty-four (24) hours before additional material is placed.

9.6.5 Auxiliary Equipment

Suitable surface preparation equipment, traffic control equipment, hand tools, and other support and safety equipment necessary to perform the work shall be provided by the contractor.

9.7 Calibration

Each mixing unit to be used in the performance of the work shall be calibrated in the presence of the B.A.R. prior to the start of the project. Previous calibration documentation covering the exact materials to be used may be acceptable, provided that no more than 60 days have lapsed. The documentation shall include an individual calibration of each material at various settings that can be related to the machine metering devices. Any component replacement affecting material proportioning requires that the machine be recalibrated. No machine will be allowed to work on the project until the calibration has been completed and/or accepted. ISSA Inspector's Manual describes a method of machine calibration. ISSA contractors and/or machine manufacturers may also provide methods of machine calibration.

9.8 Weather Limitations

Micro surfacing 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 temperatures are above 45°F (7°C) and rising. No micro surfacing shall be applied when there is the possibility of freezing temperatures at the project location within 24 hours after application. The micro surfacing shall not be applied when weather conditions prolong opening to traffic beyond a reasonable time.

9.9 Notification and Traffic Control

9.9.1 Notification

Homeowners and businesses affected by the construction shall be notified at least one day in advance of the surfacing. Should work not occur on the specified day, a new notification will be distributed. The notification shall be in the form of a written posting, stating the time and date that the surfacing will take place. If necessary, signage alerting traffic to the intended project should be posted.

9.9.2 Traffic Control

Traffic control devices shall be in accordance with agency requirements and, if necessary, conform to the requirements of the Manual on Uniform Traffic Control Devices. Opening to traffic does not constitute acceptance of the work.

9.10 Surface Preparation

9.10.1 General

Immediately prior to applying the micro surfacing, the surface shall be cleared of all loose material, silt spots, vegetation, and other objectionable material. Any standard cleaning method will be acceptable. If water is used, cracks shall be allowed to dry thoroughly before applying micro surfacing. Manholes, valve boxes, drop inlets and other service entrances shall be protected from the micro surfacing by a suitable method. The B.A.R. shall approve the surface preparation prior to surfacing.

9.10.2 Tack Coat

Normally, tack coat is not required unless the surface to be covered is extremely dry and raveled or is concrete or brick. If required, the emulsified asphalt should be SS, CSS, or the micro surfacing emulsion. Consult with the micro surfacing emulsion supplier to determine dilution stability. The tack coat may consist of one part emulsified asphalt/three parts water and should be applied with a standard distributor. The distributor shall be capable of applying the dilution evenly at a rate of 0.05-0.15 gal/yd2 (0.23-0.68 l/m2). The tack coat shall be allowed to cure sufficiently before the application of micro surfacing. If a tack coat is to be required, it must be noted in the project plans.

9.10.3 Cracks

It is recommended to treat cracks wider than 0.25” (0.64cm) in the pavement surface with an approved crack sealer prior to application of the Micro Surfacing.

9.11 Application

9.11.1 General

If required, a test strip should be placed in conditions similar to those expected to be encountered during the project. When local conditions warrant, the surface shall be fogged with water ahead of the spreader box. The rate of application of the fog spray may be adjusted as the temperature, surface texture, humidity, and dryness of the pavement, change.

The micro surfacing shall be of the appropriate consistency upon leaving the mixer. A sufficient amount of material shall be carried in all parts of the spreader at all times so that complete coverage is obtained. Overloading of the spreader box shall be avoided. No lumps or unmixed aggregate shall be permitted. No dry aggregate either spilled from the laydown machine or existing on the road, will be permitted.

No streaks, such as those caused by oversized aggregate or broken mix, shall be left in the finished surface. If excessive streaking develops, the job will be stopped until the contractor proves to the B.A.R. that the situation has been corrected. Excessive streaking is defined as more than four drag marks greater than 0.5 in (12.7 mm) wide and 4.0 in (101 mm) long, or 1.0 in (25.4 mm) wide and 3.0 in (76.2 mm) long, in any 29.9 yd2 (25 m2) area. No transverse ripples or longitudinal streaks of 0.25 in (6.4 mm) in depth will be permitted, when measured by placing a 10 ft (3 m) straight edge over the surface.

9.11.2 Rate of Application

The micro surfacing mixture shall be of the proper consistency at all times so as to provide the application rate required by the surface condition. The application rate shall be in accordance with the information in **Table 9-6 Application Rates**.

Table 9-6 Application Rates

Aggregate Type	Location	Suggested Application Rate
Type II	Urban and Residential Streets and Airport Runways	10 - 20 lb/yd² (5.4 - 10.8 kg/m²)
Type III	Primary and Interstate Routes Wheel Ruts	15 - 30 lb/yd² (8.1 - 16.3 kg/m²) As Required (See **9.15 Appendix B: Re-Profiling Rutted Wheel-paths with Micro Surfacing**)

Suggested application rates are based upon the weight of dry aggregate in the mixture. Application rates are affected by the unit weight and gradation of the aggregate and the demand of the surface to which the micro surfacing is being applied.

9.11.3 Joints

No excess buildup, uncovered areas, or unsightly appearance shall be permitted on longitudinal or transverse joints. The contractor shall provide suitable width spreading equipment to produce a minimum number of longitudinal joints throughout the project. When possible, longitudinal joints shall be placed on lane lines. Partial width passes will only be used when necessary and shall not be the last pass of any paved area. A maximum of 3.0 in (76.2 mm) shall be allowed for overlap of longitudinal joints. Also, the joint shall have no more than a 0.25 in (6.4 mm) difference in elevation when measured by placing a 10 ft (3 m) straight edge over the joint and measuring the elevation difference.

9.11.4 Mixture

The micro surfacing shall possess sufficient stability so that premature breaking of the material in the spreader box does not occur. The mixture shall be homogeneous during and following mixing and spreading. It shall be free of excess liquids which create segregation of the aggregate. Spraying of additional water into the spreader box will not be permitted.

9.11.5 Handwork

Areas which cannot be accessed by the mixing machine shall be surfaced using hand squeegees to provide complete and uniform coverage. If necessary, the area to be hand worked shall be lightly dampened prior to mix placement. As much as possible, handwork shall exhibit the same finish as that applied by the spreader box. All handwork shall be completed prior to final surfacing.

9.11.6 Lines

Lines at intersections, curbs, and shoulders will be kept straight to provide a good appearance. If necessary, a suitable material will be used to mask off the end of streets to provide straight lines. Longitudinal edge lines shall not vary by more than ± 2 in (± 51 mm) horizontal variance in any 96 ft (29 m) of length.

9.11.7 Rolling

Rolling is usually not necessary for micro surfacing on roadways. Airports and parking areas should be rolled by a self-propelled, 10-ton (maximum) pneumatic tire roller equipped with a water spray system. All tires should be inflated per manufacturer's specifications. Rolling shall not start until the micro surfacing has cured sufficiently to avoid damage by the roller. Areas which require rolling shall receive a minimum of two (2) full coverage passes.

9.11.8 Clean-up

All utility access areas, gutters and intersections, shall have the micro surfacing removed as specified by the B.A.R. The contractor shall remove any debris associated with the performance of the work on a daily basis.

9.12 Quality Control

9.12.1 Inspection

Inspectors assigned to projects must be familiar with the materials, equipment and application of micro surfacing. Local conditions and specific project requirements should be considered when determining the parameters of field inspection.

Proper mix consistency should be one of the major areas of inspector concern. If mixes are too dry, streaking, lumping and roughness will be present in the mat surface. Mixes applied too wet will flow excessively and not hold straight lane lines. Excessive liquids may also cause an asphalt-rich surface with segregation.

9.12.2 Materials

To account for aggregate bulking, it is the responsibility of the contractor to check stockpile moisture content and to set the machine accordingly. At the B.A.R.'s discretion, material tests may be run on representative samples of the aggregate and emulsion. Tests will be run at the expense of the buyer. The buyer must notify the contractor immediately if any test fails to meet the specifications.

9.12.3 Micro Surfacing

If required, representative samples of the micro surfacing may be taken directly from the micro surfacing machine. Residual asphalt content (ASTM D2172) tests may be run on the samples at the expense of the buyer. The buyer must notify the contractor immediately if any test fails to meet specifications. Data obtained from the proportioning devices on the micro surfacing machine may be used to determine individual material quantities and application rate.

9.12.4 Non-Compliance

If any two successive tests fail on the stockpile aggregate, the job shall be stopped. If any two successive tests on the mix from the same machine fail, the use of the machine shall be suspended. It will be the responsibility of the contractor, at his expense, to prove to the B.A.R. that the problems have been corrected.

9.13 Method of Measurement

9.13.1 Area

On smaller projects, the method of measurement and payment is usually based on the area covered, measured in square feet, square yards, or square meters.

9.13.2 Ton and Gallon

On larger projects of over 50,000 yd2 (41,806 m2) measurement and payment are usually based on the tons of aggregate and the gallons (liters) of emulsified asphalt used.

Aggregate delivery tickets or printed tickets from certified scales at the staging area shall be used for measurement. The emulsified asphalt used on the project will be measured by the certified tickets for each load delivered. Emulsified asphalt not used shall be deducted from the job total.

9.14 Payment

The micro surfacing shall be paid for by the unit area or the weight of the aggregate and the emulsified asphalt used on the project and accepted by the B.A.R. Payment shall be full compensation for all preparation, mixing and application of materials, and for all labor, equipment, tools, testing, cleaning, and incidentals necessary to complete the job as specified herein.

9.15 Appendix A: Agencies and Test Methods

9.15.1 Agencies

American Association of State Highway and Transportation Officials (AASHTO)

American Society for Testing and Materials (ASTM)

International Slurry Surfacing Association (ISSA)

9.15.2 Test Methods

Table 9-7 Aggregate and Material Filler

AASHTO Test No.	ASTM Test No.	Test
AASHTO T2	ASTM D75	Sampling Mineral Aggregates
AASHTO T27	ASTM C136	Sieve Analysis of Aggregates
AASHTO T11	ASTM C117	Materials Finer than No. 200 in Mineral Aggregates
176	ASTM D2419	Sand Equivalent Value of Soils and Fine Aggregate
AASHTO T96	ASTM C131	Resistance to Abrasion of Small-Size Coarse Aggregate by Use of the Los Angeles Machine (This test should be performed on the parent rock that is used for crushing the finer gradation Micro Surfacing material.)
AASHTO T104	ASTM C88	Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
AASHTO T-19	ASTM C29	Bulk Density and Voids in Aggregate

Table 9-8 Emulsified Asphalt

AASHTO Test No.	ASTM Test No.	Test
AASHTO T40	ASTM D140	Sampling Bituminous Materials
AASHTO T59	ASTM D244	Testing Emulsified Asphalt
AASHTO M208	ASTM D2397	Specifications for Cationic Emulsion

Table 9-9 Residue from Emulsion

AASHTO Test No.	ASTM Test No.	Test
AASHTO T59	ASTM D244	Residue by Evaporation (This test method may have to be modified by using lower temperatures.)
AASHTO T53	ASTM D36	Softening Point by the Use of Ring and Ball
AASHTO T49	ASTM C2397	Penetration of bituminous materials

Table 9-10 Mix Design

ISSA Test Method	Test
A-143	Standard Practice for Design, Testing and Construction of Micro surfacing
TB100	Test Method for Wet-Track Abrasion of Slurry Seals (This test is used to determine the minimum percent of asphalt in the mix.)
TB109	Excess Asphalt by LWT Sand Adhesion
TB113	Mix Time
TB114	Wet Stripping Test for Cured Slurry Seal Mixes
TB 136	Causes for Inconsistency of Wet Track Abrasion Test (WTAT) Results
TB144	Classification Compatibility by Use of the Schulze-Breuer

NOTES:

ASTM D 6372, Standard Practice for Design, Testing, and Construction of Micro Surfacing, is a combined reference of the ISSA Test Bulletins listed above.
ASTM D 2172, Standard Test Methods for Quantitative Extraction of Bitumen From Bituminous Paving Mixtures, is referenced in Section 12.3.

9.16 Appendix B: Re-Profiling Rutted Wheel-paths with Micro Surfacing

9.16.1 Rule of Thumb

For every inch of micro surfacing mix, add one-eighth (1/8) inch (3.2 mm) to one-fourth (1/4) inch (6.4 mm) as a crown to allow for compaction under traffic.

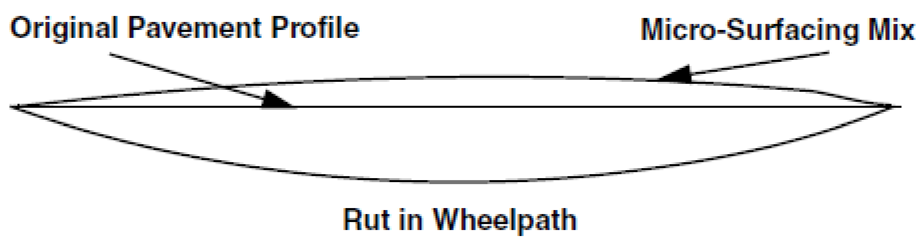

Figure 9-1 Rule of Thumb for Wheel-path Rut Resurfacing

Table 9-11 Wheel-path Rut Resurfacing Quantities

Rut Depth	Micro Surfacing Quantity Needed
0.5 - 0.75" (12.7 - 19.1 mm)	20 – 30 lb/yd² (10.8 - 16.3 kg/m²)
0.75 - 1.00" (19.1 - 25.4 mm)	25 – 35 lb/yd² (13.6 - 19.0 kg/m²)
1.00 - 1.25" (25.4 - 31.75 mm)	28 – 38 lb/yd² (15.2 - 20.6 kg/m²)
1.25 - 1.5" (31.75 - 38.1 mm)	32 – 40 lb/yd² (17.4 - 21.7 kg/m²)

SECTION 10

ASPHALT EMULSION PRIME (AEP)



10.1 Scope

This performance guide covers the use of asphalt emulsion for prime applications. This guide has been prepared for the purpose of assistance and guidance in preparing an untreated base for an asphalt surface. The information and guidelines on materials, design, and construction requirements should be used to achieve satisfactory results in Asphalt Emulsion Prime (AEP) treatments.

10.2 Description

10.2.1 Definitions

Asphalt emulsion priming consists of an application of low viscosity asphalt emulsion to an absorbent surface or granular base, in preparation for an asphalt surface course.

10.2.2 Functions of AEP Treatments

AEP is designed to:

- Penetrate rapidly into the absorbent surface and bind the granular material together.
- Partially waterproof the treated areas to make them resistant to water erosion.
- Continue to provide protection from wind, water, and traffic erosion for an extended period of time.
- Provide a bond between the base and the next course.

10.3 Applicable Documents

The following standards are to be an integral part of this performance guide and reference should be made to them.

10.3.1 ASTM Standards

- D140 *Practice for Sampling Bituminous Materials*
- D244 *Test Methods for Emulsified Asphalts*
- D977 *Specification for Emulsified Asphalt*

- D2397 *Specification for Cationic Emulsified Asphalt*
- D2995 *Practice for Determining Application Rate of Bituminous Distributors*

10.4 Asphalt Emulsion

The asphalt emulsion used for prime conforms to ASTM D977 for SS-1 and SS-1h and to ASTM D2397 for CSS-1 or CSS-1h. Other asphalt emulsion grades may be used for AEP provided the same results are obtained and the emulsion is recommended by the asphalt emulsion manufacturer for AEP.

10.4.1 Dilution

If the asphalt emulsion is used in diluted form, the water used for dilution of the AEP shall be clean, potable, free of sediments and soluble salts. A small amount of surfactant or the same emulsifier used for the preparation of the asphalt emulsion could be added to the water to dilute the AEP to obtain additional stability of the asphalt emulsion. When the asphalt emulsion is diluted, the final product should be a fluid, homogeneous mixture. The water should always be slowly added to the asphalt emulsion. (Not the asphalt emulsion to the water.) It is also recommended to add warm water or water at the temperature of the asphalt emulsion to prevent breaking of the asphalt emulsion. A test dilution should be made to be certain that the water to be used is compatible with the asphalt emulsion. These diluted asphalt emulsions should not be stored for any length of time.

The asphalt emulsion manufacturer should determine the best method and materials for dilution.

10.5 Asphalt Equipment

Successful prime treatments depend to a large extent on the equipment used, its condition, and the way it is handled. This is why specifications generally require that the equipment be in good mechanical condition, properly adjusted and free from wear which would impair the quality of the work. But, whether required or not, it is always good practice to make a careful inspection before operations begin to be sure all pieces are clean, calibrated, and in top operating form. Such equipment shall at all times be operated by skilled and experienced operators.

10.5.1 Pressure Distribution

The asphalt emulsion distributor is the most important piece of equipment on a prime treatment project. Its purpose is to uniformly apply AEP to a surface at a specified rate and to maintain this application rate regardless of changes in grade or direction of movement. Calibration and adjustment of the asphalt distributor are described in ASTM D2995.

10.5.2 Grader/Scarifier

If surface preparation is needed, any approved road grader can be used. It must be capable of scarifying and shaping the top 2 to 6 in. (50 to 150mm) of soil or aggregate.

10.5.3 Water Truck

Pre-wetting water may be applied in any spraying equipment that results in an even, controllable application of water over the entire surface to be treated.

10.5.4 Compaction Equipment

The compacting equipment shall be of the standard steel wheel, pneumatic tire, or vibratory steel wheel types.

10.6 Construction

10.6.1 Preparation of Area to be Treated

AEP can be applied in some situations without any preparation. However, the beneficial effects will be reduced by an extremely dry material, the presence of highly compacted areas, potholes, and high spots. To optimize the performance of AEP, the following steps should be employed:

10.6.1.1 Grading

Using a road grader, an angled dozer, or shovels and rakes, remove, mix and replace the top 2 to 6 in. (50 to 150mm) of material. Insure that the surface is free from local high spots and potholes, and that the material is evenly mixed and distributed to avoid segregated pockets of coarse or fine gradation. In the case where planing and cross-section is not required, the top surface should be scarified for 1/2 to 1 in. (12.5 to 25mm).

10.6.1.2 Watering

Water should be applied 2 to 12 hours before priming. The material at the time of priming should be damp, but not saturated with water. To obtain better penetration of the AEP a small amount of surfactant, or the same emulsifier used for the preparation of the emulsion could be added to the pre-wet water.

10.6.2 Application

AEP is normally used at a 1 + 1 dilution. Dilution will give somewhat deeper penetration. Table 1 provides suggested application rates are based on the diluted AEP.

NOTE

In very dense material it may be necessary to make two applications or to dilute the emulsion further and make multiple applications at even lower rates. This is done to prevent runoff and puddling of the emulsion.

10.6.3 Compaction

After priming, compaction should be used to consolidate the loosened base material and help prevent formation of ruts and potholes.

10.6.4 Application of Sand Cover

The application of a light, 4 to 6Ib/yd^2 (1.8 to 2.8kg/m^2), clean sand cover is often applied to allow traffic for some interim use period prior to the application of another surface.

10.6.5 Performance Criteria

Within the present state of the art, no formal performance criteria exist.

10.7 Precautions and Protection of Work

- AEP shall not be applied when the ambient temperature is below 50°F (10°C), or when rain is imminent.
- AEP may be harmful to growing plants, since like any other oil, it seals pores and interferes with intake of carbon dioxide. Reasonable care should be taken to prevent overspray on crops. Also, since the product is black, reasonable care should be taken to prevent spraying on buildings, fences, and other areas where dark stains are undesirable.
- Traffic should be kept off the treated surfaces until the product has penetrated and the surface is no longer tacky. There should be no pickup of the treated materials on shoes or tires.
- If puddles develop in low spots, clean sand or soil should be applied to blot them.
- Water containing surfactant or emulsifier should be used only for dilution of the emulsion and pre-wet water.

Table 10-1 Application Rates for AEP

Surface Material	% Passing No. 200 (0.075mm)	Emulsion gal/yd² (l/m²)
Loose sand	0 to 10	1.0 to 1.5 (4.5 to 6.8)
Crushed gravel	0 to 10	0.5 to 0.7 (2.3 to 3.2)
Sandy gravel	10 to 20	0.6 to 1.2 (2.7 to 5.4)
Silty gravel	20 to 50	0.5 to 1.0 (2.3 to 4.5)

SECTION 11

TACK COATS & FOG SEALS USING ASPHALT EMULSIONS

11.1 Scope

This performance guide covers the use of asphalt emulsion for both tack coat and fog seal applications. It should be used as a guide in achieving successful results through proper construction practices and adequate knowledge and understanding of asphalt emulsions.

11.2 Definitions

11.2.1 Tack Coat

A spray application of asphalt emulsion, applied to an existing asphalt or portland cement concrete surface prior to a new asphalt overlay or patching to eliminate slippage planes and provide a bond between new and existing pavement layers.

11.2.2 Fog Seal

A light spray application of dilute asphalt emulsion used primarily to seal existing asphalt surfaces to reduce raveling and to enrich dry and weathered surfaces. Can also be used as a color coating and as a paint striping surface preparation.

11.2.3 Flush Coat

A fog seal applied for the purpose of increasing the asphalt content of under-asphalted, usually newly constructed, surfaces or chip seals. Flush coats are treated herein as fog seals.

11.2.4 Asphalt Emulsion Break

The initial separation of the water from the asphalt emulsion, can be detected by a marked color change from brown to black, and often by the release of fairly clear to straw brown water. This break results in the deposition of the base asphalt on an aggregate or paved surface.

11.2.5 Dense Surface

Tight, relatively non-absorbent smooth textured surface.

11.2.6 Open Surface

Open, relatively porous and absorbent, rough textured surface. This type of surface will require a higher rate of application to compensate for the asphalt emulsion that flows into the large voids and cracks. Most chip sealed surfaces are open surfaces.

11.3 Applicable Documents

11.3.1 ASTM Documents

- D140 Practice for Sampling Bituminous Materials
- D244 Test Methods for Emulsified Asphalts
- D977 Specification for Emulsified Asphalt
- D2397 Specification for Cationic Emulsified Asphalt
- D2995 Practice for Estimating Application Rate of Bituminous Distributors

11.3.2 AEMA Documents

A Basic Asphalt Emulsion Manual

The asphalt emulsion used for tack coat or fog seals shall conform to ASTM D977 for SS-1 or SS-1h, or to D2397 for CSS-1 or CSS-1h. Normally these asphalt emulsions are diluted prior to application to reduce viscosity for spraying, to allow filling of small cracks or voids, and to more accurately apply very small quantities of residual asphalt per square yard. For fog seal, the asphalt emulsion is normally of the slow setting type in order to properly flow into and seal small cracks or porous surfaces Other asphalt emulsion grades may be used provided the same results are obtained and provided they are checked for dilution compatibility prior to dilution.

Some asphalt emulsions, especially rapid setting types, cannot be diluted with water and require dilution with specific chemical emulsifier solutions to produce stable dilutions. Some agencies accept the use of RS type asphalt emulsions for tack coat. These are not to be diluted with water and must be carefully diluted by the manufacturer's chemical solution under controlled conditions. Consult the asphalt emulsion manufacturer for assistance when using unfamiliar asphalt emulsions. Other DOT approved low residue asphalt emulsions, specified for use undiluted (eliminates dilution error). Asphalt emulsions such as AE for Indiana DOTand AE-TC for PennDOT have been found acceptable.

11.3.3 Sampling

Material samples shall be furnished by the contractor as directed by the engineer. Procedures for sampling shall be in accordance with ASTM D140, unless otherwise specified.

11.3.4 Testing

The asphalt emulsion shall be tested in accordance with ASTM D244.

11.4 Water

Water is normally used for diluting slow set asphalt emulsions for tack coat and fog seal. It should be clean, potable water, free from detectable solids or incompatible soluble salts. Test for dilution incompatibility, whenever in doubt, by diluting the asphalt emulsion in the severest conditions anticipated (e.g., high dilution, cold water, hard water, high shear pumps). No instability or coagulation should appear. Consult the asphalt emulsion supplier if there are any questions.

11.4.1 Other Methods of Dilution

When water is not desirable for asphalt emulsion dilution, a small amount of compatible emulsifier solution can be used. The asphalt emulsion manufacturer is the one most familiar with the particular asphalt emulsion and must be consulted to determine specific method and materials for dilution.

11.4.2 Diluting the Asphalt Emulsion

When the asphalt emulsion is to be diluted for spray application, the final product shall be a fluid, homogenous mixture. The use of hard or cold water or an improper emulsifier solution may chemically or thermally break the asphalt emulsion. Dilution may be improved by pre-warming the dilution liquid to 77 to 122°F (25 to 50°C). Never add asphalt emulsion to water, always add water or other diluents to asphalt emulsion. Normal dilution for tack coat is achieved by diluting 1 part water to 1 part asphalt emulsion. For fog seal, dilutions are often higher. To avoid possible problems with storage stability, it is recommended that dilution be done at the time of application. Diluted asphalt emulsions are normally not stored, unless weather or the like necessitates temporary storage. A diluted asphalt emulsion is more unstable than the original product.

11.4.2.1 Consult your AEMA asphalt emulsion supplier for guidance on exact dilutions.

11.5 Storage and Handling

Suitable storage and handling facilities shall be provided for the emulsion, so as to:

1. Prevent contamination by water, oils or other liquids.
2. Prevent contamination by other incompatible asphalt emulsions.
3. Protect from freezing and boiling temperatures that break the asphalt emulsion and cause separation into asphalt and water.
4. Protect from local overheating caused by high temperature heating coils and surface heating pads. Use of hot water is recommended for heating asphalt emulsion. Where steam, hot oil or direct fire must be used, controls must keep coil surfaces below 185°F (85°C).
5. Use bottom loading wherever possible or employ full-length drop hose to eliminate foaming. Foaming may cause a volume gauge error.
6. Allow surface crust that may form on asphalt emulsion in storage to float without disturbance. Vertical tanks can help maintain constant and minimal surface area. Return lines into tanks should have outlets near the tank bottom and circulation should not free fall or disturb surface crust.

7. Reduce high shear that can break asphalt emulsions by enlarging clearances on new gear pumps by milling if necessary.
8. Prevent unnecessary circulation that can cause drop in asphalt emulsion viscosity and instability.
9. Do not agitate asphalt emulsion with forced air as it may cause the asphalt emulsion to break

11.6 Equipment

11.6.1 Asphalt Emulsion Distributor or Hand Sprayer

A properly calibrated asphalt emulsion distributor or a hand sprayer shall be used for spraying asphalt emulsions. ASTM D2995 can be used for distributor calibration. The distributor shall be free of any contaminants that can harm the asphalt emulsion.

11.6.2 Pump

A pump for continuous circulation of asphalt emulsion through the spray bar shall be provided. Pumps should have a greater clearance for use with asphalt emulsions than with other asphalts at least 0.030in. (0.76mm) to prevent over-shearing. This can cause breakdown of the asphalt emulsion particles, especially in their diluted form. Pressure created within the distributor should be as low as possible. Heat applied to the tank or spray bar shall not exceed 185°F (85°C) at any point, which would boil the asphalt emulsion and cause it to break, plugging the nozzles with asphalt.

11.6.3 Recommended Spray Nozzle Sizes

Recommended spray nozzle sizes are 1/8 to 3/16 in. (3.2 to 4.8mm). Spray nozzle angles should be adjusted using nozzle wrench provided by equipment distributor or manufacturer and spray bar height adjusted to produce correct overlap. A hand sprayer should be used for applying small amounts of tack to cleaned potholes and utility cuts prior to filling or patching, as well as to small areas which cannot be sprayed by the distributor.

11.7 Preparation of Surface

11.7.1 Existing Surface

Existing surface shall be repaired as directed by the engineer prior to further construction. The asphalt emulsion will flow into the small cracks and seal them, but it cannot be expected to take the place of adequate repair of major deterioration of the pavement.

The surface shall be free from dust, loose or foreign matter and any objectionable material that would hinder adhesion of the asphalt emulsion. If the dust layer is minimal and brooming is not deemed necessary, a very light 0.15gal/yd² (0.68L/m²) spray of clean water prior to application can significantly improve adhesion of the tack coat or penetration into the surface cracks by the fog seal. Allow excess water to run off before applying asphalt emulsion. Parking lots or other areas with heavy oil drippings should be cleaned with detergent or by other methods prior to spraying with asphalt emulsions.

11.8 Weather

Spray application of asphalt emulsions should be avoided prior to probable rainfall and shall not be applied during rain. High humidity will slow the asphalt emulsion break. Pavement and air temperatures should be above 50°F (10°C). With extreme hot, dry conditions, it may be advantageous to lightly dampen the surface to be sprayed with 0.15gal/yd² (0.68L/m²) water to prevent premature break of the asphalt emulsion.

11.9 Application

11.9.1 Spraying

Asphalt emulsion applied by pressure distributor shall be applied at a uniform rate, without splattering or drilling from the spray bar, by using low pressure. Nozzle angle and spray bar height must be adjusted to insure correct spray pattern.

11.9.2 Application Rates for Tack Coat

Table 11-1 Suggested Application Rates Tack Coat

Rate of Dilution	Type of Surface to be Tack Coated	
	Dense Surface Low Absorption	Open Surface High Absorption
% Emulsion (emulsion + water)	gal/yd² (L/m²)	gal/yd² (L/m²)
Net residual asphalt desired	0.02 to 0.04 (0.09 to 0.18)	0.03 to 0.06 (0.14 to 0.27)
0% (undiluted)	too low	0.05 to 0.10 (0.22 to 0.44)
75% (3 + 1)	too low	0.06 to 0.13 (0.30 to 0.58)
50% (1 + 1)	0.06 to 0.13 (0.30 to 0.58)	0.10 to 0.19 (0.45 to 0.87)
40% (2 + 3)	0.08 to 0.16 (0.36 to 0.72)	0.12 to 0.24 (0.56 to 1.09)

11.9.3 Application Rates for Fog Seal

Table 11-2 Suggested Application Rates Fog Seal

Rate of Dilution	Type of Surface to be Tack Coated	
	Dense Surface Low Absorption	Open Surface High Absorption
% Emulsion (emulsion + water)	gal/yd² (L/m²)	gal/yd² (L/m²)
Net residual asphalt desired	0.01 to 0.03 (0.04 to 0.14)	0.03 to 0.05 (0.13 to 0.22)
50% (1 + 1)	0.03 to 0.11 (0.14 to 0.49)	0.09 to 0.23 (0.42 to 1.03)
40% (2 + 3)	0.04 to 0.13 (0.18 to 0.55)	0.12 to 0.30 (0.52 to 1.29)
25% (1 + 3)	0.06 to 0.21 (0.26 to 0.90)	0.19 to 0.47 (0.84 to 2.06)
20% (1 + 4)	0.08 to 0.25 (0.32 to 1.13)	0.24 to 0.59 (1.05 to 2.58)
16.7% (1 + 5)	0.09 to 0.31 (0.39 to 1.35)	too high
14.3% (1 + 6)	0.12 to 0.41 (0.52 to 1.81)	too high
12.5% (1 + 7)	0.13 to 0.47 (0.58 to 2.03)	too high

11.9.4 Objective

11.9.4.1 Tack Coat

The objective for proper application rate of tack coat is to apply a uniform coverage of residual asphalt, sufficient to provide a thin, tacky, adhesive film, yet not in excess which would create runoff or a future slippage plane. To reduce localized fat spots of tack coat or to speed the break of the asphalt emulsion, the use of pneumatic-tired rollers on the freshly applied tack is recommended. The tack coat should be allowed to break before application of the overlay or surface treatment.

11.9.4.2 Fog Seal

The objective for proper application of fog seal is to apply a uniform coverage of asphalt emulsion, sufficient to flow into and seal the pavement pores, small cracks, and voids against water and weathering. Ideally, the peaks of most aggregate particles should remain uncoated with asphalt to prevent reduction of skid resistance. Two or more successive applications of the respective proportion of the desired total application can aid in preventing excess over-application. The distributor should be operated in opposite directions on each pass to minimize inconsistencies in spray pattern. Upon over-application and at the discretion of the supervising engineer, a light cover of clean, fine sand may be applied onto the uncured fog seal at the rate of 6 to 10 Ib/yd^2 (3.3 to 5.4kg/m^2) to provide for a safe, skid resistant surface. A pass of a pneumatic tired roller should be made over this light sand dusting to firmly embed the fine sand. The fog seal should be allowed to completely cure before opening to traffic.

11.9.5 Traffic Control

Traffic control during application shall be employed to protect the freshly sprayed asphalt emulsion until it is overlaid or cured to a safe condition. Excessive pickup of the fresh asphalt emulsion by construction traffic shall be avoided especially with tack coat. Traffic volume should determine the type and extent of control needed, and safety is also a major factor, as the tack coat produces an extremely slippery film and fog seal, if over-applied, reduces skid resistance and creates unsafe conditions. Suitable methods shall be used, such as signing, barricades, flagmen, pilot cars, etc. to protect the construction and the public.

SECTION 12

RESTORATIVE SEALS USING EMULSIFIED RECYCLING AGENTS

12.1 Scope

This performance guide covers the use of rejuvenating agents for restorative seals and construction seals. It should be used as a guide in achieving successful results through proper construction practices and adequate knowledge and understanding of emulsions.

12.2 Definitions

12.2.1 Restorative Seal

A light spray application of dilute recycling emulsion, applied to an existing asphalt concrete surface which restores the chemical balance to the asphalt at the surface and some small depth below. This balance is lost from the heat of the hot mix plant, exposure to water and air, as well as deicing agents and other contaminates which primarily affect the surface asphalt. This seal may also help to seal hairline cracks and fill surface pores which develop due to aging.

12.2.2 Construction Seal

Light spray application of dilute recycling emulsion, applied to a newly constructed asphalt concrete surface which restores the chemical balance to the asphalt at the surface and some small depth below. This balance is lost primarily from the heat of the hot mix plant. This seal may also help to seal or prevent the formation of surface pores.

12.2.3 Dense Surface

Tight, relatively non-absorbent smooth-textured surface.

12.2.4 Open Surface

Open, relatively porous and absorbent, rough textured surface. This type of surface will require a higher rate of application to compensate for the recycling emulsion which flows into the large voids and cracks. Most chip sealed surfaces are open surfaces.

12.3 Applicable Documents

12.3.1 ASTM Documents

- D70 Test Method for Specific Gravity of Semi-Solid Bituminous Materials
- D140 Sampling Bituminous Materials
- D244 Standard Methods of Testing Emulsified Asphalts
- D1754 Test Method for Effects of Heat and Air on Asphaltic Materials (Thin Film Oven Test)
- D2170 Test Method for Kinematic Viscosity of Asphalts
- D 2171 Test Method for Viscosity of Asphalts by vacuum Capillary Viscometer
- D2042 Test for Solubility of Asphalt Materials in Trichloroethylene

- D2872 Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)
- D2007 Test Method for Characteristic Groups in Rubber Extender and Processing Oils by Clay Gel Adsorption Chromatographic Method
- D2995 Practice for Determining Application Rate of Bituminous Distributors
- D5505 Classifying Emulsified Recycling Agents
- D6930 Test Method for Settlement and Storage Stability of Emulsified Asphalt
- D6933 Test Method for Oversized Particles in Emulsified Asphalt
- D6935 Test Method for Cement Mixing of Emulsified Asphalt
- D6997 test Method for Distillation of Emulsified Asphalt

12.3.2 AEMA Documents

- **A Basic Asphalt Emulsion Manual (BAEM)**
- Recommended Performance Guidelines

12.4 Description of Work

This work shall consist of furnishing all labor, equipment, and materials, and in performing all operations necessary for the restorative or construction seal of asphalt concrete surfaces by the spray application of an appropriate recycling emulsion, diluted with water, complete, in accordance with the specifications, applicable drawings and subject to the terms and conditions of the contract.

12.5 Recycling Emulsion

- The emulsified rejuvenating agent must be homogenous, free-flowing at pumping temperature, and must conform to the requirements of **Table 12-1 Specification for Emulsified Recycling Agent** for ER-1.
- ER-1 is a material whose main function is to rejuvenate aged asphalt. The material is a petroleum derivative, and highly compatible with asphalts. It is classified by viscosity.
- Sampling shall be carried out in accordance with Method D140.
- Samples shall be stored in new, clean, airtight sealed containers as specified in Method D140 at a temperature not less than 40°F (4°C) until tested.
- Testing — the emulsion shall be tested in accordance with appropriate ASTM Methods.
- Normally this emulsion is diluted prior to application to reduce viscosity for spraying, to allow filling of small cracks or voids, and to more accurately apply very small quantities of residual material per square yard.
- For the restorative or construction seal, the emulsion is normally of the slow setting type in order to properly flow into and seal small cracks or porous surfaces.

12.6 Water

Water is normally used for diluting slow set emulsions for restorative seals. It should be clean, potable water, free from detectable solids or incompatible soluble salts.

Test for dilution incompatibility, whenever in doubt, by diluting the recycling emulsion in the severest conditions anticipated (e.g., high dilution, cold water, hard water, high shear pumps). No instability or coagulation should appear such as BB-sized particles. Consult the recycling emulsion supplier if there are any questions.

Table 12-1 Specification for Emulsified Recycling Agent

Tests		ER-1	
Test	**Method**	**Min**	**Max**
On Emulsion			
Viscosity, 50° C, SSF	D244		100
Sieve, %	D6933		0.1
Storage Stability, 24hr. %	D6930		1.5
Residue, by distillation, %	D6997	65	
Cement Mixing	D6935		2.0
Specific Gravity	D70	report	
Compatibility1	varies	report	
On Residue From Distillation			
Viscosity, 60° C, cSt	D2170	50	200
Saturates, %	D2007		30
Solubility in Trichloroethylene	D2042	97.5	
On RTFO2 Residue			
RTFO, Wt. change, %	D2872		4

NOTES: 1. This specification allows a variety of emulsions, including high-float and cationic emulsions. The engineer should take the steps necessary to keep incompatible materials from co-mingling in tanks or other vessels. It would be prudent to have the chemical nature (float test for high float emulsions, particle charge test for cationic emulsions, or other tests as necessary) certified by the supplier.

NOTES: 2. RTFO shall be the standard. When approved by the engineer, the Thin Film Oven Test (ASTM D 1754) may be substituted for compliance testing.

12.6.1 Other Methods of Dilution

When water is not desirable for recycling emulsion dilution, a small amount of compatible emulsifier solution can be used. The recycling emulsion manufacturer is the one most familiar with the particular recycling emulsion and must be consulted to determine specific method and materials for dilution.

12.6.2 Diluting the Recycling Emulsion

When the recycling emulsion is to be diluted for spray application, the final product shall be a fluid, homogenous mixture. Care must be exercised to prevent hard or extremely cold water or emulsifier solution from chemically breaking or thermally shocking the recycling emulsion. Dilution may be improved by pre-warming the dilution liquid to 77 to 122°F (25 to 50°C). Never add emulsion to water, always add water or other dilutent to recycling emulsion. Normal dilution for application is achieved by diluting 1 part recycling emulsion to 1 part water (1 + 1). Other dilution rates are 2 + 1.

12.7 Storage and Handling

Diluted recycling emulsions are normally not stored, unless weather or the like necessitates temporary storage. A diluted recycling emulsion is more unstable than the original.

Suitable storage and handling facilities shall be provided for the recycling emulsion, so as to:

1. Prevent contamination by water, oils or other liquids.
2. Prevent contamination by other incompatible recycling emulsions.
3. Protect from freezing or boiling temperatures which break the recycling emulsion and cause separation into asphalt and water.
4. Protect from local overheating by high temperature heating coils. Use of hot water is recommended for heating recycling emulsion. Where steam, hot oil or direct fire must be used, controls must keep coil surfaces below 185°F (85°C).
5. Use bottom loading wherever possible or employ full length drop hose to eliminate foaming. Foaming may cause a volume gauge error due to inclusion of air from free fall.
6. Allow surface crust which forms on recycling emulsion in storage to float without disturbance. Vertical tanks can help maintain constant and minimal surface area. Return lines into tanks should have outlets near the tank bottom and circulation should not free fall or disturb surface crust.
7. Reduce high shear which can break recycling emulsions by enlarging clearances on new gear pumps by milling if necessary.
8. Prevent unnecessary circulation which can cause drop in emulsion viscosity or actual recycling emulsion breakdown.
9. Do not agitate recycling emulsion with forced air as it may cause the recycling emulsion to break in the tank.

12.8 Equipment

12.8.1 Emulsion Distributor

It is the principal function of the distributor to apply recycling emulsion uniformly in both transverse and longitudinal directions at the specified rate in gal/yd² (L/m²). Failure to do so can result in streaking in which too much and too little recycling emulsion alternate every few inches across the road surface.

Streaking usually results from incorrect positioning of the nozzles in the spray bar, different nozzle sizes in the spray bar, incorrect spray bar height, damaged or nicked spray nozzles, forcing more or less than the optimum quantity of recycling emulsion through each spray nozzle, attempting to spray recycling emulsion at too low of a temperature so that it cannot fan out properly from the spray nozzles, and even by inability of the control mechanism to fully open the spray nozzles in one or more sections of the spray bar.

To avoid streaking, each nozzle in the spray bar of the asphalt distributor should be turned to make the constant angle with the longitudinal axis of the spray bar that is recommended by the manufacturer. All nozzles in the spray bar should be of the same size. The spray bar height should provide double or triple overlap of the asphalt binder being applied by the spray nozzles as recommended by the manufacturer. The distributor should be able to spray recycling emulsion within ±5.0 percent of the average application rate in the longitudinal direction and within ±10.0 percent of the average rate of application for any 4-inch (100mm) width in the transverse direction. A very simple and practical method for checking the rate of application of recycling emulsion in both the longitudinal and transverse directions is provided by ASTM D2995.

For satisfactory application of recycling emulsion, uniform pressure must be maintained in the spray bar. The optimum pressure discharges recycling emulsion at a constant rate through each spray nozzle, (e.g., 4 gal/min (15.1 L/min)). Only at this constant rate of discharge does the recycling emulsion fan out uniformly from each spray nozzle. Therefore, different rates of application of recycling emulsion in gal/yd² (L/m²) should be achieved by changing the forward speed of the distributor and not by changing the discharge rate in gal/min (L/min) from each spray nozzle.

Important accessory equipment for each asphalt distributor includes an accurate gauge, 6 in. (150mm) in diameter or larger, to indicate pressure in the spray bar, an accurate tachometer to show pump speed in r/min, an accurate thermometer for registering the temperature of the recycling emulsion in the distributor, a calibrated dipstick to enable gallons (liters) of emulsion per inch (mm) of depth to be read at any time, and a bitumeter that has been calibrated to accurately measure the distance travelled and the speed in ft/min (m/min) when spraying.

12.8.2 Foreign or Objectionable Materials

All tools and equipment shall be clean of foreign or objectionable materials so as not to contaminate the recycling emulsion. flushing and washing the distributor prior to commencing work is necessary.

The continuous cleanliness and safe, satisfactory condition of all tools and equipment are subject to the approval of the Director.

12.8.3 Calibration

At any time, the Engineer may require calibration of the recycling emulsion distributor.

12.8.4 Operator

The distributor operator shall be experienced in setting and controlling the application rate of the recycling emulsion.

12.9 Preparation of Surface

Existing surface shall be repaired as directed by the engineer prior to further construction. The recycling emulsion will flow into the small cracks and seal them, but it cannot be expected to take the place of adequate repair of major deterioration of the pavement.

The surface shall be free from dust, loose or foreign matter and any objectionable material which would hinder adhesion of the recycling emulsion. Parking lots or other areas with heavy oil drippings should be cleaned with detergent or by other methods prior to spraying with recycling emulsions.

12.10 Application

12.10.1 Spraying

Recycling emulsion applied by pressure distributor shall be applied at a uniform rate, without splattering or drilling from the spray bar, by using low pressure. Nozzle angle and spray bar height must be adjusted to insure correct spray pattern.

Distribution shall be commenced with a running start to insure a full rate of speed over the entire area, and to avoid local over-application.

12.10.2 Application Temperature

Application temperature shall be 77 to 122°F (25 to 50°C) or as recommended by the Recycling emulsion supplier.

12.10.3 Application Rate

The diluted recycling emulsion may be applied at a rate of from 0.03 to 0.10gal/yd² (0.14 to 0.44L/m²) as specified by the Director. The typical range of application for most projects is 0.05 to 0.08gal/yd² (0.22 to 0.36L/m²)

12.10.4 Objective of Restorative or Construction Seals

The objective for proper application of a restorative or construction seal is to apply a uniform coverage of rejuvenating emulsion, just sufficient to flow into and seal the pavement pores, small cracks, and voids against water and weathering. Ideally, the peaks of most aggregate particles should remain uncoated with rejuvenator to prevent reduction of skid resistance. Two or more successive applications of the respective proportion of the desired total application can aid in preventing excess application. The distributor should be operated in opposite directions on each pass to minimize inconsistencies in spray pattern.

12.10.5 Over-Application

Upon over-application and at the discretion of the supervising engineer, a light cover of clean, fine sand may be applied onto the uncured seal at the rate of 3 to 6lb/yd² (1.7 to 3.3kg/m²) to provide for a safe, skid resistant surface. A pass of a pneumatic tired roller should be made over this light sand dusting to firmly embed the fine sand.
The seal should be allowed to completely cure before opening to traffic.

12.10.6 Spills

AII spills, leaks, or other objectionable amounts of recycling emulsion on the pavement shall be immediately removed by use of suitable absorbent material, such as fine sand, and disposed of properly.

12.11 Weather

Spray application of recycling emulsions should be avoided prior to probable rainfall and shall not be applied during rain. High humidity will slow the recycling emulsion break. Pavement and air temperatures should be above 50°F (10°C). With extreme hot, dry conditions, it may be advantageous to lightly dampen the surface to be sprayed with 0.15gal/yd^2 (0.68L/m^2) water to prevent premature break of the recycling emulsion.

12.12 Traffic Control

Traffic control during application shall be employed to protect the freshly sprayed Recycling emulsion until it is cured to a safe condition. Unnecessary pickup of the fresh recycling emulsion by construction traffic shall be avoided. Traffic volume should determine the type and extent of control needed. Suitable methods shall be used, such as signing, barricades, flagmen, pilot cars, etc., to protect the construction and the public.

SECTION 13

COLD MIXED ASPHALT EMULSION MAINTENANCE MIXES

13.1 Scope

The recommended practice covers asphalt emulsion aggregate maintenance mixtures for stockpiling or immediate patching use made cold. It is written as a guide and should be used as such. Use specifications should then be adapted to conform to job, local user, and performance requirements.

13.2 Applicable Documents

13.2.1 ASTM Documents

- D140 Practice for Sampling Bituminous Materials
- D244 Test Methods for Emulsified Asphalts
- D692 Specification for Coarse Aggregate for Bituminous Paving Mixtures
- D977 Asphalt Emulsion
- D979 Practice for Sampling Bituminous Paving Mixtures
- D1073 Specification for Fine Aggregate for Bituminous Paving Mixtures
- D2172 Test for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
- D2397 Specification for Cationic Emulsified Asphalt
- D2489 Practice for Estimating Degree of Particle Coating of Bituminous-Aggregate Mixtures
- D3515 Specification for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures
- D3625 Effect of Water on Bituminous-Coated Aggregate Using Boiling Water
- D3628 Selection and Use of Emulsified Asphalts
- D4215 Specification for Cold-Mixed, Cold-Laid Bituminous Paving Mixtures
- D6704 Test Method for Determining the Workability of Asphalt Cold Mix Patching Material

13.2.2 AEMA Documents

- **A Basic Asphalt Emulsion Manual (BAEM)**

13.3 Asphalt Emulsion

13.3.1 Sampling and Testing

- The asphalt emulsion shall be sampled in accordance with procedures outlined in ASTM D140 and tested in accordance with ASTM D244.
- All samples shall be shipped and stored in clean airtight sealed plastic containers.
- Material shall be homogeneous, miscible with water and shall show no signs of separation after thorough mixing within 30 days after delivery.

- Selection of Asphalt Emulsion — In warmer climates or when material is to be used immediately, MS-2, HFMS-2 and CMS-2 or inverted asphalt emulsions are recommended.
- When prolonged stockpiling or low temperatures, 15°F (-9°C) are anticipated, HFMS-2s or inverted asphalt emulsions are recommended. When specifically approved by the purchaser, other types of asphalt emulsion may be used if experience has proven that satisfactory performance will result. Other asphalt emulsions, which can be used, can be found listed in ASTM D3628.

13.4 Aggregate

The aggregates shall be crushed stone, crushed slag, crushed gravel, or sand conforming to the requirements of the appropriate ASTM specifications.

- Coarse Aggregate Specification D692
- Fine Aggregate Specification D1073.

Other mineral aggregates, such as uncrushed gravel, crushed recycled concrete, RAP and crushed shell, and other gradings, may be specified, provided that local experience or tests have demonstrated their ability to produce satisfactory asphalt emulsion aggregate maintenance mixtures.

13.5 Testing of Asphalt Paving Mixture

- Samples shall be obtained in accordance with ASTM D979. Stockpile samples shall be taken at least 4 in. (100mm) below surface excluding any slight outer crust which may have formed.
- Adequate coating of the job aggregate by the asphalt emulsion shall be determined in accordance with ASTM D2489.
- Adequate breaking and curing characteristics can be measured by placing 100g samples of the mixture in 800ml glass beakers and covering them with water at given intervals. If the water appears as if it has diluted the asphalt emulsion, the chemistry needs to be adjusted so that the break and cure occurs in the appropriate time frame that has been predetermined for successful mixing and application in specific field conditions.
- Residual asphalt content shall be determined by extraction in accordance with ASTM D2172.
- Stripping of residual asphalt from aggregate shall be determined in accordance with ASTM D3625. Another popular method follows:

When 50 g of the mixture, whether freshly prepared or taken from the stockpile, is heated at 260°F (121°C) in a laboratory oven for one hour and cooled with stirring to 200°F (93°C) in laboratory air, then is placed in 400mL of boiling distilled water in a 600mL glass beaker and stirred with a glass rod at the rate of one revolution per second for three minutes, the aggregate shall be at least 75% coated with an asphalt film. Visual observation of the coating shall be made by decanting the water and spreading the mix on an absorbent paper.

Workability of the stockpiled mixture can be determined by using ASTM D6704. Another method to determine workability is as follows:

Workability can be determined by placing the cool, loose mix in a metal pan at least 10 in. by 10 in. size and sufficiently deep to form an uncompacted layer 2 in. (50mm) in depth. Place the pan containing the mixture in a cold room or freezer for a period of time such that the total mixture will be cooled below 15°F (-9°C). Then remove the pan and mixture from the cold environment and record the temperature at which the mixture is determined to be workable. In a workable mixture, a 1 in. putty knife will enter the sample with reasonable ease and the material may be mixed with very little conglomeration.

13.6 General Requirements

- The proportions to be used in the production of the mixture shall be determined by the engineer or the supplier of the asphalt emulsion. The proportions so established shall be known as the Job Mix Formula and be determined by using ASTM4215.
- The percentage of asphalt emulsion to be added to the aggregate shall be within the specified limits by weight of the dry aggregate. The exact percentages of aggregate and emulsion to be used shall be fixed by the engineer or the emulsion supplier on the basis of laboratory tests and analysis of the aggregate. The residual asphalt tolerance should be ±0.5% of the Job Mix Formula.
- The mixture shall be capable of being handled by the use of either hand shovels or power loading equipment, shall be workable for placing and compacting with hand tools or power equipment at the temperature of mixing or at temperatures as low as 15°F (-9°C).
- The mixture shall be usable at once from the mixer or over a period of several months from a stockpile. The mixture shall remain in place when used to patch wet or dry pavements and shall be stable under normal traffic conditions.

NOTE

These suggested limits are meant to be flexible and used as a guide. However, there have been successful mixes which performed as desired whose characteristics were outside the limits shown.

13.7 Handling & Use

- Asphalt emulsion temperature should never exceed 185°F (85°C) prior to mixing with the aggregate.
- Mix aggregate and asphalt emulsion until best coating is obtained. Stripping may result if over-mixed or if the aggregate moisture content is excessive.

13.8 Mixing

Asphalt emulsion and aggregate may be mixed in place or at a central plant pug-mill. The choice of method depends on such factors as:

1. Equipment availability
2. Size of project

3. Aggregate source, type, and cost
4. Anticipated traffic volumes and loads
5. Climatic conditions

The best balance between these factors must be evaluated. Regardless of the mixing method, 100% coating of the coarse aggregate particles is not always achieved, nor is it necessary.

13.8.1 Mixing Moisture

Mixing procedures should aim at achieving a uniform dispersion of the asphalt emulsion with a complete coating of the finer aggregate fractions. Toward achieving this uniform dispersion of the asphalt emulsion, it is sometimes necessary to moisten the aggregate before application of the asphalt emulsion. The appropriate volume of water to be added should be determined by the mix design, and if required should be added prior to the incorporation of the asphalt emulsion.

Mixing of the asphalt emulsion should be done at as Iowa of a moisture content as possible, because the compaction moisture content is usually lower than the moisture content after mixing. Under poor drying conditions, the removal of surplus moisture could be a costly and time consuming operation. Mixing asphalt emulsions with aggregates that are saturated can lead to the asphalt emulsion being diluted to a point where the viscosity properties are changed and leaching can occur. If this happens the asphalt emulsion needs adjusted or mixing should be delayed until the in situ moisture content drops.

13.8.2 Central Plant Mix

A central plant to produce the cold mix material is recommended for projects that involve close tolerances and high production. Generally, this type of mixing is done at the source of the aggregate.

The central cold mix plant consists of a mixer and certain auxiliary equipment for feeding the asphalt emulsion, water, aggregate and additives to the mixer. The asphalt emulsion central mixing plant generally has no screens other than a scalping screen to remove oversize aggregate. At the very least, the plant should consist of a pug mill, an asphalt emulsion storage tank, a metering pump, units for feeding water and additives, controls for adjusting and monitoring the various components, a conveyor, and a power source, a tachometer to aid in maintaining a constant speed on the conveyor belt, and one or more aggregate bins with belt feeders. The mixer should provide for variation in mixing times to ensure that the aggregate is properly coated but not over mixed. Mixing times can be varied in a continuous pug-mill plant by changing the angle of the paddles, by varying the height of the end-gate, or by changing the location of the asphalt spray bar.

Asphalt emulsion cold mixes require shorter mixing time than asphalt concrete mixes. The tendency is to over-mix asphalt emulsion mixes, and this may have the effect of scrubbing the asphalt from the aggregate. It may also result in premature breaking of the asphalt emulsion, causing overly stiff mixtures.

13.8.3 Travel Mixers

Aggregates are placed into the hopper of the mixer where they are drawn into the mixing chamber. The asphalt emulsion-proportioning device is interlocked to ensure a constant blend. The asphalt emulsion is added by pumping through a spray bar mounted on the mixing chamber. This method permits the addition of all the asphalt emulsion in one application. The forward speed of the mixer should be adjusted so that the material being ejected has a uniform texture. Injecting the asphalt emulsion in one application through the mixing chamber can be done at a lower moisture content than with distributor application. The single application immediately brings the aggregate to optimum mixing moisture whereas the first application with a distributor adds only part of the moisture associated with the asphalt emulsion.

The travel plant places the mix on grade ready for consolidation into a stockpile.

13.8.4 Rotary Mixers

Rotary cross-shaft mixing employs a mobile mixing chamber which is self-propelled. The mixing chamber, usually 6 to 8 ft wide, and 2 to 3 ft high, open at the bottom, contains one or more shafts, transverse to the roadbed, upon which mixing blades are mounted. As the shafts rotate rapidly, the mixing blades thoroughly agitate the material in the roadbed. The machine, moving forward, strikes off a uniform course of asphalt aggregate mixture. Self-propelled rotary mixers are designed to accurately and automatically control the predetermined mixing depth from existing surface grades.

Rotary mixers equipped with built-in spraying systems require that the asphalt emulsion application rates be matched accurately with the width and thickness of the course, forward speed of the mixer, and the density of the in-place aggregate. However, when utilizing a rotary mixer not equipped with spray-bars, an asphalt emulsion distributor, operating ahead of the mixer, applies asphalt emulsion to the aggregate. Incremental applications of asphalt emulsion and passes of the mixer are usually necessary to achieve the specified mixture. Most rotary mixers are equipped with spray systems and when using this equipment, the following steps are recommended:

1. Spread the aggregate to uniform grade and cross section with motor graders.
2. Thoroughly mix the aggregate by one or more passes of the mixer.
3. Add asphalt emulsion in increments until the total required amount of asphalt emulsion is applied and mixed. If the mixer is not equipped with spray-bars, the asphalt emulsion is to be applied with an asphalt emulsion distributor.
4. Make one or more passes of the mixer between applications of asphalt emulsion, as necessary for thorough mixing.

The total number of passes of the rotary mixer will depend on the method of adding the asphalt emulsion and on the amount of No. 200 (0.075mm) material present.

13.8.5 Distributor & Motor Grader Mixing

Asphalt emulsion mixtures may be prepared by applying the asphalt emulsion by a distributor and blade mixing with a motor grader.

The first step in the operation is to shape the prepared aggregate into a uniform windrow of a known volume by means of a spreader box, windrow proportioner, or motor grader. The motor grader then lays out a uniform lift of aggregate from the windrow onto the mixing table. If mixing water is required, it is then added at a predetermined rate to the aggregate lift. Next the asphalt emulsion is applied at the predetermined rate by the distributor to the lift of aggregate.

The motor grader then folds the aggregate over the emulsion. The motor grader may work this lift back and forth to achieve mixing, or the mixture may be windrowed on the opposite side of the mixing table and another lift of aggregate processed as above. This procedure is repeated until the design quantity of asphalt emulsion has been added to the total windrow of aggregate.

The grading of the aggregate throughout the windrow may vary. Therefore, as asphalt mixing progresses, close attention should be paid to the appearance of the mix. It is very important that uniformity of grading and moisture content be achieved. Mixing should consist of as many passes with the motor grader as needed to fully spread the emulsion and coat the aggregate particles, and when completed the windrow should be moved to one side of the mixing table.

Blades are relatively inefficient mixing devices and the aeration is high. Therefore, a water content higher than that for rotary mixers will be required to assist dispersion of the emulsion and replace relatively high evaporation losses.

The mixing moisture will be well above the optimum compacting moisture so that the stabilized material will need drying before compacting.

13.8.6 Secondary Mixing

Sometimes further mixing of the windrowed material may be necessary after the addition of the asphalt emulsion. Unless the travel mixer can be used as a multiple pass mixer, this additional mixing usually is done with a motor grader. This ensures that all the windrowed material is incorporated into the mix. The number of passes with the motor grader required for this purpose varies with different job conditions. After the mixing operation is completed, the windrow should be moved to one side of the mixing table.

13.9 Stockpile Procedure

- To prevent excess moisture on the aggregate before mixing, the aggregate may have to be aerated.
- Place stockpile on a level grade in a conical shape to promote proper drainage of precipitation.

- Stockpiles shall be constructed in such a manner that no compaction other than the weight of the material itself will result. No equipment of any kind shall be run over the surface of the stockpile.

13.10 Construction Practice

- Equipment varies from only hand shovel to modern loaders and spreaders, from hand tempers to rollers.
- Prior to patching, the pavement should be properly prepared. The distressed section is removed extending into good pavement and as deep as necessary. Cut vertical edges with one pair of edges at right angles to the direction of traffic. If water is the cause of failure, install drainage. Clear out loose material and apply a tack coat to the vertical edges. Back fill with patch mix and compact.

13.11 Methods of Sampling and Testing

Sample all material and determine the properties enumerated in this guide in accordance with ASTM methods.

SECTION 14

HOT MIXED ASPHALT EMULSION MAINTENANCE MIXES

14.1 Scope

The recommended practice covers asphalt emulsion aggregate maintenance mixtures for stockpiling or immediate patching use from an approved hot mix plant. It is written as a guide and should be used as such. Use specifications should then be adapted to conform to job, local user, and performance requirements.

14.2 Applicable Documents

14.2.1 ASTM Documents:

- C127 Test for Specific Gravity and Absorption of Coarse Aggregate
- C128 Test for Specific Gravity and Absorption of Fine Aggregate
- C131 Resistance to Degradation of Small-Size Course Aggregate by Abrasion and Impact in the Los Angeles Machine
- C136 Method for Sieve Analysis of Fine and Coarse Aggregates
- D75 Practice for Sampling of Aggregates
- D140 Practice for Sampling Bituminous Materials
- D242 Specification for Mineral Filler for Bituminous Paving Mixtures
- D244 Standard Methods of Testing Emulsified Asphalts
- D423 Test Method for Liquid Limit of Soils
- D424 Test Method for Plastic Limit and Plasticity Index of Soils
- D546 Test Method for Sieve Analysis of Mineral Filler for Road and Paving Materials
- D692 Specification for Coarse Aggregate for Bituminous Paving Mixtures
- D977 Specification for Emulsified Asphalt
- D979 Practice for Sampling Bituminous Paving Mixtures
- D1073 Specification for Fine Aggregate for Bituminous Paving Mixtures
- D2172 Test for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
- D2419 Test Method for Sand Equivalent Values of Soils and Fine Aggregate
- D2489 Test Method for Degree of Particle Coating of Bituminous-Aggregate Mixtures
- D3203 Test Method for Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
- D3515 Specification for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures
- D3628 Practice for Selection and Use of Asphalt Emulsion

14.2.2 AEMA Documents

- **A Basic Asphalt Emulsion Manual**

14.3 Asphalt Emulsion

- ASTM D977 Asphalt Emulsion
- ASTM D2397 Cationic Asphalt Emulsion

14.3.1 Sampling and Testing

- The asphalt emulsion shall be sampled in accordance with procedures outlined in ASTM D140 and tested in accordance with ASTM D244.
- All samples shall be shipped and stored in clean airtight sealed plastic containers.
- Material shall be homogeneous, miscible with water and shall show no signs of separation after thorough mixing within 30 days after delivery.

14.3.2 Selection of Asphalt Emulsion

In warmer climates or when material is to be used immediately, MS-2, HFMS-2 and CMS-2 and inverted asphalt emulsions are recommended. When prolonged stockpiling or low temperatures, 15°F (-9°C) are anticipated, HFMS-2s and inverted asphalt emulsions are recommended.

When specifically approved by the purchaser other types of asphalt emulsion may be used if experience has proven that satisfactory performance will result.

14.4 Aggregate

The aggregates shall be crushed stone, crushed slag, crushed gravel, or sand conforming to the quality requirements of the appropriate ASTM specifications.

- Coarse Aggregate Specification D692
- Fine Aggregate Specification D1073.

Other mineral aggregates, such as uncrushed gravel, crushed recycled concrete, RAP and crushed shell, and other gradings, may be specified, provided that local experience or tests have demonstrated their ability to produce satisfactory asphalt emulsion aggregate maintenance mixtures.

14.5 Testing of Asphalt Paving Mixture

- Samples shall be obtained in accordance with ASTM D979. Stockpile samples shall be taken at least 4 in. (100mm) below surface excluding any slight outer crust which may have formed.
- Adequate coating of the job aggregate by the asphalt emulsion shall be determined in accordance with ASTM D224.
- Residual asphalt content shall be determined by extraction in accordance with ASTM D2172.
- Stripping of residual asphalt from aggregate shall be determined in accordance with ASTM D1054. Another popular method follows:

When 50 g of the mixture, whether freshly prepared or taken from the stockpile, is heated at 260°F (121°C) in a laboratory oven for one hour and cooled with stirring to 200°F (93°C) in laboratory air, then is placed in 400mL of boiling distilled water in a 600mL glass beaker and stirred with a glass rod at the rate of one revolution per second for three minutes, the aggregate shall be at least 75% coated with an asphalt film. Visual observation of the coating shall be made by decanting the water and spreading the mix on an absorbent paper.

Workability of the stockpiled mixture shall be determined by placing the cool, loose mix in a metal pan at least 10 in. by 10 in. size and sufficiently deep to form an uncompacted layer 2 in. (50mm) in depth. Place the pan containing the mixture in a cold room or freezer for a period of time such that the total mixture will be cooled below 15°F (-9°C). Then remove the pan and mixture from the cold environment and record the temperature at which the mixture is determined to be workable. In a workable mixture, a 1 in. putty knife will enter the sample with reasonable ease and the material may be mixed with very little conglomeration.

14.6 General Requirements

- If the mix is intended for base construction larger sized aggregate would be used.
- The mixture shall be capable of being handled by the use of either hand shovels or power loading equipment, shall be workable for placing and compacting with hand tools or power equipment at the temperature of mixing or at temperatures as low as 15°F (-9°C). The mixture shall be usable at once from the mixer or over a period of several months from a stockpile. The mixture shall remain in place when used to patch wet or dry pavements and shall be stable under normal traffic conditions.

NOTE

These suggested limits are meant to be flexible and used as a guide. However, there have been successful mixes which performed as desired whose characteristics were outside the limits shown.

14.7 Composition of Paving Mixtures

- Mix compositions required for hot asphalt emulsion mixtures conform to ASTM D3515, Table 1. Hot asphalt emulsion maintenance mixtures generally have a nominal maximum size of 3/4 in. (19mm). In addition, laboratory testing should be performed prior to construction. This testing should include optimum asphalt determinations and mix stability studies, as well as aggregate coating and water resistance tests.

NOTE

The nominal top size aggregate (mix designation) selected should be determined by the intended use, thickness of paving courses, and desired texture. The required mix should be specified.

— Compositions shown ASTM D3515 are based on the use of fine and coarse aggregates having approximately the same bulk specific gravities; grading of the total aggregate, therefore, would be the same on either a weight or bulk volume basis. If the bulk specific gravities of coarse and fine aggregates differ greatly, it may be desirable to change the grading limitations to compensate for these differences.

- A job mixture shall be selected that comes within the specification limits and that is suitable for the traffic, climate conditions, and specific gravities of the aggregates used.
- Any variation from the job mix formula in the grading of the aggregate, as shown by the sieve analyses of materials in the plant or, any variation from the job mix formula in the asphalt content, as indicated by extraction tests of the finished mixture, greater than the percentage shown in ASTM D3515 Table 3, shall be investigated, and the conditions causing such variation shall be corrected.

14.8 Mixing Plant

- The mixing plant may be any approved type of equipment of the batch or continuous type which provides for a drum type dryer and pug-mill mixer.
- A combination dryer and mixer (drum mixer) in which the asphalt emulsion and aggregate are heated together by the direct application of heated gases from a burner may also be used. On batch plants, the pug-mill mixer chamber shall be vented to allow the escape of steam.
- The discharge end of the asphalt emulsion circulating pipe should be kept below the surface of the asphalt emulsion in the storage tank to prevent foaming and air entrainment.
- Provisions should be made in the asphalt transfer system that will enable the operator to turn off or reduce the heat media from all lines, pumps, and jacketed asphalt material buckets as soon as the system is open and circulating properly.
- Care should be taken to avoid overheating the emulsion in the lines, pumps, and tank.
- Approved storage silos for the hot asphalt emulsion mixture may be employed.

14.9 Mixing Plant Operation

14.9.1 Aggregate Storage

Aggregates furnished in different sizes or from different sources shall be kept separate, and adequate provision shall be made to keep them from becoming mixed or otherwise contaminated. Stockpiles shall be built and the materials removed there from in such a manner as to minimize size segregation.

14.9.2 Storage & Handling of Asphalt Emulsion

The asphalt emulsion shall be maintained at a temperature at which it can be properly handled through the pumping system and uniformly distributed through the mixture. At no time during the processing, from storage to mixing, will the temperature of the asphalt emulsion be allowed to exceed 185°F (85°C).

14.9.3 Preparation and Handling of Mineral Aggregates

Each size aggregate shall be separately fed by feeders to the cold elevator or elevators in proper proportion and at a rate to permit correct and uniform temperature control of the heating and drying operation.

14.10 Mix and Temperature

- The aggregate shall be dried and delivered to the mixer at a temperature such that the asphalt emulsion mixture will be produced at a temperature within the range of 220° to 260°F (104° to 127°C).
- Minimum mixing time may be established on the percentage of coating particles as determined by ASTM D2489 Test for Degree of Particle Coating of Bituminous- Aggregate Mixtures. The minimum values for percentage of coated particles used to establish the minimum mixing time should be set by the engineer. These values will vary with aggregate gradation, particle shape and surface texture, and with the asphalt content and use for which the mixture is intended.

14.11 Stockpile Procedure

- To prevent excess moisture on the aggregate before mixing, the aggregate may have to be aerated.
- Place stockpile on a level grade in a conical shape to promote proper drainage of precipitation. The stockpile shall be no more than one truckload high for the first 48 hours.
- Stockpiles shall be constructed in such a manner that no compaction other than the weight of the material itself will result. No equipment of any kind shall be run over the surface of the stockpile.

14.12 Construction Practice

- Equipment varies from only hand shovel to modern loaders and spreaders, from hand tempers to rollers.
- Prior to patching, the pavement should be properly prepared. The distressed section is removed extending into good pavement and as deep as necessary. Cut Vertical edges with one pair of edges at right angles to the direction of traffic. If water is the cause of failure, install drainage. Clear out loose material and apply a tack coat to the vertical edges. Back fill with patch mix and compact.

14.13 Methods of Sampling and Testing

Sample all material and determine the properties enumerated in this guide in accordance with ASTM methods.

SECTION 15

OPEN-GRADED MIXES USING ASPHALT EMULSIONS

15.1 Scope

This performance guide covers the use of asphalt emulsion in the construction of open-graded pavements. The attention given to materials, design, and workmanship is intended to aid those with little or no experience with open grade asphalt emulsion mixes by providing basic information and references for more detailed study. This is a guide only and is not intended to take the place of the construction specification, which governs, and takes into consideration local practice and conditions.

NOTE:

The conceptual approach to open-graded mix, which has been developed in the USA during recent years by the Federal Highway Administration and the Forest Service has resulted in strict requirements to achieve certain end results. This guide follows the FHWA concept. However, since established practices regarding open-graded mixes often differ from place to place from the FHWA requirements, a note has been added to **15.2 Description** to describe some of these differences.

15.2 Description

Open-graded mixes are designed to provide high air void capacity and when needed, pore size or drainage channels large enough to permit heavy rainfall to drain and escape, thus minimizing the danger of hydroplaning due to water buildup at the road surface.

By selection of aggregate gradation, geometry, and hardness, together with percent and grade of residual asphalt, the desired results can be achieved.

Open-graded mixes are also characterized by a thick film of binder on the aggregate. It should also be mentioned that the air voids in open mixes aid the curing of the asphalt emulsion.

Open-graded base, intermediate, and thick surface courses, placed 2 to 8 in.(50 to 200 mm) in depth are generally made from aggregate with less than 10% passing the No. 8 (2.36 mm) sieve, less than 2% passing the No. 200 (0.075 mm) sieve, and having 20 to 30% air voids after compaction. (A 2% maximum passing the No. 200 (0.075 mm) sieve has been suggested where cationic asphalt emulsions are used, and up to 5% with anionic asphalt emulsions having good mixing stability.)

Open-graded friction courses have a compacted thickness of 5/8 to ¾ in. (16 to 19 mm). When laid on an existing hard surfaced pavement, they provide an anti-skid surface, and renewal of the surface of aged, weathered pavements. A 3/8 in. (9.5 mm) top size aggregate is used, with 15% air voids after compaction is recommended for these thin friction courses.

Crushed stone, crushed gravel, or slag of a polish resistant type and which have good roughness or micro texture should be selected for surface or friction courses.

The advantages, or reasons, for selecting open-graded mixes for surface courses (either hot or cold mix) are:

1. Improved skid resistance at high speeds during wet weather.
2. Minimization of hydroplaning effects during wet weather.
3. Improved road smoothness.
4. Minimization of splash and spray during wet weather.
5. Minimization of wheel path rutting in open-graded layers.
6. Improved visibility of painted traffic markings.
7. Improved night visibility during wet weather (less glare).
8. Lower highway noise levels.

All open-graded courses have the advantages of:

9. Material and hauling cost savings due to greater spread or yield per ton of mix.
10. Good flexibility of pavement layer.

And in the case of asphalt emulsion mixes the additional advantages of:

11. Lower construction costs.
12. Lower cost mixing plant (portable pug without aggregate driers).
13. Less air pollution from dust.
14. Energy savings.

NOTE

The above cited requirements for minimum air voids and pore size to allow heavy rainfall to drain through the pavement and escape are not always deemed necessary or advisable by some authorities. In Canada and other locations, open grades mixes are used as thick surface courses over granular bases. Over thirty years ago, much open-graded asphalt emulsion mix was being laid in thick layers through motor pavers as a resurfacing course on existing secondary roads. In many regions, good durable roads have been built on granular base by the penetration macadam method using high viscosity, rapid curing asphalt emulsion. The wearing surfaces of the above cited roads were (and are) usually sealed tight to achieve good drainage from the surface. In such cases it is usually not considered necessary to construct a waterproof membrane on the sub-base as recommended in **15.7.3 Preparation of Sub-base** of this guide. Also, it is felt that even though these coarse mixtures are sealed, good skid resistance and most of the other advantages cited above are retained.

15.3 Applicable Documents

15.3.1 ASTM Documents

- C131 Resistance to Degradation of Small-Size Course Aggregate by Abrasion and Impact in the Los Angeles Machine
- D244 Test Methods and Practices for Emulsified Asphalt
- D977 Specification for Emulsified Asphalt
- D2397 Specification for Cationic Emulsified Asphalt
- D3628 Practice for Selection and Use of Emulsified Asphalts
- D4215 Specification for Cold-Mixed Cold-Laid Bituminous Paving Mixtures

15.3.2 AEMA Documents

- **A Basic Asphalt Emulsion Manual (BAEM)**

15.4 Asphalt Emulsion

15.4.1 Asphalt Emulsion for Open Graded Mixes

The four characteristics which are especially desired in an asphalt emulsion for open-graded mixes:

1. Coating Ability — the asphalt emulsion should have sufficient fluidity to facilitate mixing and coating the project aggregate and should have good attraction or wetting power for the aggregate surface. (It should be noted, however, that many operators report that the mix sometimes leaves the mixer with the appearance of not being adequately coated. By the time it exits from the paving machine it appears well coated apparently due to the additional handling and manipulation.)
2. Workability — without stripping from the time the mix is made until it is laid in place.
3. Resistance to Drain Off — with the asphalt emulsion designed with high enough viscosity or thixotropic characteristics to permit handling and placement without flowing off the aggregate.
4. Setting or Curing Time — which provides resistance to wash off from rain within one hour after placement and permits slow traffic within one to two hours after compaction, and normal traffic within 24 hours under average curing conditions of temperature and humidity (70°F (18°C) and 50% relative humidity). Asphalt emulsions have the advantage that they are susceptible to control of the desired performance factors and can be tailor made for aggregates, seasonal conditions, etc.

15.4.2 Grades of Asphalt Emulsion

The most widely used grades of asphalt emulsion for open-graded mixes are ASTM Grades MS-2, MS-2h, CMS-2, CMS-2h, HFMS-2, and HFMS-2h. (ASTM designations D977 and D2397)

15.5 Aggregates

Aggregates shall meet the requirements for grading size and type specified. The aggregate may be from a single source or blended so as to conform to the No. 4 (4.75

mm) sieve job mix formula. That fraction passing the No. 4 (4.75 mm) sieve in the base and intermediate courses, and that fraction passing the No. 8 (2.38 mm) sieve in thin surface courses provide a stabilizing action for the coarse aggregate fraction, and also aids the retention of a thick film of asphalt on the coarse aggregate. Therefore, it could be said that as much of this sand should be in the mix as can be allowed without reducing the air voids below the specified minimums mentioned below. Sharp and angular sand type material is the most effective.

The aggregate shall be crushed stone, crushed gravel, slag, or sand which meets the requirements of AEMA BAEM, Table 7.4. Aggregates which are known to polish should be excluded from the coarse aggregate fraction.

The coarse aggregate shall show wear by ASTM C131 of not more than 50% for base course and 40% for surface course.

The air void content after compaction shall not be less than 15% for a thin course, and 20 to 30% for a base course. Aggregates should have 75% (by weight) with two or more fractured faces and 90% with one or more fractured faces. Aggregates should preferably be surface dry.

15.6 Design

15.6.1 Mixtures

The aggregate shall be representative of the project materials and have compatibility with a grade of asphalt emulsion used for open-graded mixes. Good asphalt dispersion (coatability) is essential to achieve proper bond between aggregate particles (cohesion) and reduce the degradation of some aggregates by traffic and climatic action.

In general, the asphalt emulsion content used for an OGAEM has been the maximum amount possible without producing appreciable runoff (drainage).

For the thin open-graded friction courses, empirical equations have been developed to determine an asphalt content as a basis for trial laboratory mixes. A surface constant (Kc) using a modified State of California test method is measured for the predominant aggregate size fraction (retained on No. 4 sieve) and used in an equation with a further adjustment based on the asphalt content of the asphalt emulsion to determine the percent asphalt emulsion in the mix. Besides achieving good asphalt emulsion coating, a further requirement is that the mix after compaction has an adequate void capacity to serve as lateral water drainage channels (15% or more air voids).

For the thicker layers, (intermediate or base open-graded mixes involving coarser aggregates), design procedures may include a mixing test to evaluate coating (spoon and bowl or mechanical), runoff test, and a wash off test to evaluate early rain resistance (ASTM D224). The afore-mentioned tests are conducted on trial mixes at several asphalt emulsion contents with the range based on aggregate size.

Field adjustments to the laboratory mix design asphalt emulsion content may be necessary as construction progresses to obtain good coating without significant asphalt drainage and maintain good film thickness of the binder.

15.6.2 Structural Thickness

Factors considered in selecting the OGAEM layer thickness include traffic (equivalent 18K axle loads), sub-grade soil type and strength, drainage and the possible waterproofing of the sub-grade, thickness, and characteristics of already existing pavement layers, and environmental factors such as curing conditions and pavement temperatures.

Initial traffic is estimated along with the anticipated growth rate during the pavement design life. The sub-grade strength can be measured directly by CBR, R-Value or tri-axial modulus testing (preferable), or roughly predicted from soil classification.

Most pavement thickness design methods are based on layer coefficients which have resulted from engineering judgments and experience. Layer coefficients for OGAEM have ranged from about 0.18 to 0.30 with the value selected as a function of traffic, asphalt hardness of the asphalt emulsion, aggregate quality, curing conditions, etc.

Improved structural design procedures and criteria are being developed through extensive field and laboratory investigations of already constructed OGAEM pavements. This has included road condition surveys, core sampling, materials characterization using new equipment such as the diametral resilient modulus device, and the application of layer theory. With some newer design approaches, two critical elastic strains are examined in determining the proper pavement thickness. They are horizontal tensile strain at the bottom of asphalt treated layer (important relative to fatigue cracking) and vertical compressive strain at the sub-grade surface (considered relative to permanent deformation in the sub-grade, (i.e., rutting)). With OGAEM pavements, generally, only the strain at the sub-grade surface has been considered in determining the structural section.

15.7 General

15.7.1 Pre-construction Meeting

On sizeable jobs or critical test sections, a pre-construction meeting of key personnel representing the contractor, agency and material suppliers is recommended. The engineer in charge can define areas of responsibility, resolve questions, and set up working relationships for inspection, expediting, and so on.

The asphalt emulsion supplier plays an important part in mixture design and in providing technical service. The mixture design should be determined prior to this meeting. Adjustments to the starting mix are usually made to conform to field conditions.

15.7.2 Preparation of an Existing Asphalt Surface

Holes and irregularities shall be repaired with dense-graded material to produce a tight surface. All loose and foreign materials shall be removed by sweeping. If the surface remains dusty, it should be lightly moistened with water or given an asphalt emulsion tack coat. It is very important that the existing surface be impervious to water so that rain penetrating the open-graded mix will not penetrate further but drain laterally and not collect in the base or sub-grade.

15.7.3 Preparation of Sub-base

For new construction, the preparation of sub-base is essentially the same as for open-graded hot mix. However, for porous pavements, a waterproof membrane is recommended to prevent the rainwater from weakening the sub-base. This can be done by mixing an asphalt emulsion (SS or CSS grade) into the top layer of the granular, or dense-graded sub-base during blading, shaping and compaction. The top layer of the sub-base can be a plant mix of asphalt emulsion with dense-graded aggregate.

15.8 Mixing

Asphalt emulsion and aggregate may be mixed in place or at a central plant pug mill. The choice of method depends on such factors as:

1. Equipment availability
2. Size of project
3. Aggregate source, type, and cost
4. Anticipated traffic volumes and loads
5. Climatic conditions

The best balance between these factors must be evaluated. Regardless of the mixing method, 100% coating of the coarse aggregate particles is not always achieved, nor is it necessary.

15.8.1 Mixing Moisture

Mixing procedures should aim at achieving a uniform dispersion of the asphalt emulsion with a complete coating of the finer aggregate fractions. Toward achieving this uniform dispersion of the asphalt emulsion, it is sometimes necessary to moisten the aggregate before application of the asphalt emulsion. The appropriate volume of water to be added should be determined by the mix design, and if required should be added prior to the incorporation of the asphalt emulsion.

Mixing of the asphalt emulsion should be done at as low of a moisture content as possible, because the compaction moisture content is usually lower than the moisture content after mixing. Under poor drying conditions the removal of surplus moisture could be a costly and time-consuming operation.

NOTE

Excess moisture in open-graded mixes may contribute to drain-down and the reduction in asphalt film thickness which is necessary for proper performance.

15.8.2 Central Plant Mix

Central Plant Mix is recommended for projects that involve close tolerances and high production. Generally, this type of mixing is done away from the road site, and frequently at the source of the aggregate. Conventional batch and dryer-drum hot mix plants can also be used to produce asphalt emulsion mixes.

The central cold mix plant consists of a mixer and certain auxiliary equipment for feeding the asphalt emulsion, water, aggregate and additives to the mixer. The asphalt emulsion central mixing plant generally has no dryer or screens other than a scalping screen to remove oversize aggregate. At the very least, the plant should consist of a pug-mill, an asphalt emulsion storage tank, a metering pump, units for feeding water and additives, controls for adjusting and monitoring the various components, a conveyor, and a power source, a tachometer to aid in maintaining a constant speed on the conveyor belt, and one or more aggregate bins with belt feeders.

The mixer should be of a type that permits variation in mixing times to ensure that the aggregate is properly coated but not over mixed. Mixing times can be varied in a continuous pug-mill plant by changing the angle of the paddles, by varying the height of the end-gate, or by changing the location of the asphalt emulsion spray bar.

Asphalt emulsion cold mixes require shorter mixing time than asphalt concrete mixes. The tendency is to over mix asphalt emulsion mixes which may remove the asphalt from the aggregate. It may also result in premature breaking of the asphalt emulsion, causing overly stiff mixtures.

The mix produced at a central plant may be stockpiled for later use. The length of storage time in stockpile is controlled by the type of asphalt emulsion incorporated into the mix.

15.8.3 Travel Mixers

The purpose of the travel plant is to leave uniform, properly coated, asphalt emulsion and aggregate mixture on the roadbed. Aggregates are placed into the hopper of the mixer where they are drawn into the mixing chamber. The asphalt emulsion proportioning device is interlocked to ensure a constant blend. The asphalt emulsion is added by pumping through a spray bar mounted on the mixing chamber. This method permits the addition of all the asphalt emulsion in one application. The forward speed of the mixer should be adjusted so that the material being ejected has a uniform texture. Mixing times can be varied in a traveling mixing plant by changing the angle of the paddles, by varying the height of the end-gate, or by changing the location of the asphalt emulsion spray bar.

Injecting the asphalt emulsion in one application through the mixing chamber can be done at a lower moisture content than with distributor application. The single application immediately brings the aggregate to optimum mixing moisture whereas the first application with a distributor adds only part of the moisture associated with the asphalt emulsion.

The travel plant places the mix on grade with proper cross-slope to the design thickness. The mix is then ready for compaction.

15.9 Spreading and Conditioning

Asphalt emulsion mixes gain stability as the water evaporates. It is important not to hinder this process. Therefore, lift thickness may be limited by the rate of fluid loss.

The most important factors affecting this dehydration or curing are the type of asphalt emulsion, the mix water content, the gradation and temperature of the aggregate, wind velocity, ambient temperature, and humidity.

When multiple lifts are required, some curing time must be allowed between successive lifts. The length of this curing time is a function of the rate of evaporation, and this is a variable. However, an existing lift can normally be overlaid after from 2 to 5 days under good curing conditions.

The mixture should be spread uniformly on the roadbed, beginning at the point farthest from the mixing plant. Hauling over freshly laid material should not be permitted except when required for completion of the work.

Spreading central plant mixes is most professionally done with a self-propelled asphalt paver. However, base spreaders and motor graders also obtain good results.

The mixture should always be spread to a uniform thickness. This is to eliminate the chance that thin spots may occur in the final mat and to ensure a smooth riding surface. Successful placement of cold laid plant mixes require the presence of sufficient fluids. Dry mixes tend to tear beneath the screen or strike-off bar. If the mixture is too dry, the mix water content should be increased. When a self-propelled paver is used, heating the screed in attempts to eliminate this tearing does not help. It actually makes the mix less workable, since it serves to accelerate the drying process. Because of these variables, local experience is likely to be the best guide in determining allowable placement thickness.

15.10 Compaction

Fat or lean spots behind the paver should be removed and replaced with good mix before rolling. Rolling should be delayed until the mixture is able to support the roller without excessive shoving. Avoid excessive finish rolling as often a single pass is sufficient.

Frequently it is necessary to apply a choke or blotter course of fine aggregate to the fresh mat. This can be accomplished through use of a sand spinner or any conventional chip spreader at the rate of 5.4 to 10Ib/yd^2 (3.3 to 6.6kg/m^2). This serves to reduce early traffic damage and can be accomplished either before or just following the initial roller pass.

15.11 Traffic Control

If possible, traffic should not be allowed on the mix until it will support vehicles without undue displacement. When it is not possible to close the road completely, vehicles should be controlled to minimum speeds, without acceleration, deceleration, or sudden braking. Traffic should be directed through the project with such signs, barricades, devices, flagman, and pilot vehicles as maybe necessary for absolute control.

15.12 Precautions

- Construction should begin only if the ambient temperature is 50°F (10°C) and rising. Dry weather is necessary to achieve good adhesion to the existing asphalt surface and a reasonably good set time. Construction should not begin when rain is expected or be continued after rain commences.
- Equipment should be properly maintained.
- When the mat is tender and the surface sticky in the early curing stage, it is usually remedied by spreading 6 to 10lb/yd^2 (3.3 to 5.4kg/m^2) of choke or blotter stone immediately after the mix is laid or after the first pass with the roller.
- It is recommended that before attempting to lay open-graded friction courses with asphalt emulsion, the counsel of an experienced engineer or operator in this field should be obtained who can show examples of good finished work and perhaps show work in progress.
- Aggregates should not change in physical or chemical characteristics during the construction period.
- Asphalt emulsion properties should be consistent throughout the construction period to insure maximum coating, adhesion, and to minimize stripping.
- Do not mix anionic and cationic asphalt emulsions together.

SECTION 16

DENSE-GRADED MIXES USING ASPHALT EMULSIONS

16.1 Scope

This recommended performance guideline is intended to aid in understanding the preparation and use of asphalt emulsion dense-graded aggregate mixtures.

16.2 Description

This work consists of one or more courses of cold mixed asphalt emulsion coated aggregates. These mixtures may be produced in a central plant, a travel plant, or a road mix operation for immediate use or stockpiled for later use. These mixtures are to be laid cold on a prepared sub-grade or previously constructed course.

Dense graded aggregates typically have 100% passing the 1½in. (38.1mm) or 2in. (60mm) sieve; 35 to 80% passing the No. 4 (4.75mm) sieve; 25 to 66% passing the No. 8 (2.36mm) sieve; and 2 to 15% passing the No. 200 (0.075mm) sieve.

16.3 Applicable Documents

16.3.1 ASTM Documents

- C131 Resistance to Degradation of Small-Size Course Aggregate by Abrasion and Impact in the Los Angeles Machine
- C136 Method for Sieve Analysis of Fine and Coarse Aggregates
- D75 Practice for Sampling of Aggregates
- D140 Practice for Sampling Bituminous Materials
- D977 Specification for Emulsified Asphalt
- D2397 Specification for Cationic Emulsified Asphalt
- D1560 Test Methods for Resistance to Deformation and Cohesion of Bituminous Materials by Means of Hveem Apparatus

- D2172 Test for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
- D2419 Test Method for Sand Equivalent Values of Soils and Fine Aggregate
- D2489 Practice for Determining Degree of Particle Coating of Bituminous-Aggregate Mixtures
- D3625 Practice for the Effect of Water on Bituminous-Coated Aggregate using Boiling Water
- D3628 Practice for Selection and Use of Emulsified Asphalts
- D4215 Specification for Cold-Mixed, Cold-Laid Bituminous Paving Mixtures

16.3.2 AEMA Documents

- **A Basic Asphalt Emulsion Manual (BAEM)**

16.4 Asphalt Emulsion

Several factors are taken into consideration when selecting the proper asphalt emulsion type and grade. The gradation, strength, and coating characteristics of aggregate; the method of mixing; and climate conditions during mixing, laying, curing, and compaction are very important.

16.4.1 Coating Ability

The asphalt emulsion should have the ability to coat the minus No. 4 (4.75mm) sieve fraction of the aggregate without undue balling of the fines. With some types of asphalt emulsions, mixing water may help in coating the fines and preventing their balling. With dense-graded aggregates, 100% coating of the coarse fraction is not necessary.

16.4.2 Workability

The asphalt emulsion should provide a mixture which is workable on the jobsite either when placed directly from the mixing operation or when used out of stockpile.

16.4.3 Grades of Asphalt Emulsion

The most widely used grades of asphalt emulsion for dense-graded mixes are ASTM Grades SS-1, CSS-1, MS-2, CMS-2, and the high float HFMS-2 and HFMS-2s (see ASTM D3628).

When specifically approved by the purchaser, other types of asphalt emulsion may be used if experience has shown that satisfactory performance will result. It is recommended the user agency contact a local asphalt emulsion producer as to the most suited asphalt emulsion grade used with aggregate in each area. Asphalt emulsions can be formulated or modified to improve aggregate mixture characteristics.

16.5 Aggregates

Aggregates for dense-graded mixes may consist of processed or semi-processed crusher, pit, or bank run aggregates. These materials are graded from maximum size down to and including the material passing the No. 200 (0.075mm) sieve.

Samples of the aggregate intended for use should be laboratory tested in accordance with ASTM methods D75, D2419, C131, and C136. Materials for dense-graded mixes include a wide variety of types and grades and should meet one of the gradation specifications of AEMA BAEM Table 7.2.

The sand equivalent test (ASTM D2419) is used to detect the presence of excessive amounts of clay in the aggregate. In general, aggregates with a sand equivalent of 30 or above can be stabilized successfully. Aggregates having a sand equivalent of 20 to 30 are considered marginal, and the success of stabilization will depend upon the type of emulsion used and its ability to coat the clay particles.

In general, stabilization of aggregates with a sand equivalent of less than 20 have not been successful.

Aggregates selected should have a loss within the range of 40 to 60% when tested in accordance with ASTM C131. However, an aggregate with satisfactory use record not conforming to these limits could also be used.

16.6 Design

The need for a mix design based on both the asphalt emulsion and aggregate to be used for the construction project cannot be overstressed. Most asphalt emulsion producers, some state, and some consultant laboratories have the equipment and experience necessary to design dense-graded cold mixes. The importance of optimum asphalt emulsion content and strength or stability of the resultant mix should be determined in the laboratory. A review of various design procedures described in A Basic Asphalt Emulsion Manual is recommended.

A suggested design procedure follows. Various modifications are included which shorten the laboratory work and still give satisfactory results.

- Select aggregate to be used on the project and obtain representative samples.
- Obtain gradation of aggregate sample.
- Calculate trial residual asphalt content or percent asphalt emulsion using formulas:
- Formulas for Determination of Estimated Percent Asphalt Emulsion Requirement

$$\text{(A) } P = 0.5A + 0.1B + 0.5C$$

Where:

P = Percent by weight of asphalt emulsion based on weight of graded mineral aggregate

A = Percent* of mineral aggregate retained on No. 8 (2.36mm) sieve

B = Percent* of mineral aggregate passing No. 8 (2.36mm) sieve, retained on No. 200 (0.075mm) sieve

C = Percent of mineral aggregate passing No. 200 (0.075mm) sieve

$$\text{(B) } P = 0.06A + 0.018$$

Where:
P = Percent by weight of asphalt emulsion based on weight of graded mineral aggregate
A = Percent* passing No. 4 (4.75mm) sieve
B = Percent* retained No. 4 (4.75mm) sieve
*Expressed as a whole number

- Run laboratory coating tests with aggregate to aid in selection of correct grade of asphalt emulsion. To do this, weigh 400 grams of aggregate and predetermined percent asphalt emulsion into mixing bowl. Stir briskly for 6 min. Allow mixture to set for 3 hours and remix for 5 minutes. Then place a portion of mix on plate and immerse remaining portion with water. Decant water and compare coatings. Due to slow setting characteristics, it is not recommended to run immersion tests on SS and CSS type asphalt emulsions. Use this same procedure to determine necessity or benefit of adding water to the aggregate at the time of mixing. ASTM D244 describes a coatability and water resistance test.

- After selection of proper asphalt emulsion grade, make mixture with trial percent asphalt emulsion for stability testing. To more rapidly cure mix sample for determination of stability after all moisture is removed from mix, heat and stir mix to 230°F (110°C). Cool and compact for Hveem or Marshall stability determination.

- For stabilized base mixes. Hveem stabilities above the 25 to 30 range are recommended. However, successful experience with local aggregates yielding lower Hveem stabilities have been found. Generally, Hveem stability of 20 to 25 is satisfactory for low volume roads. A minimum Marshall stability of 500 pounds (2224N), 2 to 8% air voids, and 50% minimum coating is suggested in *A Basic Asphalt Emulsion Manual*.

16.7 General

16.7.1 Preparation of the Roadbed

Every part of the structure contributes to the effective performance of the completed pavement. Careful shaping and compacting of the roadbed in conjunction with properly designed and constructed surface drainage system is the first step in building a sound pavement structure.

The area to be overlaid (stabilized) shall be substantially true to line, grade, and cross section, and have a firm prepared surface before laying operations begin. An important part of this process involves the repair or replacement of unstable areas with sound material equal in quality to the rest of the roadbed. Holes and depressions in existing surfaces shall be repaired by removing all loose and defective material and replacing with an asphalt aggregate patching material which shall be compacted to produce a tight surface conforming to the adjacent pavement area.

All bumps, waves, and corrugations should be removed. Whether it is a new sub-grade or an existing aggregate surface, the final step in preparation of the roadbed is compacting the foundation. When the compacted sub-grade is loosely bonded, it should be primed, and when the sub-grade is an existing hard surface, an asphalt emulsion tack coat should be applied.

16.7.2 Aggregate Preparation

The in-place material may need additional aggregate to make it meet grading requirements of mix design. Therefore, a laboratory evaluation should be made to determine if blending of an imported aggregate is necessary. The materials may be mixed on the roadbed or in another approved area by using portable tillers and motor graders. Where mixing of the aggregate is to be by means other than a travel mixer, any mineral filler or other aggregate to be blended with the natural material shall be spread over the surface of the scarified material in a uniform quantity, and in such quantity as will provide a mixture meeting the requirements of the predetermined mix design. Such applications shall be made immediately after the scarifying operations; mixing with rotary type mixer shall continue until a uniform mixture is obtained. To combine the correct amount of mineral filler or other aggregate to be added to the natural material, the following procedure can be used:

Mineral aggregate from the old roadbed shall be scarified and bladed into one or more windrows for measurement and sampling. After the proportions of coarse and fine aggregate are adjusted, the total loose aggregate shall be thoroughly and uniformly mixed and placed into one or more windrows of uniform cross section for final measurement and adjustment.

When virgin aggregate is brought in, it shall be deposited in one or more windrows in such quantity and proportions as to provide sufficient total aggregate conforming with the specified gradation, and to produce a finished course of specified thickness.
When a travel mixer is to be used, the prepared in-place material shall be bladed into one or more windrows suitable for the type of travel mixer. Any additional aggregate required to be blended with the windrowed material shall be uniformly distributed over the windrows. These windrows shall contain sufficient material to produce the required thickness of compacted pavement If a central mix plant is to be used, the aggregates can be blended with the plant's hopper-belt-feeder systems. From the laboratory evaluation, the correct amount of asphalt emulsion and mixing water, if necessary, to be combined with the aggregates is determined. In a travel plant or road mixing operation, these materials will often be added to the windrowed aggregate; it is vital that the correct application rate be determined and adhered to.

Excess water in the aggregate can be removed through aeration prior to or after mixing with asphalt emulsion.

16.7.3 Windrows

Whenever construction requires that the aggregates be placed in windrows prior to mixing and spreading, the roadway must be cleared of all vegetation to a width sufficient to accommodate both windrow and traffic while the mixture cures. Mat thickness is directly proportional to the amount of aggregate in the windrow; accurate control and measurement of the volume of the windrowed material is necessary.

Usually, there is not enough loose material on the road surface to use as the road mix. In this case, it is best to blade the loose material onto the shoulder rather than perform the several operations that are necessary to blend it with the material brought in from other sources. Sometimes, however, incorporation of the existing material on the roadbed into the mixture is considered practical if it is uniform and enough is available. When this is done, the loose aggregate first must be bladed into a windrow and measured. Next, it must be made to meet grading specifications by adding other aggregates as necessary.

Finally, the windrow is built up to the required volume with imported material to meet mix specifications. If two or more materials are to be combined on the road to be surfaced, each should be placed in its own windrow. These windrows are then mixed together thoroughly before emulsion is added.

16.8 Mixing

Asphalt emulsion and aggregate may be mixed in place or at a central plant pug mill.

The choice of method depends on such factors as:

1. Equipment availability
2. Size of project
3. Aggregate source, type, and cost
4. Anticipated traffic volumes and loads
5. Climatic conditions

The best balance between these factors must be evaluated. Regardless of the mixing method, 100% coating of the coarse aggregate particles is not always achieved, nor is it necessary.

16.8.1 Mixing Moisture

Mixing procedures should aim at achieving a uniform dispersion of the asphalt emulsion with a complete coating of the finer aggregate fractions. Toward achieving this uniform dispersion of the asphalt emulsion, it is sometimes necessary to moisten the aggregate before application of the asphalt emulsion. The appropriate volume of water to be added should be determined by the mix design, and if required should be added prior to the incorporation of the asphalt emulsion.

Mixing of the asphalt emulsion should be done at as low moisture content as possible, because the compaction moisture content is usually lower than the moisture content after mixing. Under poor drying conditions, the removal of surplus moisture could be a costly and time consuming operation.

16.8.2 Central Plant Mix

The use of a central plant is recommended for projects that involve close tolerances and high production. Generally, this type of mixing is done away from the road site, and frequently at the source of the aggregate. Conventional batch and dryer-drum hot mix plants can also be used to produce asphalt emulsion mixes. The central cold mix plant consists of a mixer and certain auxiliary equipment for feeding the asphalt emulsion, water, aggregate and additives to the mixer. The asphalt emulsion central mixing plant generally has no dryer or screens other than a scalping screen to remove oversize aggregate. At the very least, the plant should consist of a pug mill, an asphalt emulsion storage tank, a metering pump, units for feeding water and additives, controls for adjusting and monitoring the various components, a conveyor, and a power source, a tachometer to aid in maintaining a constant speed on the conveyor belt, and one or more aggregate bins with belt feeders.

The mixer should permit variations in mixing times to ensure that the aggregate is properly coated but not over mixed. Mixing times can be varied in a continuous pug mill plant by changing the angle of the paddles, by varying the height of the end gate, or by changing the location of the asphalt emulsion spray bar.

Asphalt emulsion cold mixes require shorter mixing time than asphalt concrete mixes. The tendency is to over mix asphalt emulsion mixes which may remove the asphalt from the aggregate. It may also result in premature breaking of the asphalt emulsion, causing overly stiff mixtures.

The mix produced at a central plant may be stockpiled for later use. The length of storage time in the stockpile is controlled by the type of asphalt emulsion incorporated into the mix.

16.8.3 Travel Mixers

The purpose of the travel plant is to leave uniform, properly coated, asphalt emulsion aggregate mixture on the roadbed. Aggregates are placed into the hopper of the mixer where they are drawn into the mixing chamber. The asphalt emulsion proportioning device is interlocked to ensure a constant blend. The asphalt emulsion is added by pumping through a spray bar mounted on the mixing chamber. This method permits the addition of all the asphalt emulsion in one application. The forward speed of the mixer should be adjusted so that the material being ejected has a uniform texture.

Injecting the asphalt emulsion in one application through the mixing chamber can be done at a lower moisture content than with distributor application. The single application immediately brings the aggregate to optimum mixing moisture whereas the first application with a distributor adds only part of the moisture associated with the asphalt emulsion.

The travel plant places the mix on grade with proper cross-slope to the design thickness. The mix is then ready for compaction.

16.8.4 Rotary Mixers

Rotary cross-shaft mixing employs a mobile mixing chamber which is self-propelled. The mixing chamber, usually 6 to 8ft (2 to 2.7m) wide, and 2 to 3ft (0.66 to 1m) high, open at the bottom, contains one or more shafts, transverse to the roadbed, upon which mixing blades are mounted. As the shafts rotate rapidly, the mixing tines thoroughly agitate the material in the roadbed. The machine, moving forward, strikes off a uniform course of asphalt aggregate mixture.

Self-propelled rotary mixers are designed to accurately and automatically control the predetermined mixing depth from existing surface grades. This assumes that the rotary mixer is operated at a speed slow enough for the rotor tines to cut their path through the aggregates.

The rotary mixer should produce a mixture with a uniform percentage of asphalt emulsion. If the existing grade is different from final grades and cutting and filling operations are carried out, the depth of the finished material will vary but it should have a uniform percentage of stabilizing agent.

Rotary mixers equipped with built-in spraying systems require that the asphalt emulsion application rates be matched accurately with the width and thickness of the course, forward speed of the mixer, and the density of the in-place aggregate. However, when utilizing a rotary mixer not equipped with spray bars, an asphalt emulsion distributor, operating ahead of the mixer, applies asphalt emulsion to the aggregate. Incremental applications of asphalt emulsion and passes of the mixer are usually necessary to achieve the specified mixture.

Most rotary mixers are equipped with spray systems and when using this equipment, the following steps are recommended:

1. Spread the aggregate to uniform grade and cross section with motor graders.
2. Thoroughly mix the aggregate by one or more passes of the mixer.
3. Add asphalt emulsion in increments until the total required amount of asphalt emulsion is applied and mixed. If the mixer is not equipped with spray bars, the asphalt emulsion is to be applied with an asphalt emulsion distributor.
4. Make one or more passes of the mixer between applications of asphalt emulsion, as necessary for thorough mixing.
5. Maintain the surface true to grade and cross section by using a motor grader during the mixing operations.

Any variation of the mixer along the longitudinal joint will cause a fat area at overlaps and lean areas where the joint is missed. This can also occur when applying asphalt emulsion with a distributor because the exact location of the longitudinal joint is difficult to follow or even to find. In the case of the distributor which must make one pass per inch of depth, there is some chance of averaging the error. Subsequent passes of the mixer over the lean or fat area will have little effect of blending the variation. To eliminate this problem with in-place construction, transverse mixing is essential. This is usually done with multiple passes with a blade. This is then followed by longitudinal mixing. This procedure effectively eliminates lean or fat areas at longitudinal joints as well as areas where a nozzle may have been plugged. This procedure also does an effective job of blending different types of aggregates which may occur in the operation.

The total number of passes of the rotary mixer will depend on the method of adding the asphalt emulsion and on the amount of No. 200 (0.075mm) material present.

16.8.5 Distributor & Motor Grader Mixing

Asphalt emulsion mixtures may be prepared by applying the asphalt emulsion by a distributor and blade mixing with a motor grader.

The first step in the operation is to shape the prepared aggregate into a uniform windrow of a known volume by means of a spreader box, windrow proportioner, or motor grader. The motor grader then lays out a uniform lift of aggregate from the windrow onto the road surface or mixing table. If mixing water is required, it is then added at a predetermined rate to the aggregate lift. Next the asphalt emulsion is applied at the predetermined rate by the distributor to the lift of aggregate. The motor grader then folds the aggregate over the asphalt emulsion. The motor grader may work this lift back and forth to achieve mixing, or the mixture may be windrowed on the opposite side of the road and another lift of aggregate processed as above. This procedure is repeated until the design quantity of asphalt emulsion has been added to the total windrow of aggregate.

The grading of the aggregate in the windrow may vary and cause asphalt demand to vary. Therefore, as asphalt mixing progresses, close attention should be paid to the appearance of the mix. It is very important that uniformity of grading and moisture content be achieved. Mixing should consist of as many passes with the motor grader as needed to fully spread the asphalt emulsion and coat the aggregate particles, and when completed the windrow should be moved to one side of the roadbed in preparation for spreading.

Blades are relatively inefficient mixing devices and the aeration is high. Therefore, a water content higher than that for rotary mixers will be required to assist dispersion of the asphalt emulsion and replace relatively high evaporation losses. The mixing moisture will be well above the optimum compacting moisture so that the stabilized material will need drying before compacting.

Windrow mixing requires the close control of grade and cross-section that is required of all in-place construction. In addition, it also requires close control of the grade and cross-section of the exposed sub-grade. Variations from either surface or sub-grade elevations will result in a non-uniform windrow. If this occurs, the uniform longitudinal application of emulsion to the windrow will result in a varying percentage of residual asphalt.

16.8.6 Secondary Mixing

Sometimes further mixing of the windrowed material may be necessary after the addition of the asphalt emulsion. Unless the travel mixer can be used as a multiple pass mixer, this additional mixing usually is done with a motor grader or small rotary mixers. This ensures that all the windrowed material is incorporated into the mix. The number of passes with the motor grader required for this purpose varies with different job conditions.

After the mixing operation is completed, the windrow should be moved to one side of the area to be surfaced in preparation for spreading.

16.9 Spreading and Conditioning

Asphalt emulsion mixes gain stability as the water evaporates. It is important not to hinder this process. Therefore, lift thickness may be limited by the rate of fluid loss.

The most important factors affecting this dehydration or curing are the type of asphalt emulsion, the mix water content, the gradation and temperature of the aggregate, wind velocity, ambient temperature, and humidity.

Although each job has its own particular combination of these factors, experience has shown that under the best conditions, dense-graded mixes should be placed in a compacted thickness no greater than 3in. (75mm).

When multiple lifts are required, some curing time must be allowed between successive lifts. The length of this curing time is a function of the rate of evaporation, and this is a variable. However, an existing lift can normally be overlaid after from 2 to 5 days under good curing conditions.

The mixture should be spread uniformly on the roadbed, beginning at the point farthest from the mixing plant. Hauling over freshly laid material should not be permitted except when required for completion of the work.

Spreading central plant mixes is best accomplished with a self-propelled asphalt paver. However, base spreaders and motor graders also obtain good results.

The mixture should always be spread to a uniform thickness. This is to eliminate the chance that thin spots may occur in the final mat. Blade spreading should be done in layers, with no layer thinner than about two times the diameter of the maximum particle size. As each layer is spread, compaction should follow at once. Mixtures to be spread with a motor grader are generally placed on a roadbed in windrows. The windrow may be located along the center line of the road or along one side. Because there is a tendency to leave a hump in the road when blade spreading from the centerline windrow, it is better practice to place the windrow to the side for spreading. For a smooth riding surface, the motor grader should be used to trim and level the mix as the rollers complete compaction of the top layer.

Successful placement of cold laid plant mixes require the presence of sufficient fluids.

Dry mixes tend to tear beneath the screen or strike-off bar. If the mixture is too dry, the mix water content should be increased. When a self-propelled paver is used, heating the screed in attempts to eliminate this tearing does not help. It actually makes the mix less workable, since it serves to accelerate the drying process. Because of these variables, local experience is likely to be the best guide in determining allowable placement thickness.

16.10 Compacting

Breakdown rolling of asphalt emulsion mixes should begin just before the asphalt emulsion starts to break. Breaking is indicated by a marked color change from brown to black. When this happens, there is enough water in the mixture to act as a lubricant between the aggregate particles but not enough to fill the void spaces. The void spaces can thus be reduced by rolling the mixture. Also, by this time the mixture should be able to support the roller without excessive displacement.

Because the tires of the motor grader compact the freshly spread mix, their tracks will appear as ridges in the finished mat unless there is adequate rolling between the spreading of each layer. The roller should follow directly behind the motor grader to eliminate these ridge marks.

If at any time during compaction, the asphalt emulsion mixture ruts or shoves, rolling should be stopped. Compaction should not be attempted until there is a reduction in fluid content. After one course is compacted thoroughly, other courses may be placed on it. This operation should be repeated as many times as needed to bring the road to proper grade and crown.

After the mat is shaped to its final required cross-section, it must be finish rolled, preferably with a steel drum roller. Proper timing is of utmost importance in compacting a dense-graded mix. Rolling seals the pavement as it reduces the voids in the mix. If done prematurely, it retards dehydration of the excess water required to facilitate mixing, and thereby greatly extends the time required for the mix to reach design strength.

It also is necessary that the mix be allowed to develop strength sufficient to support the rollers. However, if rolling is delayed too long, it will be difficult to achieve good compaction, and in some cases the developing asphalt aggregate bond will be broken.

Because dense-graded mixes are often initially low in stability, it has been found advantageous to use vibratory or static steel drum rollers for breakdown rolling. Vibratory rollers are effective for two passes, but thereafter the asphalt and water in dense-graded mixes will tend to migrate. After the breakdown rolling, a light application of choke aggregate is sometimes spread uniformly on the surface at about 10lbs/yd^2 (5.4kg/m^2). This choke aggregate may be coarse sand or 1/4in. (6.3mm) screenings. This will prevent pickup of the mix by construction traffic or by additional rolling.

16.11 Seal Coat & Fog Seals

A seal coat should be placed when the road mixture is thoroughly cured. The use of a fog seal over the dense graded mix helps to prevent any raveling and helps to seal the surface prior to placing a chip seal or other types of surface course. The asphalt emulsion (CSS-1 or SS-1) used for fog sealing is typically diluted 1:1 with water.

A dense-graded mixture is more likely to show reflected cracking than an open-graded mixture. Therefore, the use of an asphalt emulsion surface treatment will give some protection from this condition. Also, it will help prevent the entry of water. Sanding may be desirable to prevent pickup.

16.12 Traffic Control

If possible, traffic should not be allowed on the mix until it will support vehicles without undue displacement. When it is not possible to close the road completely, vehicles should be controlled to minimum speeds, without acceleration, deceleration, or sudden braking. Traffic should be directed through the project with such signs, barricades, devices, flagman, and pilot vehicles as maybe necessary for absolute control.

16.13 Weather

Lay-down construction should not continue during rainfall, and should not begin when rain is expected. The ambient temperature must be above 70°F (21°C) if possible during construction, because this is also the temperature of the mix, and it will not be as easily handled in cooler temperatures.

16.14 Precautions

Use a design procedure to determine the optimum asphalt emulsion aggregate mixture and moisture content. Use a coating test to determine asphalt emulsion and aggregate compatibility and benefit of adding water to aggregate at time of mixing.

Dense graded mixes usually resist water damage during construction. But if it rains, traffic should be kept off until the mixture cures and necessary compaction is accomplished.

Use only the mixing water needed to disperse the asphalt emulsion and gain good workability. Too much water will prolong curing and delay rolling.

Do not mix any longer than is necessary to disperse the asphalt emulsion. Over mixing may cause the asphalt emulsion to strip from the aggregate or break prematurely. Increasing the asphalt emulsion content may improve coating but it will also tend to reduce the stability of the mix. It may be better to use a different type or grade of asphalt emulsion to improve coating. For faster curing, place asphalt emulsion cold mixes in several thin layers rather than a single thick layer.

Do not seal asphalt emulsion cold mix surfaces too soon. Shoving and rutting may occur as a result of excess fluids in the mix during compaction, poor aggregate friction, or a combination of the two eliminated by aerating the mix. Additional compaction will not help.

Early compaction seals the surface and retards further removal of water, or it causes surface cracking and checking. This results in raveling under traffic. It is much better to delay compaction, reduce mix water, add cement or dehydrated lime, open up the grading, or add crushed rock.

If raveling occurs under traffic, the loose material should be boomed off as soon as possible to prevent further damage to the surface. If the raveling is increasing, then asphalt enrichment of the surface may be desirable. This may be done by a single seal coat or light fogging with a diluted SS type asphalt emulsion (1 : 1). The intent is to obtain some penetration so as to avoid a tacky surface and potential pickup by vehicle tires. If the raveling is due to an already tacky surface, then a light blotting with sand will be necessary.

SECTION 17

SAND MIXES USING ASPHALT EMULSIONS

17.1 Scope

Asphalt emulsion sand mixes shall consist of a fine aggregate and an asphalt emulsion. These mixtures can be applied and compacted at ambient temperatures for the purpose of base or surface stabilization. The materials, general requirements, composition, equipment, and construction procedures will be discussed in this performance guide.

17.2 Applicable Documents

17.2.1 ASTM Documents

- C136 Method for Sieve Analysis of fine and Coarse Aggregates
- D75 Practice for Sampling of Aggregates
- D977 Specification For Emulsified Asphalt
- D2397 Specification For Cationic Emulsified Asphalt
- D2419 Test Method for Sand Equivalent Values of Soils and fine Aggregate

17.2.2 AEMA Documents

- **A Basic Asphalt Emulsion Manual (BAEM)**

17.3 Asphalt Emulsion

Asphalt emulsion for sand emulsion mixes would conform to the following specifications:

- ASTM D997 HFMS-2h, MS-2h, HFMS-2, HFMS-2s, SS-1, SS-1h
- ASTM D2397 CMS-2h, CMS-2, CMS-1, CSS-1, CSS-1h.

When specifically approved by the purchaser, other types of asphalt emulsion may be used, if experience has proven that satisfactory performance will result. Selection of the type and grade of asphalt emulsion will depend primarily on the aggregate gradation, the method of mixing the materials, and weather conditions.

17.4 Aggregates

Bank run sands, poorly graded gravel, and dune or sugar sands treated with asphalt emulsions have shown good performance as sub-base and base course layers where adequately confined by strong binders and surfaces. The use of marginal materials provides an opportunity for the engineer and asphalt emulsion supplier to combine their knowledge to provide optimum performance from such materials. Generally, sand mixes are restricted to fine granular sands and silty sands low in clay content. When tested according to ASTM D2419, the aggregate should have a sand equivalent not less than fifty percent.

17.5 Mineral Filler

The addition of small amounts of cement or other mineral filler to asphalt emulsion treated mixes may assist in early stiffness and stability of the material. However, the addition of too much cement can cause a brittle mix. A ratio of cement to asphalt emulsion content on the order of 1 to 5 appears acceptable when this option is used.

17.6 Other Additives

Caution should be exercised if the in-place aggregate has received chemical dust treatments or chemical salts or stabilizers. Such chemical treatments may react with the emulsifier and cause premature separation of the asphalt emulsion before complete coating has taken place. In some instances it may be possible to treat aggregates with a small amount of lime to reduce the plastic character of the fines or clay portion of the material passing the No. 200 (0.075mm) sieve.

17.6.1 Mix Composition

- A proper mix design formulated by a laboratory is essential for good field results. A laboratory analysis will provide a guideline of the approximate percentage of water, asphalt, and mineral filler, although field adjustments may be necessary.
- A representative sample should be submitted to the laboratory in accordance with ASTM D75. A sieve analysis of this sample is run on the aggregate following methods outlined in ASTM C136. Using the Young Method, the pure asphalt requirement can be computed. This formula multiplies the retention of each sieve by a calibration factor to find the surface area. The surface area in conjunction with the Centrifuge Kerosene Equivalent (CKE) California DOT 3038 will yield the amount of residual asphalt required. The Percent Asphalt Emulsion Requirement is generally between 6 to 15%.
- Trial Mixes — knowing the asphalt emulsion requirement, trial mixes can be made varying the amount of water and mineral filler. Water, is often necessary in a mix as it serves to dissipate surface charges of the aggregate. Mineral filler, normally cement, may be added for early curing strength, resistance to water, and abrasion.
- Compaction — Laboratories with the proper equipment can calculate the time for compaction of the designed mix (California Division of Highways Test Method 301). It is helpful to have this time calculated.

17.7 Preparation of Roadbed

Every part of the structure contributes to the effective performance of the completed pavement. Careful shaping and compacting of the roadbed in conjunction with a properly designed and constructed surface drainage system is the first step in building a sound pavement structure. The roadway must first be cleared of all vegetation to a width sufficient to accommodate both windrows and traffic during mix operation and while the mixture cures after mixing.

If the existing road is composed of sand, the structure may itself be stabilized, or alternately the existing grade may be overlaid with an asphalt emulsion sand mix. In either case the work area shall be substantially true to line, grade, and cross section, and have a firm prepared surface before any overlay or mix-in-place operation begins. An important part of this process involves the repair or replacement of unstable areas, including holes and depressions, with sound material equal in quality to the rest of the road bed.

Whether it is a new sub-grade or existing aggregate surface, the final step in preparation of the roadbed is compacting the foundation. Where the sandy aggregate has low cohesion, it may be necessary to add water to the grade in order to achieve the shaping and compaction operations. If the existing grade is to be overlaid, and existing surface is loosely bonded, it should be primed prior to placing additional mix on the grade.

17.8 Aggregate Preparation

Asphalt emulsion sand mixtures normally use existing aggregates as they occur in the area of the roadbed or in selected pits in the adjacent areas. If it is convenient, the in-place material may be modified by the addition of other aggregates (sands) to produce improved gradation or stability. Such blending should be based on laboratory evaluation and economics. If the mix is to be prepared in a pit, then blending of aggregates, fillers, or both can be accomplished with hoppers and a belt feeder system.

Where aggregate or filler addition is to be made to existing aggregate on the road surface, the mineral aggregate from the old roadbed should be scarified. The additive material should be spread over the surface of the scarified material in a uniform quantity, and in such quantity as will provide a mixture meeting the requirements of the predetermined mix design. Mixing with a rotary type mixer shall take place until a uniform mixture of aggregates is obtained.

Aggregate from the old roadbed should be scarified and bladed into one or more windrows for measuring and sampling. These windrows are then mixed together thoroughly before asphalt emulsion is added. When the asphalt emulsion is to be combined with the aggregate by a mixing operation on the road, the aggregate shall be positioned on the surface of the roadbed in such a manner as to facilitate processing with the mixing machine equipment.

When the traveling unit has a spray bar and one or more rotating mixers at right angles to the direction of motion of the unit, the aggregate may be spread uniformly over the road surface in a manner representative of the final structural cross section. The machine will then combine the asphalt emulsion and aggregate in place.

Traveling units having a spray bar and rotating shaft fixed axially to the direction of the motion require the aggregate to be positioned in one or more windrows containing sufficient materials to produce the required thickness of compacted mix. If the mixing operation is to be performed by spray truck, motor graders, and rotary mixers, the aggregate should be positioned in one windrow along one side of the road bed.

17.9 Mixing

Asphalt emulsion and aggregate may be mixed in place or at a central plant pug mill.
The choice of method depends on such factors as:

1. Equipment availability
2. Size of project
3. Aggregate source, type, and cost

4. Anticipated traffic volumes and loads
5. Climatic conditions

The best balance between these factors must be evaluated. Regardless of the mixing method, 100% coating of the coarse aggregate particles is not always achieved, nor is it necessary.

17.9.1 Mixing Moisture

Mixing procedures should aim at achieving a uniform dispersion of the asphalt emulsion with a complete coating of the finer aggregate fractions. Toward achieving this uniform dispersion of the asphalt emulsion, it is sometimes necessary to moisten the aggregate before application of the asphalt emulsion. The appropriate volume of water to be added should be determined by the mix design, and if required should be added prior to the incorporation of the asphalt emulsion.

Mixing of the asphalt emulsion should be done at as low of a moisture content as possible, because the compaction moisture content is usually lower than the moisture content after mixing. Under poor drying conditions, the removal of surplus moisture could be a costly and time consuming operation.

17.9.2 Central Plant Mix

A central plant mixing operation is recommended for projects that involve close tolerances and high production. Generally, this type of mixing is done away from the road site, and frequently at the source of the aggregate. Conventional batch and dryer-drum hot mix plants can be used to produce asphalt emulsion mixes.

The central cold mix plant consists of a mixer and certain auxiliary equipment for feeding the asphalt emulsion, water, aggregate and additives to the mixer. The asphalt emulsion central mixing plant generally has no dryer or screens other than a scalping screen to remove oversize aggregate. At the very least, the plant should consist of a pug-mill, an asphalt emulsion storage tank, a metering pump, units for feeding water and additives, controls for adjusting and monitoring the various components, a conveyor, and a power source, a tachometer to aid in maintaining a constant speed on the conveyor belt, and one or more aggregate bins with belt feeders.

The mixer should permit variations in mixing times to ensure that the aggregate is properly coated but not over mixed. Mixing times can be varied in a continuous pug-mill plant by changing the angle of the paddles, by varying the height of the end gate, or by changing the location of the asphalt emulsion spray bar.

Asphalt emulsion cold mixes require shorter mixing time than asphalt concrete mixes. The tendency is to over mix asphalt emulsion mixes which may remove the asphalt from the aggregate. It may also result in premature breaking of the asphalt emulsion, causing overly stiff mixtures.

The mix produced at a central plant may be stockpiled for later use. The length of storage time in the stockpile is controlled by the type of asphalt emulsion incorporated into the mix.

17.9.3 Travel Mixers

The purpose of the travel plant is to leave a uniform, properly coated, asphalt emulsion and aggregate mixture on the roadbed. Aggregates are placed into the hopper of the mixer where they are drawn into the mixing chamber. The asphalt emulsion proportioning device is interlocked to ensure a constant blend. The asphalt emulsion is added by pumping through a spray bar mounted on the mixing chamber. This method permits the addition of all the asphalt emulsion in one application. The forward speed of the mixer should be adjusted so that the material being ejected has a uniform texture.

Injecting the asphalt emulsion in one application through the mixing chamber can be done at a lower moisture content than with distributor application. The single application immediately brings the aggregate to optimum mixing moisture whereas the first application with a distributor adds only part of the moisture associated with the asphalt emulsion.

The travel plant places the mix on grade with proper cross-slope to the design thickness. The mix is then ready for compaction.

17.9.4 Rotary Mixers

Rotary cross-shaft mixing employs a mobile mixing chamber which is self-propelled. The mixing chamber, usually 6 to 8ft (2 to 2.7m) wide, and 2 to 3ft (0.66 to 1m) high, open at the bottom, contains one or more shafts, transverse to the roadbed, upon which mixing blades are mounted. As the shafts rotate rapidly, the mixing tines thoroughly agitate the material in the roadbed. The machine, moving forward, strikes off a uniform course of asphalt aggregate mixture.

Self-propelled rotary mixers are designed to accurately and automatically control the predetermined mixing depth from existing surface grades. This assumes that the rotary mixer is operated at a speed slow enough for the rotor tines to cut their path through the aggregates. The rotary mixer should produce a mixture with a uniform percentage of asphalt emulsion. If the existing grade is different from final grades and cutting and filling operations are carried out, the depth of the finished material will vary but it should have a uniform percentage of stabilizing agent.

Rotary mixers equipped with built-in spraying systems require that the asphalt emulsion application rates be matched accurately with the width and thickness of the course, forward speed of the mixer, and the density of the in-place aggregate. However, when utilizing a rotary mixer not equipped with spray-bars, an asphalt emulsion distributor, operating ahead of the mixer, applies asphalt emulsion to the aggregate. Incremental applications of asphalt emulsion and passes of the mixer are usually necessary to achieve the specified mixture.

Most rotary mixers are equipped with spray systems and when using this equipment, the following steps are recommended:

1. Spread the aggregate to uniform grade and cross section with motor graders.
2. Thoroughly mix the aggregate by one or more passes of the mixer.
3. Add asphalt emulsion in increments until the total required amount of asphalt emulsion is applied and mixed. If the mixer is not equipped with spray-bars, the asphalt emulsion is to be applied with an asphalt emulsion distributor.
4. Make one or more passes of the mixer between applications of asphalt emulsion, as necessary for thorough mixing.
5. Maintain the surface true to grade and cross section by using a motor grader during the mixing operations.

Any variation of the mixer along the longitudinal joint will cause a fat area at overlaps and lean areas where the joint is missed. This can also occur when applying asphalt emulsion with a distributor because the exact location of the longitudinal joint is difficult to follow or even to find. In the case of the distributor which must make one pass per inch of depth, there is some chance of averaging the error. Subsequent passes of the mixer over the lean or fat area will have little effect of blending the variation.

To eliminate this problem with in-place construction, transverse mixing is essential. This is usually done with multiple passes with a blade. This is then followed by longitudinal mixing. This procedure effectively eliminates lean or fat areas at longitudinal joints as well as areas where a nozzle may have been plugged. This procedure also does an effective job of blending different types of aggregates which may occur in the operation.

The total number of passes of the rotary mixer will depend on the method of adding the asphalt emulsion and on the amount of No. 200 (0.75mm) material present.

17.9.5 Distributor & Motor Grader Mixing

Asphalt emulsion mixtures may be prepared by applying the asphalt emulsion by a distributor and blade mixing with a motor grader.

The first step in the operation is to shape the prepared aggregate into a uniform windrow of a known volume by means of a spreader box, windrow proportioner, or motor grader. The motor grader then lays out a uniform lift of aggregate from the windrow onto the road surface or mixing table. If mixing water is required, it is then added at a predetermined rate to the aggregate lift. Next the asphalt emulsion is applied at the predetermined rate by the distributor to the lift of aggregate. The motor grader then folds the aggregate over the asphalt emulsion. The motor grader may work this lift back and forth to achieve mixing, or the mixture may be windrowed on the opposite side of the road and another lift of aggregate processed as above. This procedure is repeated until the design quantity of asphalt emulsion has been added to the total windrow of aggregate.

The grading of the aggregate in the windrow may vary and cause asphalt demand to vary. Therefore, as asphalt emulsion mixing progresses, close attention should be paid to the appearance of the mix. It is very important that uniformity of grading and moisture content be achieved. Mixing should consist of as many passes with the motor grader as needed to fully spread the asphalt emulsion and coat the aggregate particles, and when completed the windrow should be moved to one side of the roadbed in preparation for spreading.

Blades are relatively inefficient mixing devices and the aeration is high. Therefore, a water content higher than that for rotary mixers will be required to assist dispersion of the asphalt emulsion and replace relatively high evaporation losses. The mixing moisture will be well above the optimum compacting moisture so that the stabilized material will need drying before compacting.

Because the fine grained sands (which are to be stabilized) have a low stability, they provide poor working surfaces on which to perform a windrow mixing operation. The grader will tend to disturb the exposed sub-grade and thus continually draw sub-grade material into the windrow. Once mixed, efforts to spread the windrow must be made with caution or sub-grade material will be churned up into the mix.

Windrow mixing requires the close control of grade and cross-section that is required of all in-place construction. In addition, it also requires close control of the grade and cross-section of the exposed sub-grade. Variations from either surface or sub-grade elevations will result in a non-uniform windrow. If this occurs, the uniform longitudinal application of asphalt emulsion to the windrow will result in a varying percentage of residual asphalt.

17.9.6 Secondary Mixing

Sometimes further mixing of the windrowed material may be necessary after the addition of the asphalt emulsion. Unless the travel mixer can be used as a multiple pass mixer, this additional mixing usually is done with a motor grader or small rotary mixers. This ensures that all the windrowed material is incorporated into the mix. The number of passes with the motor grader required for this purpose varies with different job conditions. After the mixing operation is completed, the windrow should be moved to one side of the area to be surfaced in preparation for spreading.

17.10 Spreading and Conditioning

Asphalt emulsion mixes gain stability as the water evaporates. It is important not to hinder this process. Therefore, lift thickness may be limited by the rate of fluid loss.
The most important factors affecting this dehydration or curing are the type of asphalt emulsion, the mix water content, the gradation and temperature of the aggregate, wind velocity, ambient temperature, and humidity.

Although each job has its own particular combination of these factors, experience has shown that under the best conditions, sand mixes should be placed in a compacted thickness no greater than 2in. (50mm).

When multiple lifts are required, some curing time must be allowed between successive lifts. The length of this curing time is a function of the rate of evaporation, and this is a variable. However, an existing lift can normally be overlaid after from 2 to 5 days under good curing conditions. The mixture should be spread uniformly on the roadbed, beginning at the point farthest from the mixing plant. Hauling over freshly laid material should not be permitted except when required for completion of the work.

Spreading central plant mixes is best accomplished with a self-propelled asphalt paver. However, base spreaders and motor graders also obtain good results.

The mixture should always be spread to a uniform thickness. This is to eliminate the chance that thin spots may occur in the final mat.

Blade spreading should be done in layers, with no layer thinner than about two times the diameter of the maximum particle size. As each layer is spread, compaction should follow at once. Mixtures to be spread with a motor grader are generally placed on a roadbed in windrows. The windrow may be located along the center line of the road or along one side. Because there is a tendency to leave a hump in the road when blade spreading from the centerline windrow, it is better practice to place the windrow to the side for spreading. For a smooth riding surface, the motor grader should be used to trim and level the mix as the rollers complete compaction of the top layer.

Successful placement of cold laid plant mixes requires the presence of sufficient fluids. Dry mixes tend to tear beneath the screen or strike-off bar. If the mixture is too dry, the mix water content should be increased. When a self-propelled paver is used, heating the screed in attempts to eliminate this tearing does not help. It actually makes the mix less workable, since it serves to accelerate the drying process.

Because of these variables, local experience is likely the best guide in determining allowable placement thickness.

17.11 Compaction

Compaction of asphalt emulsion sand mixtures is intended to consolidate the mixed materials into a state which will eventually produce maximum stability and longest life. This condition has usually been determined in the laboratory.

Besides the aggregate, there are two fundamental components of the mixture whose quantities have been evaluated in the laboratory study, asphalt emulsion and moisture. The design quantity of asphalt emulsion has been added during the mixing process. It is now necessary to compact the mixture at the design moisture content, based on either density or stability. The moisture content of the mixture can be measured on site or evaluated by experienced personnel. The mixture should be brought to the desired moisture level (or slightly above) during the spreading and conditioning process.

Generally, compaction can be achieved with less than 4% moisture in the mix. Rubber tired rollers are normally used for compaction. Because the tires of the motor grader compact the freshly spread mix their tracks may appear as ridges in the finished mat unless there is adequate rolling between the spreading of each layer. The roller should follow directly behind the motor grader to eliminate these ridges. If the stabilized asphalt emulsion sand mixture becomes too dry before compaction it will be impossible to achieve desired density. When the mixture becomes too dry, some asphalt emulsions will set or break, which results in further resistance to the compaction effort.

This breaking may be indicated by the darkening in the color of the mix. Therefore, there is some advantage to begin compaction at a slightly higher moisture level than the design level. Rolling should continue until the desired moisture is obtained before placing the next lift.

If the mix is at too high a moisture content when compaction is attempted, the mat may rut or shove. The upper crust may crack after compaction is apparently completed.

This indicates the mix is above optimum moisture for compaction and although the surface may be at the right moisture content, the lower section of the lift is unstable due to high moisture level. Under these conditions, the moisture content must be reduced by further aeration, usually obtained by reblading the mix. After one course is thoroughly compacted, other courses may be placed on it. This operation should be repeated as many times as needed to bring the road to proper grade and crown.

After the mat is shaped to its final required cross-section, it must be finished rolled. Care should be taken to avoid over compaction.

17.12 Surface Seal

Asphalt emulsion and sand mixtures prepared with 7% or less asphalt emulsion may be expected to need additional surface treatment in order to withstand the abrasion of traffic. A prime or fog seal should be applied within a day or two after compaction is completed. A seal coat should be placed when the mixture is thoroughly cured.

17.13 Traffic Control

If possible, traffic should not be allowed on the mix until it will support vehicles without undue displacement. When it is not possible to close the road completely, vehicles should be controlled to minimum speeds, without acceleration, deceleration, or sudden braking. Traffic should be directed through the project with such signs, barricades, devices, flagman, and pilot vehicles as maybe necessary for absolute control.

SECTION 18

WARM MIXES USING ASPHALT EMULSIONS

18.1 Scope

This performance guide covers the preparation and use of warm mixed, warm laid asphalt emulsion mixtures for base, binder, and surface courses.

18.1.1 Applicable Documents

18.1.2 ASTM Documents:

- C127 Standard Test Method for Density, Relative Density(Specific Gravity) and Absorption of Coarse Aggregate
- C128 Standard Test Method for Density, Relative Density (Specific Gravity) and Absorption of Fine Aggregate
- C131 Standard Test Method for Resistance to Degradation of Small-Size Course Aggregate by Abrasion and Impact in the Los Angeles Machine Check and Impact in the Los Angeles Machine
- C136 Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates Check
- D75 Standard Practice for Sampling of Aggregates
- D140 Standard Practice for Sampling Bituminous Materials
- D242 Standard Specification for Mineral Filler for Bituminous Paving Mixtures
- D244 Standard Methods and practices for Emulsified Asphalts
- D448 Standard Classification for Sizes of Aggregate for Road and Bridge Construction
- D546 Standard Test Method for Sieve Analysis of Mineral Filler for Road and Paving Materials
- D692 Standard Specification for Coarse Aggregate for Bituminous Paving Mixtures
- D977 Standard Specification for Emulsified Asphalt
- D979 Standard Practice for Sampling Bituminous Paving Mixtures
- D1073 Standard Specification for Fine Aggregate for Bituminous Paving Mixtures
- D2172 Standard Test Methods for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
- D2397 Standard Specification for Cationic Emulsified Asphalt
- D2419 Standard Test Method for Sand Equivalent Values of Soils and Fine Aggregate
- D2489 Standard Practice for Estimating for the Degree of Particle Coating of Bituminous-Aggregate Mixtures
- D3203 Standard Test Method for Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
- D3628 Standard Practice for Selection and Use of Asphalt Emulsion
- D4318 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

• AASHTO M-323-07 Standard Specification for Superpave Volumetric Mix Design

18.1.3 AEMA Documents

• **A Basic Asphalt Emulsion Manual**

18.2 Descriptions

This performance guide describes base, binder, and surface mixture types mixed and placed warm using asphalt emulsion. It intended to be descriptive only and to present types of construction which have been in use for many years but which have not been promoted outside of limited areas.

The basic concepts supporting the use of asphalt emulsion in warm mixtures are twofold. Both are dependent upon the use of asphalt emulsions which have been properly formulated to meet the desired objectives. First, by this means it is possible to readily coat large size and very open graded coarse aggregates with thick films of asphalt. This is normally difficult to accomplish in the conventional hot mix process using asphalt cements. Second, by this means, asphalt can be incorporated with the aggregate, irrespective of whether the mix is an open or dense-graded, that can have improved characteristics of greater toughness and less temperature susceptibility than would normally be the case.

There are additional benefits that accrue in the use of mixtures of this type. More thorough mixing is achieved because initial distribution of the asphalt occurs while the asphalt is emulsified and in a highly dispersed state. Any fines present are individually coated in this stage. The process significantly reduces asphalt hardening when compared to the conventional hot mix process due to the lower mixing temperatures. The water vapor generated during the mixing process, effectively reduces viscosity and allows lower mixing temperatures and more thorough coating of the aggregate mix.

18.3 Asphalt Emulsions

Asphalt emulsion for warm mixes would conform to the following ASTM specifications:

• D977 HFMS-2h, MS-2h, HFMS-2, MS-2, HFMS-2 D2397 CMS-2h, CMS-2

Polymer modified asphalt emulsions may also be used which employ the use of various polymers to improve adhesion, elastomeric, and modulus properties. When specifically approved by the purchaser, these and various other types of asphalt emulsion may be used if experience has proven that satisfactory performance will result.

18.4 Aggregate

• The aggregates should conform to the quality requirements of ASTM, AASHTO, state and local highway specifications. Other mineral aggregates, such as uncrushed gravel and crushed shell may be specified provided that local experience or tests have demonstrated their ability to produce satisfactory warm asphalt emulsion paving mixtures. However, crushed aggregates tend to produce the best mix stability and performance as a rule.

• Recommended grading requirements for coarse and fine aggregates are found in ASTM D448 and D1073, respectively. Other aggregate gradations may be used, provided that the combined coarse and fine aggregates, and filler when used, produce a mixture that conforms to the requirements for grading of the total aggregate.

NOTE:

Other gradations may be specified, provided that local experience or tests have demonstrated their ability to produce satisfactory warm asphalt emulsion mixtures.

18.5 Mineral Filler

The mineral filler, if any, should conform to the quality requirements of ASTM D242 or to similar specifications of AASHTO, state or local highway departments.

18.6 Design Considerations

18.6.1 Sub-grade

Whether it be new construction or a resurfacing operation, the performance of the pavement is affected by the characteristics of the sub-grade. Desirable properties that the sub-grade should possess include strength, drainage, ease of compaction, permanency of compaction, and permanency of strength. In a resurfacing operation, any existing surface irregularities which can be traced to a sub-grade problem should be corrected.

18.6.2 Sub-base

The sub-base, along with the base, helps spread the load which is applied to the surface. This is to minimize sub-grade deformation which can lead to pavement failure. Sub-bases should consist of select materials such as natural gravels that are stable and drainable, but have characteristics which may make them not completely suitable as base courses.

18.6.3 Base

The base course may be placed on the sub-base or upon the existing old asphalt or unpaved surface provided any defects have been corrected prior to placement. It is suggested that the base be made up of suitably graded crushed stone, gravel or slag. These aggregates can be mixed warm with asphalt emulsion to provide a suitable base layer.

18.6.4 Binder

The binder course, if used, is a transitional layer between the base course and the surface course. Warm asphalt emulsion mixtures may also be used for this lift.

18.6.5 Surface

The surface course must possess skid resistance, resist load and non-load associated fracturing and be resistant to permanent deformation. A warm asphalt emulsion mixture of a gradation listed in AASHTO M-323-07 may be used as a surface mixture.

NOTE:

The aforementioned pavement layers should, prior to constructing, be designed to meet the standards as specified by ASTM, AASHTO, state or local highway authorities.

18.7 Composition of Paving Mixtures

AASHTO M323-07 lists mix compositions which may be used for designing warm asphalt emulsion mixtures. Warm asphalt emulsion mixtures should conform to these composition limits. In addition, laboratory testing should be performed prior to construction. This Testing should include optimum asphalt determinations and mixture performance studies as well as aggregate coating and water resistance tests.

NOTE:

The nominal top size aggregate (mix designation) selected should be determined by the intended use, thickness of paving courses, and desired texture. The required mix should be specified.

These aggregate compositions are based on the use of fine and coarse aggregates having the approximately the same bulk specific gravities. Grading of the total aggregate, therefore, would be the same on either a weight or bulk volume basis. If the bulk specific gravities of coarse and fine aggregates differ greatly, it may be desirable to change the grading limitations to compensate for these differences.

A job mixture shall be selected that comes within the specification limits and that is suitable for the traffic, climate conditions, and specific gravities of the aggregates used.

Any variation from the job mix formula in the grading of the aggregate, as shown by the sieve analyses of the materials in the plant, or any variation from the job mix formula in the asphalt content, as indicated by extraction or ignition oven tests of the finished mixture, greater than the percentage determined as optimum from the design process shall be investigated. The conditions causing such variation shall be determined and corrected.

18.8 Mixing Plant

- The mixing plant may be any approved type of equipment of the batch or continuous type which provides for a drum type dryer and pug-mill mixer.
- A combination dryer and mixer (drum mixer) in which the asphalt emulsion and aggregate are heated together by the direct application of heated gases from a burner may also be used. On batch plants the pug-mill mixer chamber shall be vented to allow the escape of steam.

- The discharge end of the asphalt emulsion circulating pipe should be kept below the surface of the asphalt emulsion in the storage tank to prevent foaming and air entrainment.
- Provisions should be made in the asphalt transfer system that will enable the operator to turn off or reduce the heat media from all lines, pumps, and jacketed asphalt material buckets as soon as the system is open and circulating properly.
- Care should be taken to avoid overheating the asphalt emulsion in the lines, pumps, and tank.
- Approved storage silos for the hot asphalt emulsion mixture may be employed.

18.9 Mixing Plant Operation

18.9.1 Aggregate Storage

Aggregates furnished in different sizes or from different sources shall be kept separate, and adequate provision shall be made to keep them from becoming mixed or otherwise contaminated. Stockpiles shall be built and the materials removed there from in such a manner as to minimize size segregation.

18.9.2 Storage & Handling of Asphalt Emulsion

The asphalt emulsion shall be maintained at a temperature at which it can be properly handled through the pumping system and uniformly distributed throughout the mixture. At no time during the processing from storage to mixing will the temperature of the asphalt emulsion be allowed to exceed 185°F (85°C).

18.9.3 Preparation and Handling of Mineral Aggregates

Each size aggregate shall be separately fed by feeders to the cold elevator or elevators in proper proportion and at a rate to permit correct and uniform temperature control of the heating and drying operation.

18.10 Mix and Temperature

- The aggregate shall be dried and delivered to the mixer at a temperature such that the asphalt emulsion mixture will be produced at a temperature within the range of 150 to 220°F (66 to 104°C).
- Minimum mixing time may be established on the percentage of coated particles as determined by ASTM D2489 Standard Practice for Estimating for the Degree of Particle Coating of Bituminous-Aggregate Mixtures.
- The minimum values for percentage of coated particles used to establish the minimum mixing time should be set by the engineer. These values will vary with aggregate gradation, particle shape and surface texture, and with the asphalt content and use for which the mixture is intended.

18.11 Construction

18.11.1 Spreading

The asphalt emulsion warm mix should be spread by the use of a self-propelled spreading and finishing machine that will finish the surface to the line, grade, and cross-section shown on the plans. No mechanical spreader should be permitted that fails to provide an even surface of uniform texture. Nor should it be operated at a speed that fails to allow proper screed action. All patches and areas of fine or undersized aggregate appearing in this course should be removed and replaced with properly combined mix. Each succeeding course should be varied in thickness to take up any unevenness of the previous layer and be compacted to the desired compaction level.

18.11.2 Compaction

As soon as the asphalt emulsion warm mix has become sufficiently hard to bear the weight of the roller without shoving, it should be rolled with a self-propelled pneumatic, three-wheeled or vibratory roller. These rollers should be followed by a tandem roller. The rollers should compact the pavement sufficiently to provide not less than 95% of laboratory density as determined by the Engineer.

18.12 Methods of Sampling and Testing

Sample all material and determine the properties enumerated in this guide in accordance with ASTM Methods.

SECTION 19

HOT MIXES USING ASPHALT EMULSIONS

19.1 Scope

This performance guide covers the preparation and use of hot mixed, hot laid asphalt emulsion mixtures for base, binder, and surface courses.

19.2 Applicable Documents

19.2.1 ASTM Documents:

- C127 Standard Test Method for Density, Relative Density (Specific Gravity) and Absorption of Coarse Aggregate
- C128 Standard Test Method for Density, Relative Density (Specific Gravity) and Absorption of fine Aggregate
- C131 Standard Test Method for Resistance to Degradation of Small-Size Course Aggregate by Abrasion and impact in the Los Angeles Machine
- C136 Standard Test Method for Sieve Analysis of fine and Coarse Aggregates
- D75 Standard Practice for Sampling of Aggregates
- D140 Standard Practice for Sampling Bituminous Materials
- D242 Standard Specification for Mineral filler for Bituminous Paving Mixtures
- D244 Standard Methods and Practices for Emulsified Asphalts
- D448 standard Classification for Sizes of Aggregate for Road and Bridge Construction
- D546 Standard Test Method for Sieve Analysis of Mineral filler for Road and Paving Materials
- D692 Standard Specification for Coarse Aggregate for Bituminous Paving Mixtures
- D977 Standard Specification for Emulsified Asphalt
- D979 Standard Practice for Sampling Bituminous Paving Mixtures
- D1073 Standard Specification for fine Aggregate for Bituminous Paving Mixtures
- D2172 Standard Test Methods for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
- D2397 Standard Specification for Cationic Emulsified Asphalt
- D2419 Standard Test Method for Sand Equivalent Values of Soils and fine Aggregate
- D2489 Standard Practice for Estimating the Degree of Particle Coating of Bituminous-Aggregate Mixtures
- D3203 Standard Test Method for Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
- D3628 Practice for Selection and Use of Asphalt Emulsion

- D4318 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- AASHTO M-323-07 Standard Specification for Superpave Volumetric Mix Design

19.2.2 AEMA Documents

- **A Basic Asphalt Emulsion Manual**

19.3 Descriptions

This performance guide describes base, binder, and surface mixture types mixed and placed hot using asphalt emulsion. It is intended to be descriptive only, and to present types of construction which have been in use for many years but which have not been promoted outside of limited areas.

Basic concepts supporting the use of asphalt emulsion in hot mixtures are twofold. Both are dependent upon the use of asphalt emulsions properly formulated to meet the desired objectives. First, by this means it is possible to readily coat large size and very open graded coarse aggregates with thick films of asphalt. This is normally difficult to accomplish in the conventional hot mix process using asphalt cements. Second, by this means, asphalt can be incorporated with the aggregate, irrespective of whether the mix is an open or dense-graded, that can have improved characteristics of greater toughness and less temperature susceptibility than would normally be the case.

There are additional benefits that accrue in the use of mixtures of this type. More thorough mixing is achieved because initial distribution of the asphalt occurs while the asphalt is emulsified and in a highly dispersed state. Any fines present are individually coated at this stage. The process significantly reduces asphalt hardening when compared to conventional hot mix processes due to the lower mixing temperatures. The water vapor generated during the mixing process effectively reduces viscosity and allows for lower mixing temperatures and more thorough coating of the aggregate mix.

19.4 Asphalt Emulsions

Asphalt emulsion for hot mixes would conform to the following ASTM specifications:

- D977 HFMS-2h, MS-2h, HFMS-2, MS-2, HFMS-2 D2397 CMS-2h, CMS-2

Polymer modified asphalt emulsions may also be used which employ the use of various polymers to improve adhesion, elastomeric, and modulus properties. When specifically approved by the purchaser, other types of asphalt emulsion may be used, if experience has proven that satisfactory performance will result.

19.5 Aggregate

The aggregates should conform to the quality requirements of ASTM, AASHTO, state and local highway specifications. Other mineral aggregates, such as uncrushed gravel and crushed shell may be specified provided that local experience or tests have demonstrated their ability to produce satisfactory hot asphalt emulsion paving mixtures.

However, crushed aggregates tend to produce the best mix stability and performance as a rule.

Recommended grading requirements for coarse and fine aggregates are found in ASTM D448 and D1073, respectively. Other aggregate gradations may be used, provided that the combined coarse and fine aggregates, and filler when used, produce a mixture that conforms to the requirements for grading of total aggregate.

NOTE:

Other gradations may be specified, provided that local experience or tests have demonstrated their ability to produce satisfactory hot asphalt emulsion mixtures.

19.6 Mineral Filler

The mineral filler, if any, should conform to the quality requirements of ASTM D242 or to similar specifications of AASHTO, state or local highway departments.

19.7 Design Considerations

19.7.1 Sub-grade

Whether it is new construction or a resurfacing operation, the performance of the pavement is affected by the characteristics of the sub-grade. Desirable properties that the sub-grade should possess include strength, drainage, ease of compaction, permanency of compaction, and permanency of strength. In a resurfacing operation, any existing surface irregularities which can be traced to a sub-grade problem should be corrected.

19.7.2 Sub-base

The sub-base, along with the base, helps spread the load which is applied to the surface. This is to minimize sub-grade deformation which can lead to pavement failure. Sub-bases should consist of select materials such as natural gravels that are stable and drainable, but have characteristics which may make them not completely suitable as base courses.

19.7.3 Base

The base course may be placed on the sub-base or upon the existing old asphalt or unpaved surface provided any defects have been corrected prior to placement. It is suggested that the base be made up of suitably graded crushed stone, gravel, or slag. These aggregates can be mixed hot or warm with asphalt emulsion to provide a suitable base layer.

19.7.4 Binder

The binder course, if used, is a transitional layer between the base course and the surface course. Hot asphalt emulsion mixtures may also be used for this lift.

19.7.5 Surface

The surface course must possess skid resistance, resist load and non-load associated fracturing and be resistant to permanent deformation. A hot asphalt emulsion mixture of a gradation listed in AASHTO M-323-07 may be used as a surface mixture.

NOTE:

The aforementioned pavement layers should, prior to constructing, be designed to meet the standards as specified by ASTM, AASHTO, state or local highway authorities.

19.8 Composition of Paving Mixtures

AASHTO M-323-07 lists mix compositions which may be used for designing hot asphalt emulsion mixtures. Hot asphalt emulsion mixtures should conform to these composition limits. In addition, laboratory testing should be performed prior to construction. This testing should include optimum asphalt determinations and mixture performance studies as well as aggregate coating and water resistance tests.

NOTE:

The nominal top size aggregate (mix designation) selected should be determined by the intended use, thickness of paving courses, and the desired texture. The required mix should be specified.

These aggregate compositions are based upon the use of fine and coarse aggregates having the approximately same bulk specific gravities. Grading of the total aggregate, therefore, would be the same on either a weight or bulk volume basis. If the bulk specific gravities of coarse and fine aggregate differ greatly, it may be desirable to change the grading limitations to compensate for these differences.

A job mixture shall be selected so that it comes within the specification limits and is suitable for the traffic, climate conditions, and specific gravities of the aggregates used.

Any variation from the job mix formula in the grading of the aggregate, as shown by the sieve analyses of the materials in the plant or, any variation from the job mix formula in the asphalt content, as indicated by extraction or ignition oven tests of the finished mixture, greater than the percentage determined as optimum from the design process shall be investigated. The conditions causing such variation shall be determined and corrected.

19.9 Mixing Plant

The mixing plant may be any approved type of equipment of the batch or continuous type which provides for a drum type dryer and pug-mill mixer.

- A combination dryer and mixer (drum mixer) in which the asphalt emulsion and aggregate are heated together by the direct application of heated gases from a burner may also be used. On batch plants the pug mill mixer chamber shall be vented to allow the escape of steam.

- The discharge end of the asphalt emulsion circulating pipe should be kept below the surface of the asphalt emulsion in the storage tank to prevent foaming and air entrainment.
- Provisions should be made in the asphalt transfer system that will enable the operator to turn off or reduce the heat media from all lines, pumps, and jacketed asphalt material buckets as soon as the system is open and circulating properly.
- Care should be taken to avoid overheating the asphalt emulsion in the lines, pumps, and tank.
- Approved storage silos for the hot asphalt emulsion mixture may be employed.

19.10 Mixing Plant Operation

19.10.1 Aggregate Storage

Aggregates furnished in different sizes or from different sources shall be kept separate, and adequate provision shall be made to keep them from becoming mixed or otherwise contaminated.

Stockpiles shall be built and the materials removed there from in such a manner as to minimize size segregation.

19.10.2 Storage & Handling of Asphalt Emulsion

The asphalt emulsion shall be maintained at a temperature at which it can be properly handled through the pumping system and uniformly distributed throughout the mixture. At no time during the processing, from storage to mixing, will the temperature of the asphalt emulsion be allowed to exceed 185°F (85°C).

19.10.3 Preparation and Handling of Mineral Aggregates

Each size aggregate shall be separately fed by feeders to the cold elevator or elevators in proper proportion and at a rate to permit correct and uniform temperature control of the heating and drying operation.

19.11 Mix and Temperature

- The aggregate shall be dried and delivered to the mixer at a temperature such that the asphalt emulsion mixture will be produced at a temperature within the range of 220° to 260°F (66° to 127°C).
- Minimum mixing time may be established on the percentage of coated particles as determined by ASTM D2489 Standard Practice for Estimating for the Degree of Particle Coating of Bituminous-Aggregate Mixtures.
- The minimum values for percentage of coated particles used to establish the minimum mixing time should be set by the engineer. These values will vary with aggregate gradation, particle shape and surface texture, and with the asphalt content and use for which the mixture is intended.

19.12 Construction

19.12.1 Spreading

The asphalt emulsion hot mix should be spread by the use of a self-propelled spreading and finishing machine that will finish the surface to the line, grade, and cross-section shown on the plans. No mechanical spreader should be permitted that fails to provide an even surface of uniform texture; nor should it be operated at a speed that fails to allow proper screed action. All patches and areas of fine or undersized aggregate appearing in this course should be removed and replaced with properly combined mix. Each succeeding course should be varied in thickness to take up any unevenness of the previous layer and be compacted.

19.12.2 Compaction

As soon as the asphalt emulsion hot mix has become sufficiently hard to bear the weight of the roller, without shoving, it should be rolled with a self-propelled pneumatic, three-wheeled or vibratory roller; followed by a tandem roller. The rollers should compact the pavement sufficiently to provide not less than 95% of laboratory density as determined by the Engineer.

19.13 Methods of Sampling and Testing

Sample all material and determine the properties enumerated in this guide in accordance with ASTM methods.

SECTION 20

TECHNICAL DISCIPLINES – Cold Recycling



20.1 Overview

The **Asphalt Recycling and Reclaiming Association (ARRA)** is a non-profit international trade association made up of contractors, equipment manufacturers, suppliers, public officials and engineers. Its members are engaged in the recycling and reclaiming of asphalt and are working to build a stronger and safer network of highways, streets and roads across the country and around the world. ARRA is a forum for the exchange of ideas and solutions to recycling concerns. It will continue to develop new programs, strategies, and funding, not only to improve the technological side of the industry, but to increase the market share for recycled asphalt.

The **ARRA** is able to readily respond to the needs of its members and the public for rebuilding a stronger transportation network. A primary purpose of ARRA is to develop and maintain professional guidelines for the recycling industry. This is accomplished through four active technical committees within ARRA.

Parts of this publication were taken directly from the Basic Asphalt Recycling Manual (BARM), published by ARRA. It is the intent of AEMA, through the Recommended Performance Guidelines (RPG) to provide an overview of the technical discipline contained in this Section. A more in-depth and detailed description can be found in the BARM.

20.1.1 Cold Recycling (CR)

Cold Recycling consists of recycling asphalt pavement without the application of heat during the recycling process. Cold recycling consists of two disciplines: cold in-place recycling (CIR) and cold central plant recycling (CCPR). CR is a pavement preservation and corrective maintenance technique, and when combined with a HMA overlay can be easily classified as a major structural overlay rehabilitation.

20.1.2 Cold In-place Recycling Introduction

Cold recycling has been practiced by various methods and under a variety of names for over half a century. Cold in-place recycling (CIR) is a road construction technique that reuses existing asphalt pavement structure. All work takes place on the existing pavement surface and requires minimal transportation of new material. The process uses tanker trucks, milling machines, crushing/screening or sizing units, mixers, pavers and compaction rollers. The combined equipment spreads out over a considerable distance and is commonly referred to as a train. The CIR process is maintained within the bituminous portion of the asphalt pavement; it does not incorporate material from base layers within the reclaimed layer. Cold in-place recycling results in a stable road at a total expenditure less than that required by conventional methods (mill and fill with new HMA). Thanks to cooperation between equipment manufacturers, the asphalt industry, and contractors and contracting agencies, great advances have been made.

Today, the process combines sophisticated engineering and testing procedures, microprocessor blending controls, specially formulated additives, and highly productive machinery to achieve both superior quality and economy.

Many contracting agencies that are responsible for maintaining and rebuilding bituminous surfacing are using the cold in-place recycling process. These agencies include: cities, townships, counties, state highways, federal and inter-state highways, and other federal agencies such as the B.- I.A. and the Army Corps of Engineers.

20.1.2.1 Cold In-place Recycling Methods of Application

Cold in-place recycling is not a new method of rehabilitating deteriorating roadways.

For several decades, cold in-place recycling has been practiced by various methods on a wide variety of roadway types. CIR occurs within the roadway and uses 100 percent of the RAP generated during the process. CIR treatment depth is typically 2 to 5 inches (50 to 125mm) with an asphalt emulsion. Greater depths are possible with a two-layer system.

Cold in-place recycling is not a new method of rehabilitating deteriorating roadways. For the last 50 years or more, cold recycling has been practiced by various methods. These methods have included rippers, scarifiers, pulvimixers and stabilizers to reclaim the existing surface and base. Asphalt emulsions, cutbacks and other additives have been added and mixed by spraying the liquid on a windrow and mixing with a blade, with cross-shaft mixers and various types of traveling plants. In the past, the cold recycled material was laid with a motor grader and compacted with sheep-foot, pneumatic, grid, steel or a combination of rollers.

There are different types of CIR trains with different equipment configurations. The trains differ from one another in how the RAP is removed and sized, how the asphalt emulsion, water and additives are added, and how the materials are mixed, placed and compacted.

Cold planing machines are used to pulverize the roadway to the required size while at the same time cutting to a specified depth in preparation for liquid addition. Multi-unit recycling trains consist of a cold planer and a screening and crushing unit, which is followed by a mixing, proportioning unit and paver. Two unit trains do not include the screening and crushing unit but incorporate pug mill mixed pavers and use down-cutting cold planing machines. Single unit trains have a cutting head that removes the pavement to required depth and cross-slope, sizes the RAP and blends the asphalt emulsion with the RAP. It also down cuts and does not contain the screening and crushing unit. Densification of CR mixes requires more compactive energy than conventional HMA. This is due to the high internal friction developed between mix particles, the higher viscosity of the binder due to aging and colder compaction temperatures.

Another aspect of cold recycling that is very important is the liquid additives. Special asphalt derived products such as cationic, anionic, and polymer modified asphalt emulsions, rejuvenators and recycling agents have been developed especially for the cold in-place recycling process. These products are commonly referred to as Bituminous Recycling Agents.

Last but not least are the engineering and testing procedures. Engineering involves determining the depth and width to be cold recycled, along with the type of bituminous recycling agent to be added. Depth is normally determined by the amount of suitable material available. Consideration should be given to the depth of a lift that can be compacted to the specified density. Width of the roadway should be compatible with a standard milling machine mandrel.

20.1.2.2 Cold In-place Recycling Advantages

Cold in-place recycling has a number of advantages including:

- Conservation of non-renewable resources
- Energy conservation compared to other methods
- Eliminates disposal problems inherent with conventional methods
- Surface irregularities are corrected
- A portion of existing cracks are removed and reflective cracking mitigated
- Minor rutting, potholes and raveling are eliminated
- Base and sub-grade materials are not disturbed
- Pavement cross-slope and profile are improved
- Problems with existing aggregate and/or asphalt binder can be corrected
- Improved safety by reducing traffic disruptions and user inconvenience
- Economic Savings are realized
- Low mobilization costs
- Improvement of structural capacity if needed
- Reduces haul costs
- Traffic can generally be maintained through the project
- Roadway can be opened to traffic very quickly
- Reduced greenhouse gas emissions
- Projects can be completed in a minimal number of working days

20.1.2.3 Cold In-place Recycling Economics

Cost savings have been realized on cold in-place projects in the range of 20 to 50 percent lower than conventional mill and fill with HMA techniques. The major areas of savings are utilization of the existing aggregates in the roadway, reduction of haul costs, and the maintenance of the roadway geometry eliminating rework of associated structures.

20.2 Guidelines for Cold in-Place Recycling

20.2.1 Sample Specifications for Cold In-Place Recycling

20.2.1.1 Description

A copy of typical or suggested specifications can be obtained through ARRA or from the BARM.

In general, the specifications can look similar to but should not be limited to the following:

This work shall consist of milling the existing bituminous surface to the width and depth shown on the plans, mixing a bituminous recycling agent with the pulverized bituminous surface, then spreading and compacting said mixture as shown on the plans and as provided therein.

20.2.2 Materials

- The bituminous recycling agent shall be the type called for on the plans or in the proposal
- The pulverized bituminous material shall meet the gradation requirements stated in the plans.

A typical gradation would see 100% passing a 1-¼" sieve and 90% to 100% passing a 1" sieve.

20.2.3 Typical Construction Requirements

- The existing bituminous surfacing shall be cold recycled in a manner that does not disturb the underlying material in the existing roadway. However, in some circumstances, a small amount of the base may have to be incorporated in the mix to maintain a constant milling depth.
- Recycling operations shall not be performed when the atmospheric temperature is below 50° Fahrenheit or when the weather is foggy or rainy, or when weather conditions are such that proper mixing, spreading, and compacting of the recycled material cannot be accomplished in the judgment of the project manager.
- When commencing recycling operations, the bituminous recycling agent shall be applied to the pulverized bituminous material at the initial design rate determined by the material laboratory. The exact application rate of the bituminous recycling agent will be determined and varied by the project engineer

as required by existing pavement conditions. An allowable tolerance of plus or minus 0.2 percent of the initial design rate or project engineer directed rate of application shall be maintained at all times unless allowances for further variations have been made in the mix design. The contractor may add water to the pulverized material to facilitate uniform mixing with the bituminous recycling agent. Water may be added prior to or concurrently with the bituminous recycling agent and shall not cause any adverse effect on the additive or the recycled material.

- The number, weight and type of rollers shall be sufficient to obtain the required compaction while the mixture is in a workable condition. The project engineer may require a re-demonstration of rolling capabilities when a change in the recycled material is observed, whenever a change in the rolling equipment is made or if density is not being obtained with the rolling pattern being used.

After the recycled material has been spread and compacted, the area may be opened to traffic. Prior to placing the final surfacing or any secondary compaction, if required, the CIR shall meet the following criteria:

1. The completed CIR shall cure for a minimum of 3 days.
2. The moisture content shall be less than 3.0 percent. If the moisture content does not fall below the maximum limit of 3.0 percent after 10 days and if the roadway has been free of rain for a minimum of 2 days, the Contractor shall be permitted to place the final surfacing or perform the secondary compaction, as required.

20.2.4 Equipment

- The contractor shall furnish a self-propelled machine capable of pulverizing the existing bituminous materials to the depth shown on the plans in one pass. The machine shall be equipped with standard automatic depth controls and must maintain a constant cutting depth and width. Said machine shall be capable of producing the proper size RAP required or additional screening and crushing will be required. The equipment shall be capable of mixing the pulverized bituminous material and the bituminous recycling agent to a homogeneous mixture, and placing the mixture in a windrow or directly into the hopper of a paver. The method of depositing the mixed material shall be such that segregation does not occur.
- A positive displacement pump, capable of accurately metering the required quantity of bituminous recycling agent, down to a rate of 4 gal/min., into the pulverized bituminous material shall be used. Said pump shall be equipped with a positive interlock system which will automatically shut off when the material is not in the mixing chamber. Each mixing machine shall be equipped with a meter capable of registering the rate of flow and total delivery of the additive introduced into the mixture.
- Placing of the recycled bituminous base course shall be accomplished with a self-propelled bituminous paver. The bituminous recycled material shall be spread in one continuous pass, without segregation, to the lines and grades established by the project engineer. When a pick-up machine is used to feed the

windrow into the paver hopper, the pick-up machine shall be capable of picking up the entire windrow to the underlying material.

- The number, weight and type of rollers shall be sufficient to obtain the required compaction while the mixture is in a workable condition. When cold in-place recycling depths of 3" or more, breakdown rolling shall be with a 25 or 30 ton pneumatic roller equipped with a watering device and scrapers to prevent material from adhering to the tires. Rolling shall be performed until maximum density is achieved, as determined by a test strip placed prior to construction. Final rolling to eliminate pneumatic tire marks and achieve density shall be done by steel wheel roller(s), either in static or vibratory mode, as required to achieve density. Rollers shall not be started or stopped on uncompacted recycled material. Rolling shall be established so that starting and stopping will be on previously compacted recycled material or on the existing bituminous roadway, if at all possible. Any type of rolling that results in cracking, movement, or other types of pavement distress shall be discontinued until such time as the problem can be resolved. Discontinuation and commencement of rolling operations shall be at the sole discretion of the project engineer.

20.2.5 Method of Measurement and Payment

Cold in-place recycling shall be measured and paid by the square yard. The bituminous recycling agent of the type shown on the plans will be measured and paid by the ton or gallon. Additives shall be measured and paid by the ton.

20.2.6 Advantages of Cold In-Place Recycling

20.2.6.1 Deteriorated Roadways can be Returned to Original Standards:

- Restores the old pavement to the desired profile, eliminates existing wheel ruts, restores the crown and cross slope, eliminates potholes, irregularities and rough areas.
- Destroys the existing crack pattern. Alligator cracks as well as transverse and longitudinal cracks are eliminated, to the depth of the milling.
- Proper testing to determine the additive best suited to the existing material along with the proper proportioning will restore the old pavement to near its original properties.

20.2.6.2 Cost Effective:

- Hauling costs for materials except liquid additives are eliminated.
- High production. Equipment can cold recycle up to 3 lane miles per day.
- Thin overlay or a chip seal (for low volume roads) is all that is required for a surface course.
- All existing materials are reused. The only new material required is a small amount of bituminous recycling agent that is determined by the designated project design procedure.
- Engineering costs are much lower than for any other type of rehabilitation.

20.2.6.3 Convenience to Traveling Public:

- One lane traffic can be maintained through project at all times.
- Full width roadway is open to traffic at night and on weekends.
- Pollution, including dust, fumes and smoke are at a minimum
- Projects can be completed in a minimal number of working days.

20.2.6.4 Environmental Advantage

- Reuses all bituminous material
- Eliminates hauling and disposal of existing deteriorated surfacing.

20.3 Cold Central Plant Recycling Introduction

CCPR is the process in which the asphalt recycling takes place in a central location using a stationary cold mix plant. The stationary plant could be a specifically designed plant or a CIR train, minus the milling machine, set up in a stationary configuration. The CCPR mix can be used immediately or it can be stockpiled for later use in applications such as maintenance blade patching or pothole repair.

20.3.1 Cold Central Plant Recycling Methods of Application

RAP used in CCPR is obtained by cold planing or by ripping, removing, and crushing operations, and is stockpiled at the plant location. Sometimes existing RAP piles are used. Bituminous recycling agents are typically used as the recycling additives. The asphalt emulsion or emulsified recycling agent type, grade, and addition rate are determined through evaluation of the RAP and the mix design process.

New aggregates, if required, are also stockpiled at the plant site. The CCPR plant usually consists of a number of cold feed bins for RAP and new aggregate, a belt scale, a computer controlled liquid recycling additive system, and a pug-mill. Sometimes a hopper for temporary storage and loading of trucks or a conveyor/belt stacker, if the CCPR mix is being stockpiled, is used.

The CCPR mix is hauled to the job site with conventional dump trucks or belly dump trucks if a windrow pickup machine is being used. Placement of the CCPR mix is with conventional HMA pavers, but a motor grader could also be used. Compaction is with large sized rubber-tired and vibrating steel drum rollers. The compacted CCPR mix is generally overlain with a layer of HMA, although for some very low traffic roadways a single or double seal coat is sometimes used.

20.3.2 Cold Central Plant Recycling Advantages

Cold central plant recycling has a number of advantages including:

- Conserves non-renewable resources
- Energy conservation compared to other methods (HMA Plants)
- Eliminates disposal problems inherent with conventional methods
- Surface irregularities are corrected
- A portion of existing cracks are removed and reflective cracking mitigated
- Minor rutting, potholes and raveling are eliminated
- Base and sub-grade materials are not disturbed

- Pavement cross-slope and profile are improved
- Problems with existing aggregate and/or asphalt binder can be corrected
- Improved safety by reducing traffic disruptions and user inconvenience, as compared to conventional mill and fill
- Economic Savings are realized
- Low mobilization costs
- Improvement of structural capacity if needed
- Traffic can generally be maintained through the project
- Roadway can be opened to traffic very quickly
- Reduced greenhouse gas emissions
- Projects can be completed in a minimal number of working days
- Problems with existing aggregate gradation and/or asphalt binder can be corrected with proper selection of new granular materials and stabilizing additives

20.3.3 Cold Central Plant Recycling Economics

Cost savings have been realized on cold central plant recycling projects in the range of 20 to 50 percent lower than conventional maintenance, reconstruction, or new construction with mill and fill HMA overlay techniques.

20.4 Guidelines for Cold Central Plant Recycling

20.4.1 Sample Specifications for Cold Central Plant Recycling

20.4.1.1 Description

A copy of typical or suggested specifications can be obtained through ARRA or from the BARM.

In general, the specifications can look similar to but should not be limited to the following:

This work shall consist of milling the existing bituminous surface to the width and depth shown on the plans, Transporting of the reclaimed material to a central location. mixing a bituminous recycling agent with the pulverized bituminous surface, transporting the recycled bituminous mixture back to the reclaimed roadway, then spreading and compacting said mixture as shown on the plans and as provided therein.

20.4.2 Materials

- The bituminous recycling agent shall be the type called for on the plans or in the proposal
- The pulverized bituminous material shall meet the gradation requirements stated in the plans.

A typical gradation would see 100% passing a 1 ¼” sieve and 90% to 100% passing a 1” sieve.

20.4.3 Typical Construction Requirements

- The existing bituminous surfacing shall be cold recycled in a manner that does not disturb the underlying material in the existing roadway. However, in some circumstances, a small amount of the base may have to be incorporated in the mix to maintain a constant milling depth.
- Recycling operations shall not be performed when the atmospheric temperature is below 50° Fahrenheit or when the weather is foggy or rainy, or when weather conditions are such that proper mixing, spreading, and compacting of the recycled material cannot be accomplished in the judgment of the project manager.
- The pulverized bituminous material shall be transported to a central location where it is stockpiled, further processed and or mixed with the bituminous recycling agent.
- When commencing recycling operations, the bituminous recycling agent shall be applied to the pulverized bituminous material at the initial design rate determined by the material laboratory. The exact application rate of the bituminous recycling agent will be determined and varied by the project engineer as required by existing pavement conditions. An allowable tolerance of plus or minus 0.2 percent of the initial design rate or project engineer directed rate of application shall be maintained at all times unless allowances for further variations have been made in the mix design. The contractor may add water to the pulverized material to facilitate uniform mixing with the bituminous recycling agent. Water may be added prior to or concurrently with the bituminous recycling agent and shall not cause any adverse effect on the additive or the recycled material.
- The recycled / pulverized bituminous material is then stockpiled or hauled to the jobsite and placed according to the plans.
- The number, weight and type of rollers shall be sufficient to obtain the required compaction while the mixture is in a workable condition. The project engineer may require a re-demonstration of rolling capabilities when a change in the recycled material is observed, whenever a change in the rolling equipment is made or if density is not being obtained with the rolling pattern being used.

After the recycled material has been spread and compacted, the area may be opened to traffic. Prior to placing the final surfacing or any secondary compaction, if required, the CIR shall meet the following criteria:

1. The completed CIR shall cure for a minimum of 3 days.
2. The moisture content shall be less than 3.0 percent. If the moisture content does not fall below the maximum limit of 3.0 percent after 10 days and if the roadway has been free of rain for a minimum of 2 days, the Contractor shall be permitted to place the final surfacing or perform the secondary compaction, as required.

20.4.4 Equipment

Cold Central Plant Recycling (CCPR) is the process in which the asphalt recycling takes place at a central location using a stationary cold mix plant. The stationary plant could be a specifically designed plant or a CIR train, minus the milling machine, set up in a stationary configuration. The CCPR mix can be used immediately or it can be stockpiled for later use in applications such as maintenance blade patching or pothole repair.

RAP used in CCPR is obtained by cold planing or by ripping and removing. The material is then transported to a central plant where it is crushed, screened and mixed with a bituminous recycling agent. The recycling agent type, grade and addition rate are determined through evaluation of the RAP and the mix design process. Rollers shall not be started or stopped on uncompacted recycled material. Rolling shall be established so that starting and stopping will be on previously compacted recycled material or on the existing bituminous roadway, if at all possible. Any type of rolling that results in cracking, movement, or other types of pavement distress shall be discontinued until such time as the problem can be resolved. Discontinuation and commencement of rolling operations shall be at the sole discretion of the project engineer.

New aggregates, if required, are also stockpiled at the plant site. The CCPR plant usually consists of cold feed bins for RAP and new aggregate, if used, belt scale, computer controlled recycling agent system, chemical additive system if necessary, and pugmill. For temporary storage or loading of trucks, a hopper may be used, or a conveyor/belt stacker is used if the CCPR mix is being stockpiled.

CCPR mix is hauled to the job site with conventional dump trucks or belly dump trucks if a windrow elevator is used. Placement of the CCPR mix is with conventional HMA pavers. If smoothness is not a factor a motor grader could be used. Compaction is with conventional large sized rubber-tired and vibrating steel drum rollers. The compacted CCPR mix is generally overlaid with HMA, although for some low traffic roadways surface treatments may be used.

20.4.5 Method of Measurement and Payment

Cold Central Plant recycling shall be measured and paid by the square yard. The bituminous recycling agent of the type shown on the plans will be measured and paid by the ton or gallon. Additives shall be measured and paid by the ton.

20.4.6 Advantages of Cold Central Plant Recycling

20.4.6.1 Deteriorated Roadways can be Returned to Original Standards:

- Restores the old pavement to the desired profile, eliminates existing wheel ruts, restores the crown and cross slope, eliminates potholes, irregularities and rough areas.
- Destroys the existing crack pattern. Alligator cracks as well as transverse and longitudinal cracks are eliminated.
- Proper testing to determine the additive best suited to the existing material

along with the proper proportioning will restore the old pavement to its original properties.

20.4.6.2 Cost Effective:

- High production. Equipment can cold recycle up to 3 lane miles per day.
- Thin overlay or a chip seal (for low volume roads) is all that is required for a surface course.
- All existing materials are reused. The only new material required is a small amount of bituminous recycling agent.
- Engineering costs are much lower than for any other type of rehabilitation.

20.4.6.3 Convenience to Traveling Public:

- One lane traffic can be maintained through project at all times.
- Full width roadway is open to traffic at night and on weekends.
- Pollution, including dust, fumes and smoke are at a minimum
- Projects can be completed in a minimal number of working days.

20.4.6.4 Environmental Advantage

- Reuses all bituminous material
- Eliminates hauling and disposal of existing deteriorated surfacing.

20.5 Cold Central Plant Recycling Economics

Cost savings have been realized on cold central plant recycling projects in the range of 20 to 50 percent lower than conventional maintenance, reconstruction, or new construction with mill and fill HMA overlay techniques.

SECTION 21

TECHNICAL DISCIPLINES – Full Depth Reclamation

21.1 Overview

The **Asphalt Recycling and Reclaiming Association (ARRA)** is a non-profit international trade association made up of contractors, equipment manufacturers, suppliers, public officials and engineers. Its members are engaged in the recycling and reclaiming of asphalt and are working to build a stronger and safer network of highways, streets and roads across the country and around the world. ARRA is a forum for the exchange of ideas and solutions to recycling concerns. It will continue to develop new programs, strategies, and funding, not only to improve the technological side of the industry, but to increase the market share for recycled asphalt.

The **ARRA** is able to readily respond to the needs of its members and the public for rebuilding a stronger transportation network. A primary purpose of ARRA is to develop and maintain professional guidelines for the recycling industry. This is accomplished through four active technical committees within ARRA.

Parts of this publication were taken directly from the Basic Asphalt Recycling Manual (BARM). It is the intent of AEMA, through the Recommended Performance Guidelines (RPG) to provide an overview of the technical discipline contained in this Section. A more in-depth and detailed description can be found in the BARM.

21.1.1 Full Depth Reclamation (FDR)

Full Depth Reclamation (FDR) consists of reclaiming asphalt pavement and a portion of the underlying material (base, sub-base and/or sub-grade) layer without the application of heat. FDR is a pavement rehabilitation technique that results in a pavement layer that can be used as a foundation for additional pavement layers. When FDR is combined with a HMA overlay, it can be easily classified as a major structural pavement rehabilitation.

21.1.2 Full Depth Reclamation Overview

Full depth reclamation is a reclamation technique in which the full flexible pavement structure and a predetermined portion of the underlying material are uniformly crushed, pulverized/reclaimed and blended, resulting in a upgraded, homogeneous stabilized base course material. The treatment depths vary depending upon thickness of pavement structure and design but generally range between 4 to 10 inches (100 to 254mm). Further enhancement of the mechanical properties of the stabilized material may be obtained through the use of available bituminous stabilizing agents and additives.

21.1.3 Full Depth Reclamation Application

Full depth reclamation/stabilization is an increasingly attractive method of reclaiming flexible pavement sections. Equipment for this process is generally limited to high horse-powered, self-propelled reclaiming machines. These are used to reclaim the existing asphalt structure and a predetermined depth of the base material. Reclaimers have specially designed pulverizing/mixing drums equipped with replaceable cutting tools. The drum normally rotates in an upward cut or opposite direction to the forward movement of the reclaimer. The size of the material is controlled by the forward speed, drum rotation speed, position of the breaker bar or mixing chamber and exit door opening. Compaction and shaping equipment is also used. The shaping equipment is generally limited to a motor grader while the compaction equipment is typically pad foot, pneumatic tired and steel wheel rollers.

A broad range of bituminous stabilizing agents can be used. Additives may also be incorporated to enhance specific mechanical properties. In some cases, multiple passes are used to incorporate the stabilizer and additives along with providing a finer, more uniform material.

Final compaction and shaping to the required longitudinal profile and cross-slope is followed by a curing period when a bituminous stabilizing agent has been used. The curing period is dependent on the type or combination of bituminous stabilizing agents and additives along with the ambient conditions. Curing periods of 1 to 14 days are typical. The application of a surface treatment or HMA overlay is undertaken as a separate operation at the end of the curing period. Before applying the wearing course, the recycled material shall be allowed to cure such that the free moisture content is reduced to ≤50% of optimum moisture content from mix design or <2.0% total moisture.

Presently, applications include roadways, highways, runways, parking lots and other flexible pavement sections.

21.1.4 Full Depth Recycling Advantages

Full Depth Reclamation (FDR) has a number of advantages including:

- Conservation of non-renewable resources
- Energy conservation compared to other reconstruction methods
- Elimination of all existing surface distresses
- Problems with existing aggregate gradation can be corrected with proper selection of new granular materials
- Deteriorated base can be reshaped to restore surface profile and drainage
- Significant structural improvement with the addition of stabilizing additive(s)

- Produces thick, bound layers that are homogeneous
- Permits more flexibility in the choice(s) of wearing surface type and thickness
- In-place construction and high production rates improve safety by reducing traffic disruptions and user inconvenience
- Eliminates disposal problems inherent with conventional methods
- Economic savings are realized
- Improvement of structural capacity if needed
- Reduces haul costs
- Emergency and local traffic can generally be maintained through the project
- Reduced greenhouse gas emissions

21.1.5 Full Depth Reclamation Economics

Cost savings have been realized on FDR projects in the range of 30 to 50 percent lower than conventional reconstruction techniques.

21.2 Guidelines for Full Depth Reclamation

21.2.1 Introduction

Full depth reclamation is a reclamation technique in which the full flexible pavement section and a predetermined portion of the underlying materials are uniformly crushed, pulverized, or blended, resulting in a stabilized base course; further stabilization may be obtained through the use of available bituminous recycling agents and additives.

Full depth reclamation is a process that offers economic advantages and design alternatives to conventional pavement rehabilitation.

This process revolves around the ability to pulverize and blend the deteriorated pavement structure to the specified maximum size gradation and incorporate that material into the structural design of the restored roadway. Full depth reclamation offers several in-place alternatives to the designer in creating the desired roadway section.

21.2.2 Design

Full depth reclamation does not alter the usual design steps of evaluating existing conditions, determining the cause of pavement failure and deciding the desired project requirements.

In many cases, full depth reclamation will prove to be the most economical solution for providing load-carrying capacity. The cost for preparing the existing surface by various methods such as scarifying, pre-leveling, adding a crushed rock cushion, extra depth pavement overlay, or a fabric application will usually be greater than the cost of pulverizing the existing material. By taking advantage of the capability of introducing liquid additives, additional structural value and cost savings may be realized.

21.2.3 Process

Full depth reclamation consists of three basic steps: pulverizing, introduction of bituminous stabilizing agents and or imported materials; grading and compacting and finally, the application of a wearing surface.

Pulverizing and blending is a mechanical process that physically breaks the pavement material to a usable gradation while incorporating a specified amount of existing base material.

During the mixing phase, materials may be added that will help create the desired base. The percentages of additives are expressed as a percent of the weight of the material being mixed. Most projects will require the addition of water to obtain optimum moisture for proper mixing of material and bituminous stabilizing agents. On some projects the amount of on-site material may not be sufficient to create the desired depth of treated base. In this case imported material to be incorporated into the base can be placed on the existing pavement prior to the mixing pass. After the mixing pass is completed the base material is ready for shaping and compaction. It may be necessary to apply a fog seal to the completed base. The fog seal will help control raveling and ensure a good bond between the base and the wearing course. In some cases, the fog seal may be sanded in order to open the road sooner to traffic.

Full depth reclamation itself can offer many alternatives to the restoration of a particular pavement. All or some combination of the following steps may be found on a full depth reclamation project.

- Cleaning shoulders and ditches
- Pulverizing surface
- Shaping and compacting pulverized material
- Application and mixing of additives such as
    - — imported material
    - — water
    - — bituminous stabilizing agent (i.e. asphalt emulsion)
    - — additives (i.e. cement, lime, calcium chloride, other)
- Shaping and compaction of the treated base material
- Application of a surface course

21.3 Sample Specifications for Full Depth Reclamation

21.3.1 Description

A copy of typical or suggested specifications can be obtained through ARRA or from the BARM.

In general, the specifications can look similar to but should not be limited to the following:

This work shall consist of the preparation of a stabilized base course composed of a mixture of the existing bituminous pavement and existing base course material. The manufacture of the stabilized base course shall be done by in-place pulverizing and blending of the existing pavement and base materials, and the introduction of bituminous stabilizing agents as called for in the Special Conditions. The process which results in a stabilized base course, shall be accomplished in accordance with these specifications and conform to the lines and grades shown on the plans or as established by the engineer.

The remaining base material and/or sub-grade may be modified to properly accommodate the stabilized base material. Any modification of this nature, if required, such as but not limited to the excavation and replacement of unsuitable materials and shaping and fine grading the sub-grade, will be accomplished under separate payment items. Any movement of the stabilized base material for these modifications is also to be accomplished under a separate payment item.

Existing asphalt pavement shall be pulverized by a method that does not damage the material below the plan depth as shown on the appropriate roadway section.

21.3.2 Equipment

In general, the contractor has the option to utilize whatever equipment can effectively pulverize and blend the materials. The equipment to be used must also have the capability of introducing liquid additives uniformly and accurately.

FDR equipment consists of a reclaimer unit, bituminous stabilizing agent unit or units, motor grader, and rollers.

The development of large, high horse-powered, self-propelled reclaiming machines has increased the use of FDR due to increased treatment depths, higher productivity, and more sophisticated metering systems for the controlled addition of bituminous stabilizing agents and additional additives.

Reclaimers have a specially designed pulverizing/mixing drum equipped with placeable tungsten carbide tipped cutting tools.

Specific machine requirements can be found in the BARM.

21.3.3 Application and Mixing of Bituminous Stabilizing Agents

The bituminous stabilizing agent shall be uniformly distributed and mixed with the pulverized material and any existing underlying material or imported material as specified. The mixing operation may be accomplished by using either the same machine used for the pulverizing operation or a separate machine designed for in-place continuous mixing approved by the engineer. Regardless of which method is used, a positive displacement variable speed pump and control system capable of metering the bituminous stabilizing agent shall be used.

The mixing machine shall be equipped with a foot per minute instrument that is integral to the variable speed pump controller ensuring that the bituminous stabilizing agent can be added only when the machine is moving.

The metering system shall include a totalizer, so the amount of the bituminous stabilizing agent used during any given period can be read directly, and a gallon per minute gauge to indicate the instantaneous flow rate during the mixing operation.

The application rate of the bituminous stabilizing agent will be expressed in terms of gallons per square yard. This rate shall be based on the percent by weight of the total mixture as determined by the engineer and shown on the appropriate roadway section.

The mixing operation shall be completed in continuous segments. Each segment must be completed and compacted by the end of each day and opened to traffic.

21.3.4 Construction Requirements

The existing pavement and base material shall be pulverized and blended so the entire mass of material shall be uniformly graded and the new bituminous stabilizing agent, if required, shall be uniformly dispersed throughout the processed material.

After the material has been processed, it shall be shaped, graded, and compacted to the lines, grades, and depth as shown on the plans and cross sections. Water may be applied to ensure optimum moisture content at the time of mixing and compaction. The restored cross section shall be thoroughly compacted to not less than ninety-five percent of the maximum dry density or determined in the field by the Modified Proctor (AASHTO T180).

The completed stabilized base shall be tested for smoothness and accuracy of grade and if any portions are found to lack the required smoothness or accuracy such portions shall be reshaped and recompacted until the required smoothness and accuracy are obtained. The Special Conditions will indicate the depth of existing base material to be incorporated into the recycling process and also the rate of application of any additives specified.

> A typical pulverized gradation would see 98 to 100% passing a 2 inch (50mm) sieve and 95% passing a 1.5 sieve. Material gradation may vary due to local aggregates and conditions.

21.3.5 Method of Measurement and Payment

Full Depth Recycling shall be measured and paid by the square yard. The bituminous recycling agent of the type shown on the plans will be measured and paid by the ton or gallon. Additives shall be measured and paid by the ton.

21.3.6 Advantages and Performance of Full Depth Reclamation

- Cost effective method for creating Improved sections and ride quality.
- Eliminates potential reflective cracking of new overlays
- Recycles existing materials saving natural resources and energy.

• Process is accomplished in-place.
• Heating, mixing and hauling costs of conventional maintenance techniques can be eliminated.
• Roadway cross-section can be maintained or adjusted; grade can be lowered in curbed sections to regain curbs or reshaped in poor draining sections to improve drainage.
• Emergency and local traffic can usually continue to use roadway during construction.
• Eliminate material disposal concerns
• Improved resistance to frost penetration of sub-grade.
• Savings realized by reducing total pavement thickness

SECTION 22

TECHNICAL DISCIPLINES – Hot In-Place Recycling

22.1 Overview

The **Asphalt Recycling and Reclaiming Association (ARRA)** is a non-profit international trade association made up of contractors, equipment manufacturers, suppliers, public officials and engineers. Its members are engaged in the recycling and reclaiming of asphalt and are working to build a stronger and safer network of highways, streets and roads across the country and around the world. ARRA is a forum for the exchange of ideas and solutions to recycling concerns. It will continue to develop new programs, strategies, and funding, not only to improve the technological side of the industry, but to increase the market share for recycled asphalt.

The **ARRA** is able to readily respond to the needs of its members and the public for rebuilding a stronger transportation network. A primary purpose of ARRA is to develop and maintain professional guidelines for the recycling industry. This is accomplished through four active technical committees within ARRA.

Parts of this publication were taken directly from the Basic Asphalt Recycling Manual (BARM). It is the intent of AEMA, through the Recommended Performance Guidelines (RPG) to provide an overview of the technical discipline contained in this Section. A more in-depth and detailed description can be found in the BARM.

22.1.1 Hot In-Place Recycling (HIR)

Hot in-place recycling provides a low-cost maintenance strategy that enables the effective reuse of existing materials. Reclaimed aggregates and asphalt cements are broken down to their original state and reused to produce a new wearing surface.

The process consists of heating and softening the existing asphalt pavement, permitting it to be scarified or hot rotary milled to a specified depth. The scarified or loosened asphalt pavement is thoroughly mixed and subsequently placed and compacted with traditional HMA paving equipment. Virgin aggregates, new asphalt binder or asphalt emulsions, bituminous recycling agents and/or new HMA can be added on an as required basis.

22.1.2 Hot In-Place Recycling Introduction

Hot In-Place Recycling is an on-site, in-place method that rehabilitates deteriorated bituminous pavements and thereby minimizes the use of new materials.

This process may be performed as either a single pass (one phase) operation that monolithically recombines the restored pavement with virgin material, or as a two pass procedure, wherein the restored material is recompacted and the application of the new wearing surface then follows a prescribed interim period that separates the process into two distinct phases.

Hot In-Place Recycling provides a very low cost maintenance strategy that enables the public works official to effectively re-use existing materials. This process demonstrates that asphalt is a rather unique construction material in that it can be effectively and economically restored. Rather than bury the deteriorated pavement with inordinate depths of new material conventionally applied, or lose it to the grinder, proponents of Hot In-Place Recycling encourage restoration.

HIR is a pavement preservation and corrective maintenance technique, and when combined with a HMA overlay can be classified as structural overlay rehabilitation.

Hot In-Place Recycling effectively addresses the classic symptoms of deteriorated pavement:

- Cracks are interrupted and filled.
- Aggregate stripped of the bitumen is remixed and recoated.
- Ruts and holes are filled, shoves and bumps are leveled, drainage and crowns are re-established.
- Flexibility is restored by chemically rejuvenating the aged and brittle pavement.
- Aggregate gradation and asphalt content may be modified by some variations of this process.
- Enhance highway safety through improved skid resistance.

22.1.3 Hot In-Place Recycling Application

With HIR, 100 percent recycling of the existing asphalt pavement is completed on site. Typical treatment depths range from 3/4 to 2.5 inches (20 to 62.5 mm) by utilization of sequential heating, milling and windrowing the heated material. The process consists of heating and softening the existing asphalt pavement, permitting it to be scarified with spring-loaded tines, augers or hot rotary milled to the specified depths. The scarified, augured or loosened HMA pavement is then thoroughly mixed, placed and compacted with conventional HMA paving equipment.

Virgin aggregates, new asphalt binder or asphalt emulsions, bituminous recycling agents and/or new plant-mixed HMA (often HMA RAP mixes) can be integrated into HIR mixes on an as-required basis. The addition of admixtures is governed by the existing material properties and required mixture and pavement layer needs. Addition rates of all of the various bituminous recycling agents and admixtures are determined from an analysis of the existing asphalt pavement properties and subsequent laboratory mix designs, where required, to confirm compliance with required mix specifications.

There are subtle variations in HIR equipment trains and methodologies but they can be categorized into one of three sub-disciplines: Surface Recycling, Remixing and Repaving.

The HIR process uses a number of pieces of equipment that may include all or some of the following:

- Pre-heater units
- Heater units
- Heater-scarification units
- Auguring heads
- Heater-milling units
- Mixing units
- Windrowing equipment
- Pick-up spreaders
- Paving equipment
- Pneumatic rollers
- Steel drum rollers

As the process equipment may be spread out over several hundred feet, the combined equipment is often referred to as an HIR "train."

22.1.4 Hot In-Place Recycling Advantages

Hot in-place advantages include:

- Conservation of non-renewable resources
- Energy conservation compared to other reconstruction methods
- Reduced truck hauling compared with other rehabilitation methods
- Eliminate disposal problems inherent in conventional methods
- Treatment of complete roadway width or only driving lanes
- Surface irregularities and cracks are interrupted
- Improves ride quality
- Minor rutting, potholes, and raveling are eliminated
- Curb reveal height and overhead clearance can be maintained
- Oxidized asphalt binder can be rejuvenated to restore pavement flexibility and prolong and retard crack mitigation from underlying aged asphalt layers

- Problems with in-place aggregate gradation, moisture damage and/or asphalt binder can be corrected with proper selection of virgin aggregates, new asphalt binder or asphalt emulsions and/or bituminous recycling agents
- Friction numbers can be restored or improved Hot or thermal bond between longitudinal joints
- In-place construction reduces traffic disruptions and user inconvenience
- Roadway opened to traffic at end of day with little or no edge drop off
- Economic savings are realized, often up to 20% to 40%

22.1.5 Hot In-Place Recycling Economics

Cost savings have been realized on HIR projects in the range of 20 to 40 percent lower than conventional techniques.

22.2 Guideline for Hot In-Place Recycling

22.2.1 Pre-Bid Considerations

- Many asphalt pavements are appropriate to Hot In-Place Recycling. Pavement characteristics, relative to depth, mix design, and base stability, should be considered in the selection process.
- Preliminary evaluation of the deteriorated pavement should be performed in the company of qualified Recycling specialists to verify that the degree of distress is within the capabilities of this process for effective restoration. The candidate roadway must be a structurally sound pavement with surface distortions only. Localized distortions, failures, or concentration of contaminants may require advance treatment to qualify as a potential candidate. A request issued to interested recycling contractors listing basic data, questions, and expectations will be particularly useful, as a means for securing professional input, to agencies unfamiliar with recycling projects.
- Surface courses containing unusually large aggregate, (i.e., one inch, may not be suitable for Hot In-Place Recycling).
- Rejuvenation of the aged asphalt is necessary for complete recycling. However, the awarding authority should have representative cores analyzed to determine.

  a. the penetration or viscosity of the asphalt binder,

  b. the effect on the penetration or viscosity of the asphalt binder by adding varying quantities of bituminous recycling agent,

  c. the volume of residual bitumen to reveal the practical limits for additional binding agents.

  The results of these tests should be used to select the type and quantity of bituminous recycling agent or modified new hot mix to be added to the existing material to meet the specific pavement requirements of the owner.
- Mix design, and depth (volume) of virgin materials to be incorporated in or applied to the restored pavement remain the responsibility of the awarding authority. Specifications for final wearing course mix design can be

achieved by using either the “remix” method which provides a thorough recombination of the restored existing mixture with specified virgin materials, or the single pass “repave” method, wherein the virgin materials as specified are placed on top of the restored pavement. Also, the “delay”, method similarly provides for the application of specified virgin materials upon the restored pavement but, after a delay or interim period which separates the recycling and paving phases. Regional climatic conditions, raw material, availability, load bearing consideration, and service requirements shall be, as in conventional resurfacing, the basis for these considerations. Hot In-Place Recycling restores the structural integrity of the recycled pavement to the equivalent of new pavement of similar mix design and its contribution should therefore be considered in the total pavements estimated structural capacity. Depth or volume of virgin materials specified will be affected accordingly.

22.2.2 Hot In-Place Recycling Methods

22.2.2.1 Hot In-Place Recycling Methods – Surface Recycling

Surface Recycling is the HIR process in which softening of the asphalt pavement surface is achieved with heat from a series of pre-heating and heating units. The heated and softened surface layer is then scarified to the desired treatment depth with either a series of spring activated teeth or “tines,” or a small diameter rotary milling head. Once the surface has been scarified, the addition of a bituminous recycling agent (if required) takes place; the loose recycled mix is thoroughly mixed and then placed with a standard paver screed.

Specified treatment depths generally range from 3/4 to 2-1/2 inches (20 to 62.5 mm). No new plant-mixed HMA or virgin aggregates are added during the Surface Recycling process and the overall pavement thickness remains essentially the same. Surface Recycling is often used in preparation for a subsequent HMA overlay.

Compaction of an HIR Surface Recycled mix is performed with conventional rubber-tired, static steel, and/or vibrating steel drum rollers. A chip seal, slurry seal, micro surfacing or HMA overlay is generally placed in a subsequent operation for most functional classes, although the HIR Surface Recycled mix has been left as the surface course on some low volume roads.

22.2.2.2 Hot In-Place Recycling Methods – Remixing

HIR Remixing is the HIR technique where the existing asphalt pavement is heated, softened, scarified and remixed typically with bituminous recycling agents, in a train of equipment. New HMA mixture, virgin aggregates, and/or asphalt binders or asphalt emulsions, i.e. admixtures, may be added as required for pavement mixture needs and/or grade control. The result is a thoroughly mixed, homogeneous layer. The recycled mix is often left as the wearing surface but it could be overlaid with HMA or other surface treatments such as chip seal, slurry or micro surfacing, as a separate operation, depending on the pavement needs.

HIR Remixing is further classified into single and multiple-stage methods. In the single-stage method, the existing asphalt pavement is sequentially heated and softened, scarified, augured or milled to the desired depth and mixed. Treatment depths for single-stage HIR Remixing are generally between 1 to 2 inches (25 and 50 mm).

In the multiple-stage HIR Remixing method, the existing asphalt pavement is heated, softened, and scarified in a number of thin layers prior to mixing until the full specified treatment depth is reached. Usually between two and four layers are sequentially heated and scarified and placed in windrows to permit heating and scarification of the next underlying layer, with all materials eventually combined into one homogeneous mixture. The specified treatment depth for multiple-stage HIR Remixing is generally between 1.5 to 3 inches (40 to 75 mm).

The multiple-stage method will permit slightly more admixture than the single stage method but both are restricted to about 30 percent new materials. Hence, the HIR Remixing process will only marginally increase the overall pavement thickness unless a subsequent HMA mixture is placed.

In all equipment setups, the measured amount of bituminous recycling agent, admix or virgin HMA is added prior to the mixing phase. The exact location in which the various materials are added may vary, but it is always at or prior to the mixing chamber. Addition of the bituminous recycling agent is most often applied as early as possible in the process in order to maximize the dispersion time with the aged asphalt binder.

Bituminous recycling agent application rates of from 0 to 0.5 gallons per square yard (0 to 2 liters per square meter) can be easily added. The admix application rate is limited to a maximum of about 30 percent by weight of recycled mix or 110 pounds per square yard (55 kilograms per square meter).

Compaction of an HIR Remix application is performed with conventional rubber-tired, static steel, and/or vibrating steel drum rollers.

22.2.2.3 Hot In-Place Recycling Methods – Repaving

HIR Repaving combines the Surface Recycling or Remixing process with the placement of an integral HMA overlay. The Surface Recycled or Remixed layer and the HMA overlay are then compacted. The thickness of the HMA overlay can be less than a conventional thin lift overlay since there is a thermal bond between the two layers and they are compacted simultaneously.

In the HIR Repaving process, the recycled mix functions as a base or leveling course while the HMA is the surface or final wearing course. The new HMA wearing course can be as thin as 1/2 inch (12.5 mm), if the appropriate mix is used, or as thick as 3 inches (75 mm). Hence, the overall pavement thickness can be increased a significant amount in the HIR Repaving process. However, since the overlay can be a very thin layer of specialized mix or a HMA they can be placed more economically. Specialty mixes such as Open Grade Friction Courses, polymer modified mixes, etc, can be used.

HIR Repaving is further classified into multiple and single-pass methods. In the multiple-pass method, the surface recycled mix is placed to the proper longitudinal profile and cross-slope by its own placing and screening unit. The new HMA overlay material is then immediately placed on the hot, uncompacted recycled mix with a conventional asphalt paver. The two layers are then compacted simultaneously with conventional compaction equipment. With single-pass HIR Repaving, a single heater paver unit equipped with two screeds is used. This single unit also scarifies the heated, softened pavement, adds the required amount of bituminous recycling agent, mixes the recycled mix prior to the first screed, receives the new HMA, and transports it over the underlying recycled mix. The first screed places the recycled HIR mix while the second screed places the new HMA on top of the recycled mix. Further, the use of tack coat is eliminated due to the thermal bond between the layers. The two layers are then compacted simultaneously with conventional compaction equipment.

22.3 Guideline Bid Specifications for Hot In-Place Recycling

A copy of typical or suggested specifications can be obtained through ARRA or from the BARM.

In general, the specifications can look similar to but should not be limited to the following:

22.3.1 Prequalification Clause

Prospective bidders are hereby informed that prior to construction a complete description of the type of equipment to be used shall be supplied to the engineer. Also, a list of comparable projects, if any, performed using this equipment and the techniques specified shall be provided. The engineer reserves the right to reject equipment he feels is unsuitable. The cost of this demonstration shall be borne by the supplier.

22.3.2 Scope

Hot In-Place Recycling consists of furnishing all labor, equipment and materials, and performing all operations with equipment specifically designed to heat and soften the existing asphalt concrete pavement to allow scarifying, or hot rotary mixing, to the depth specified without tensile fracturing the aggregate. The heated scarified material is then thoroughly remixed, redistributed, and leveled either in combination with, or in preparation for bituminous recycling agents and virgin materials applied as specified. All work under this item shall be in conformity with typical sections shown on the plans and to the lines and grades established by the engineer.

22.3.3 Cleaning and Preparation

Prior to commencing hot in-place recycling operations, the pavement shall be cleaned of all loose material. Power brooms shall be supplemented when necessary by hand brooming and such other tools as required to bring the surface to a clean, suitable condition, free of all deleterious material. Localized patching, remedial conditioning, or structure adjustments should be completed prior to beginning this process.

22.3.4 Equipment and Construction Details

1. Single Pass Method

The equipment for this type shall be self-contained, self-propelled, automated units capable of heating, viscously scarifying and/or hot rotary mixing and redistribution with automatic screed control for longitudinal leveling of either a homogeneous mixture of existing and virgin materials to the specified depth and design (REMIXING), or a similar rehabilitation of the existing asphalt pavement upon which a totally new mix is monolithically applied in accordance with accepted bituminous paving procedures (REPAVING).

a. Method A: REMIX. The reclaimed material shall be automatically fed into a mixing unit. When required, new hot bituminous pavement material and, when required, a bituminous recycling agent or other liquid additive material shall be added to the reclaimed material at the mixer. The type and quantity of the new hot bituminous pavement material and the proportion of new material and reclaimed material shall be specified in the job mix formula. All materials shall then be thoroughly mixed while maintaining the minimum temperature. After mixing, the combined bituminous material shall be automatically fed into a finishing unit which will spread and level the mixture to the required thickness in conformance with specified cross-section, at a minimum temperature of 240° F.

b. Method B: REPAVE. After the addition of the bituminous recycling agent, the reclaimed material shall be gathered by a leveling device equipped with augers for mixing and spread to a uniform depth over the width being processed. After it is placed, and while it still has a residual minimum temperature of 225° F, a layer of new hot bituminous pavement material conforming to the job mix formula shall be placed over it. The application rate of the new material shall be sufficient to provide the required pavement thickness, as shown on the plans.

2. Multiple Pass Method

The equipment for this type shall be a self-contained, self-propelled automated unit capable of heating, viscously scarifying and/or hot rotary mixing, redistributing, and screeding with a controlled leveling at crown and both extremities to insure a cross-section that conforms to the pavement profile specified. Recompaction of the restored material at a minimum temperature of 240° F follows immediately. The application of the final wearing surface follows after a prescribed interval or delay. These materials are applied with conventional equipment in conformance with standard construction techniques.

3. General (Common to all methods)

a. Heating: The equipment used to heat the existing asphalt surface shall fully meet the standards of the state and local Air Pollution Control Authority. The combustion chamber shall be insulated and totally enclosed. Sufficient heat shall be generated to soften the pavement to the depth required to achieve specified performance.

b. Scarifying: The scarifiers or rotary mixers shall be able to both thoroughly remix and recoat aggregate stripped of its bitumen coating and penetrate the pavement surface so as to cut to the specified depth, without tensile fracturing the pavement, to provide a surface conforming to the desired finished profile of the pavement.

c. Bituminous Recycling Agent Applicator: The liquid spray equipment shall be capable of applying the bituminous recycling agent in a uniform manner across the full width of the processed material and shall incorporate a meter for continuous verification of quantities. The volume applied shall vary in direct proportion to the operating speed of the recycler and shall be synchronized with the volume of material mixed or scarified to maintain a tolerance within 5% of the specified rate.

d. Compaction Equipment: Immediate compaction shall take place with rolling equipment of sufficient type and size to compact either virgin materials or the combined bituminous materials to the required density. State specifications for bituminous concrete surfaces shall apply. Rubber tire compaction equipment is, however, recommended for initial consolidation due to the minimum depth of the recycled or overlay materials.

22.3.5 Method of Measurement and Payment

Heating, scarifying, leveling and compacting of the pavement shall be paid for at the contract unit price per square yard. Such price shall constitute full compensation for the item as herein described and specified. Bituminous Recycling agent will be paid for at the contract unit price per gallon by certified weight. The certified weight shall be determined by weighing on sealed scales regularly inspected by the State Bureau of Weights and Measures. The unit price shall include full compensation for furnishing and applying the bituminous recycling agent. New hot mix asphalt concrete pavement material shall be measured and paid for by the ton.

SECTION 23

ASPHALT EMULSION EQUIPMENT: PUMPS

23.1 Introduction

The purpose of this guide is to assist the asphalt emulsion end user in pumping the asphalt emulsion. The brochure covers the pros and cons of positive displacement and centrifugal pumps, the need for specific pump features, proper pump installation, and suggested pump sizing. Proper cleaning, maintenance and off-season storage procedures are given. Finally, a troubleshooting guide is included.

23.2 Pumps

The most common type pumps used for asphalt emulsions are positive displacement and centrifugal pumps. The following is general information on these two types of pumps.

23.2.1 Positive Displacement Pumps

23.2.1.1 Mechanical Operations of the Pump

The rotating member(s) inside the pump creates a vacuum at the suction port. Liquid is drawn into the port and carried between the rotating member and the pump housing since there is close tolerance between the two. As the liquid reaches the outlet port it is forced outward as the pumping chamber is squeezed down by some means. For each revolution of the pump, a fixed amount of liquid is displaced. The liquid must flow somewhere since there is little slippage and thus the name positive displacement.

23.2.1.2 Pump Features

The following are special suggested pump features:

1. Relief Valve - In case of downstream blockage, this valve opens dumping liquid back to the suction side of the pump or back to tank, depending on the type relief valve used. Most valves are adjustable so relief pressure can be regulated.
2. Jacketing - These pumps require some type of heat and can be ordered with various jacket arrangements for the circulation of hot oil, water or low-pressure steam.

3. Extra Clearance - Due to the nature of asphalt emulsion, most pump manufacturers suggest special clearances between certain pump members. This varies for different pump manufacturers. Be sure to emphasize the material to be pumped is asphalt emulsion, not asphalt cement or asphalt cutback.
4. Special Materials - Since asphalt emulsion pumps can be exposed to shock loads during startup or while running, it is suggested that a steel alloy fitted pump be considered rather than a standard fitted one. However, many pumps are in operation whose working members are made of ductile iron or high-grade carbon steel.
5. Packing Seal - Normally specified for any type of asphalt usage because of its lower cost and because mechanical seals damage easily due to asphalt glued faces.

23.2.2 Centrifugal Pump

23.2.2.1 Mechanical Operations of the Pump

Material is fed into the center of the pump by gravity and a high-speed impeller slings the material to the outside of the pump casing and through the outlet.

23.2.2.2 Pump Features

Normally, no special pump features are required with a centrifugal pump.

23.2.3 Pros and Cons Between the Two Types of Pumps

23.2.3.1 Positive Displacement

1. Will create a suction lift.
2. Is reversible.
3. Will pump to a higher discharge head.
4. Meters

23.2.3.2 Centrifugal

1. Is less expensive since the initial pump cost is less and a direct non-reducing drive can be used.
2. Requires heat only with high viscosity materials, or cold weather.
3. Less efficient with higher viscosity emulsions.
4. Takes more power.
5. Not all are self-priming.
6. Max. speed should be 1750 RPM or less.

23.3 Sizing the Pump and Motor

In specifying the size pump required, considerations should be given to the primary use of the pump. By contacting your local pump vendor, they will be able to help size the appropriately-fitted pump for your application.

Items to consider and to have on hand should include the desired pumping capacity, a viscosity/temperature curve for the material, specific gravity, and expected temperature range for the material being pumped. This will allow the vendor to accurately choose the pump that most economically meets your demands. Be sure to specify to your vendor that the pump is for asphalt emulsion service. Most manufacturers will machine additional tolerances into their equipment to compensate for large temperature differences. It is also recommended to specify heavy duty versions on the vendor's pump styles. Pumps used in asphalt emulsion plants see severe duty.

Over-sizing pumps should be given careful consideration. This practice may be beneficial for long-term flexibility, but may unnecessarily raise the initial cost of the project. Additional costs will come from installing larger piping, increased motor size, motor starter costs, etc. Ultimately, each organization needs to decide what is right for them at the time of purchase.

Electrical wiring should comply with local standards.

If the pump or equipment is used at a 25% or greater duty cycle, they should specify a "Premium" efficiency style motor. This will save them money in the long run.

23.4 Installing the Pump-Motor-Tank Systems

23.4.1 Pump-Motor Foundation

A solid foundation to help absorb any abnormal loads is important. It is suggested the pump and motor be mounted together on a separate integral base before being plumbed into the system. Do not attach pump mounted base to the floor since expansion and contraction caused by hot and cold cycles cause plumbing to draw and the base to move.

23.4.2 Direct versus Indirect Drive

Most pumps are driven by an indirect drive by V-belts. This is a more economical installation, as opposed to a gear box, and, in case the pump stops, the belts will usually break, preventing a more costly breakage; and the indirect drive gives more flexibility in pump mounting. The major disadvantage of the indirect drive is size since reducing the pump speed often requires a large pulley. Centrifugal pumps are nearly always driven by a direct drive since they turn at a much faster speed. Always provide suitable belt or coupling guards for protection.

23.4.3 Proper Pump Installation

Motor Alignment-Some pumps require the use of an outboard bearing near the shaft end. Exact centering of the shaft in relation to the pump housing is of extreme importance. It may be necessary to use shim material to insure correct centering. In the case of the indirect drive, drive pulleys of the pump and motor must be aligned properly. For the direct drive, the same proper alignment applies to coupling halves. The following examples are given for proper alignment. Always turn the pump over by hand after mounting and plumbing to make sure there are no tight spots. Some pump manufacturers recommend removing the head of the pump and checking between internal members and the pump casing for proper clearances with a feeler gauge. Failure to properly align the pump and its motor will result in increased wear and maintenance for the unit.

23.4.4 Pump Location

Always locate the pump as close to the source of the liquid to be pumped as possible. Remember a pump can push material easier than it can suck it. Also, locate the pump so it is accessible for maintenance and repair. Being able to remove the pump's internal members without removing the pump from the base is often very handy. If at all possible be sure a positive suction head exists, that is, the liquid level of the tank is always above the suction port of the pump.

23.4.5 Pump Heating

Can be accomplished by hot water, oil or low-pressure steam if the pump is jacketed, or by electrical trace lines. Insulation around the pump helps hold the heat. Means should be provided to regulate the amount of heat to the pump. If electrical trace lines are used, fill the pump jacket(s) 80 to 90% full of heating oil.

23.4.6 Strainer

Most pump manufacturers will normally specify a basket strainer. They are, in fact, rarely used in the field because a strainer fine enough to protect the pump needs a very large surface area and is very expensive. They also require isolation valves for cleaning.

23.4.7 System Plumbing

General comments:

- Plan the system to provide maximum flexibility and utilization.
- Plan for future expansion.
- Be sure suction piping is at least the same size as the suction port of the pump or larger for long suction lines and more viscous materials.
- Keep suction piping as short as possible.
- Use of a swedge or bell reducer one size larger than the suction line is recommended at the tank outlet, Also, the use of an elbow inside the tank will permit sucking near the bottom of the tank and still leave scum buildup inside.
- Always put a length of return or recirculate line inside tank to permit better tank circulation which may be required.
- Design piping systems to allow for the transfer of materials from one tank to another. This system may also be used to mix or re-circulate the product.

— **Note:** This should only be done on a limited basis. A continued need for mixing should be addressed by the use of a side entry mixer.

- Never use the same pump for anionic and cationic asphalt emulsions, unless thoroughly cleaned and flushed.
- Always turn the pump by hand after final installation to make sure the plumbing has not caused any bind.

- Minimize all tees, elbows, and other restrictions in the suction line. Use of full port valving is recommended.
- Provide plumbing to accommodate a vacuum or pressure gauge in the suction and discharge lines.
- Use of direct flame heat on any part of the plumbing or pump should be done with extreme caution.
- If a positive displacement pump is used, it is suggested to take advantage of its reversing ability to clean lines at end of loading. When installing positive displacement pumps, you should also install some type of pressure release system.
- Use of unions, flanges, and spools will permit rapid removal of components for maintenance.

23.5 Pump Maintenance

23.5.1 Lubrication

Grease all points of the pump and the outboard bearing per manufacturer's recommendation.

The electric motor also needs to be lubricated according to the manufacturer’s recommendations.

23.5.2 Packing Adjustment

For a new pump make sure the packing gland is loose (by hand). Do not tighten gland until pump has run and the packing has expanded from absorption of the pumped liquids. With pump stopped, adjust gland evenly just enough to reduce leakage to a drip every few seconds. Packing is designed or intended to leak. This process allows the shaft to be lubricated. NEVER tighten packing too tight. It will cut a groove in the pump shaft causing a leak which will be very difficult to repair. All appropriate safety measures should be taken when adjusting the packing gland.

23.5.3 Replacing Packing

The packing gland can be slid up the shaft and a new ring of packing added as required. If the total packing is replaced, the new rings should slide over a well lubricated shaft, with the connected ends of the ring staggered in relation to the one next to it. Always turn pump by hand after installing packing to make sure it turns freely.

23.5.4 Ground Packing Material

Material is poured into the pump stuffing box in place of packing rings. Adjust carefully with packing gland to form a light but flexible seal.

23.6 Cleaning and Winter Storage

23.6.1 Cleaning

If the pump is properly installed, has suitable means for heating, and the asphalt emulsions being pumped are in specification, little or no cleaning during the work season is normally required. Vent the line and remove as much asphalt emulsion from the line and pump into the tank as possible. Fill the pump with approved product and close the necessary valve downstream to cause the pump relief valve to open. This will cause the product to circulate within the pump, causing it to warm up and provide good cleaning.

NOTE:

Be careful not to allow the product to be mixed with the asphalt emulsion since even a little may affect product quality. Proper disposal should also be addressed.

23.6.2 Winter Storage

Always drain the tank, lines, and pump during the winter since asphalt emulsion will freeze.

Leave approved product in the pump over the winter to prevent rust. If the asphalt emulsion is to be used in the winter, always drain the lines and pump after each use and provide heat for the tank.

23.7 Troubleshooting

The following are offered as helpful guides to solving a pump problem.

23.7.1 Pump Does Not Pump

1. Suction and discharge valves closed.
2. Relief valve set too low or stuck open.
3. Lost its prime; air leak or low tank level.
4. Lines plugged.
5. Belts may be loose.
6. Bent or broken internal pump member.

23.7.2 Pump Is Noisy

1. Pump is starved because possibly viscous liquid is not getting to the pump fast enough. Heat liquid to a maximum of 85° C (185° F) to reduce viscosity, increase suction pipe size or reduce suction length.
2. Check alignment.
3. Bent or broken internal pump member.
4. Relief valve chatter, increase pressure setting.
5. Securely anchor to base to reduce vibration.
6. Foreign object trying to enter pump or inside pump.
7. Suction line partially plugged.

23.7.3 Pump Delivery is Low

1. Starving: Pump is starved because possibly viscous liquid is not getting to the pump fast enough. Heat liquid to a maximum of 85° C (185° F) to reduce viscosity, increase suction pipe size or reduce suction length. As done in 23.7.2 Pump Is Noisy.

2. Air leak in suction side or through packing.
3. Relief valve set to loose or stuck partially open.
4. Running too slow, motor wired incorrectly.
5. Partial suction line blockage.
6. Pump worn out.

23.7.4 Pump Takes TOO Much power

1. Running too fast.
2. Viscous material-heat material to reduce viscosity.
3. Discharge pressure too high; lessen pressure relief setting, reduce length of pipe, or increase pipe size.
4.Packing gland drawn too tight.

23.7.5 Use of Vacuum Gauge in Suction Port

23.7.5.1 High Reading

1. Suction line blocked, valve closed.
2. Liquid too viscous to flow through plumbing.
3. Lift too high.
4. Line too small or too long.

23.7.5.2 Low Reading

1. Air leak in suction line.
2. End of pipe not in liquid.
3. Pump is worn.
4. Pump is dry; prime pump.

23.7.5.3 Erratic Reading

1. Liquid coming to pump in slugs; air leak.
2. Vibrating from cavitation, misalignment, damaged parts or foreign object in pump,

23.7.6 Use of Pressure Gauge in Discharge Port

23.7.6.1 High Reading

1. High viscosity and/or small and/or long discharge line.
2. Valve partially closed.
3. Line partially plugged.
4. Relief valve set too high.

23.7.6.2 Low Reading

1. Relief valve set too low.
2. Pump warm.

23.7.6.3 Erratic Reading

1. Cavitation.

2. Liquid coming to pump in slugs.
3. Air leak in suction hose.
4. Vibration.

SECTION 24

ASPHALT EMULSION EQUIPMENT: TANKS & HEAT SYSTEMS

24.1 Introduction

The purpose of this brochure is to provide the asphalt emulsion end user with helpful information on asphalt emulsion storage tanks, heating systems, and tankers. Only general information is provided, therefore the asphalt emulsion user should contact their local AEMA emulsion supplier. For all installations, contact the appropriate local authorities and be guided by their recommendations and requirements.

24.2 Storage Tanks

The following information will aid the asphalt emulsion end user in selecting the proper storage tank.

24.2.1 Tank Foundations

Asphalt emulsions usually weigh 1 kg/L (8.3 to 8.4 Ib/gal). The tank foundation should be designed for the weight of the maximum volume to be stored plus the weight of the tank shell. Vertical tanks are best set on a concrete foundation while horizontal tanks require a saddle for each end and one in the middle, or as required by local building codes.

24.2.2 Tank Design

Asphalt emulsion storage tanks can be either vertical or horizontal.

24.2.2.1 Vertical Tanks

These type tanks are normally preferred over horizontal tanks because less of the Asphalt emulsion is exposed to the atmosphere which causes a scum to form on top of it. Other advantages of vertical tanks are they occupy less land area, are easier to heat, easier to insulate if required and their asphalt emulsion level can be measured more easily.

24.2.2.2 Horizontal Tanks

These tanks offer the advantage of being less susceptible to high tension power lines because of their low profile, easier to recirculate completely and easier to drain completely since they are usually set on a slight slope.

24.2.2.3 Tank Features

AII vertical tanks should have manholes for clean out located approximately 0.6 m (2 F) from their bottom. There should be a safety ladder on the outside and a manhole on top of the tank. Governing safety standards should be used at all times. Any tank should be properly vented and provided with a suitable electrical ground. Some type of liquid level and measurement indicator can be installed if needed. Used tanks are acceptable, provided they are thoroughly cleaned, usually with steam, and the necessary tank features installed.

NOTE:

Be extremely careful when cutting on used tanks especially if they have previously contained some type of petroleum product. Only certified personnel using accepted industry safety standards should modify these types of tanks.

24.2.2.4 Tank Plumbing

Proper plumbing of a tank is very important. Provide a 19 to 25 mm (3/4 to 1 in.) sample line for each tank. The line should be located approximately 0.6 m (2 ft) above the tank bottom with the line extending 0.6 m (2 ft) inside the tank.

Fittings should also be supplied for the installation of a tank thermometer or RTD. Usually 3/4".

Always provide a full-size suction line, that is, the same size as the transfer pump inlet or larger. Keep the suction line as short as possible and with as few bends as practical. Inside the tank, install an elbow at the suction inlet keeping the bottom of the elbow approximately 50 mm (2 in.) off the tank bottom.

Always provide a tank return or re-circulate line. This line should be the same size or no less than one size smaller than the suction line. Inside the vertical tank, turn the return line to the wall of the tank and away from the suction line. Allow the pipe to extend several feet inside the tank. Inside horizontal tanks, allow the return line to extend halfway into the tank. This permits better recirculation in both type tanks. It is best to always place the return line near the bottom of the tank. If the return line must enter higher in the tank bring the line inside the tank and back to the tank bottom. Never allow the asphalt emulsion to drop through the air, always return it to a submerged outlet or one very near the tank bottom.

Arrange tank plumbing so the transfer pump can draw from more than one tank. Be sure the plumbing is arranged to permit the transfer pump to unload the supply tanker, recirculate the storage tank and load the user equipment. The asphalt emulsion can be loaded either through the top or bottom of a tanker. However, if loading through the top the loading hose or pipe should be lowered near the bottom of the tank.

24.2.2.5 Location

Tanks can be located as desired as long as they are approved by local authorities. Tanks should not be located near high tension electric power lines because of the electrical charge around the wires could affect the electrical charge on the asphalt emulsion particles causing instability or even cause an arc between the tank and the wires. Protection from spillage must be provided as required by local codes. Some standards call for a berm around the storage area that provides a volume from 1.10 to 1.25 times the volume of the largest tank.

Provision should be made for small spills that can occur at the loading site. A suitable drain or other method should be used to prevent tracking asphalt outside the loading area.

24.3 Heating Systems

Some grades of asphalt emulsion require heating during storage and use. Table III-1 from AEMA's *A Basic Asphalt Emulsion Manual* may be helpful. The end user should check with the local AEMA emulsion supplier for their suggestions on storage temperatures.

24.3.1 Heaters

Several types of heaters may be used for asphalt emulsion. The main requirement is that the heater be regulated to provide the desired temperatures and that it use indirect heat instead of direct heat, such as an open flame.

24.3.1.1 Hot Oil Heaters

These self-contained heaters heat a special heat transfer fluid using gas or diesel burners or electricity. The heater pump circulates the hot oil through the system and asphalt emulsion tank coils (described later). The hot oil temperature must be kept 85° C (185°F) or below as required. Thermostatic controls can be used to set tank temperatures as required.

If the hot oil is used to heat other materials, (e.g., asphalt cement), that require higher temperatures, modifications must be made to the system. The hotter oil can first heat a tank of water and then the water can be circulated through the storage tanks or a special system can use a second recirculating pump and a thermostatically controlled mixing valve to keep the temperature of the oil for the asphalt emulsion at the desired level.

24.3.1.2 Steam

Low pressure steam can be circulated through coils similar to the hot oil. This probably is the desired system where steam is already available. A method for moving the asphalt emulsion over the surface of the steam coils should be considered. A side entry tank mixer is preferred, but re-circulation by a pump may also be used. Note: Avoid over-pumping/shearing of asphalt emulsions.

24.3.1.3 Water

Water can be heated by hot oil, steam or electricity, and circulated through tanks in the same manner as hot oil and steam. This is a safe method since water seldom gets hot enough to damage the asphalt emulsion.

24.3.1.4 Solar

In recent years solar heaters have been used to heat hot oil or water which in turn heats the asphalt emulsion tanks.

24.3.1.5 Electrical

Electrical heaters are available to heat the asphalt emulsion. These heaters offer the advantage of eliminating tank coils and related plumbing required for hot oil, steam or water.

Each tank heater is separately controlled, thus making it simple to set tank temperatures at different levels or individually cut off the heat to any tank. Again, some method for moving the asphalt emulsion over the heating surface should be considered. This will prevent the asphalt emulsion from localized over-heating and contribute to more even product temperatures.

24.3.2 Coils

Heating coils are placed in tanks as previously noted for circulation of hot oil, steam or water. Either thick wall or standard pipe or tubing is used. Finned tubing is not recommended for asphalt emulsion tank service. As an asphalt emulsion tank drains, the asphalt emulsion gathers in the voids between the fins. As soon as the tank is empty, the asphalt emulsion will begin to break and coat the fins. Over time, the fins will become plugged and will not transfer heat very well. The only choice is to clean the coils by hand (difficult and time consuming) or use a solvent. This raises issues of cost, waste disposal, and product quality. The hot oil system uses black pipe or tubing.

The amount of coil required for each tank depends on size of tank, amount of tank insulation, wind velocity, lowest expected ambient air temperature, amount and type of insulation, type of asphalt emulsion, and how rapidly the asphalt emulsion temperature must be increased, if at all. Consult a heating specialist for information on this.

24.3.3 Other

Asphalt emulsion lines and transfer pumps must be heated, especially if asphalt emulsion is used during winter. This insures uniform asphalt emulsion temperature and trouble-free pump starting. Lines and pumps must be heat jacketed or traced and then insulated.

24.4 Tankers

Asphalt emulsion tankers can be any suitable mobile tank such as a specially designed tanker for asphalt emulsion, an asphalt distributor or even a water tank. Any tanker should have a correct bottom fitting, usually 75 mm (3 in.), and a suitable top manhole to receive asphalt emulsion from the supplier. The manhole can also be used for cleaning, inspection, etc. The tanker should have suitable baffles to prevent undue sloshing. It should be properly vented, have a thermometer and sample line. The tanker should be properly cleaned to prevent contamination of the product being loaded. If possible, use dedicated tankers that haul asphalt emulsion only. Table 3-2 Guide for Condition of Emptied Tanks Before Loading Asphalt Emulsions in AEMA's **A Basic Asphalt Emulsion Manual** lists suggested cleaning practices. This chart also is valid for storage tanks. Consult your local AEMA emulsion supplier for more specific local practices.

SECTION 25

ASPHALT EMULSION DEFINITIONS

Anionic (Anion) — A negatively charged ion in a solution; that portion of a compound which when dissolved (usually in water) tends to move toward the anode under the influence of a direct current.

Arc — The luminous bridge formed by the passage of a current across a gap between two conductors or terminals.

Asphalt — “A dark brown to black cementitious material in which the predominating constituents are bituminous which occur in nature or are obtained in petroleum processing” (ASTM D8). Asphalt is a constituent in varying proportions of most crude petroleum.

Asphalt Emulsion — An emulsion of asphalt cement and water which contains a small amount of a surface-active agent (emulsifier). Emulsified droplets of asphalt may be of either the anionic (negative charge) or cationic (positive charge) type, depending on the surfactant used.

Asphalt Emulsion Distributor — An asphalt distributor, either truck or trailer mounted, which may consist of an insulated tank, self-contained heating system, pump, and a spray bar with nozzles through which asphalt emulsion is metered and applied under pressure onto the prepared aggregate materials or bituminous surfaces.

Asphalt Emulsion Prime — An application of low viscosity asphalt emulsion to an absorbent surface or granular base, in preparation for an asphalt surface course.

Asphaltene — The high molecular weight hydrocarbon fraction precipitated from asphalt by a designated paraffinic naphtha solvent at a specified solvent to asphalt ratio.

Asphalt Rubber — Blend of asphalt and pre-vulcanized rubber.

Base — A layer of granular material placed on the sub-base, an old bituminous or non-bituminous pavement. It may be composed of suitably graded crushed stone, gravel, slag and sand, or combinations of these materials. These materials may be mixed or treated with asphalt emulsion for added stability.

Bell/Swedge Reducer — A pipe fitting that allows the connection of pipes of different diameters. The Bell reducer has the center points of the diameters concentric; the Swedge reducer is offset so the outside surfaces of the pipes are congruous.

Belt or Coupling Guard — A protective or safety device that surrounds the moving mechanical coupling parts between motors and pumps preventing accidental contact.

Binder Course — A transitional layer between the base course and the surface course (sometimes called intermediate course).

Bituminous Recycling Agent — Special asphalt derived products such as cationic, anionic, and polymer modified asphalt emulsions that have been developed especially for recycling processes. These emulsions may have rejuvenators and recycling agents that have been added to gain specific properties for a recycling process. These products are commonly referred to as Bituminous Recycling Agents.

Block Copolymer — A copolymer whose structure is composed of alternating sections of one monomer separated by sections of a different monomer or a coupling group of low molecular weight.

Breakdown Rolling — The initial compaction of a mixture which usually begins as the asphalt emulsion starts to break as shown by a change in color of the mix.

Breaking — The phenomenon when the asphalt and water in the asphalt emulsion separate, beginning the curing process. The rate of breaking is controlled primarily by the emulsifying agent.

Cape Seal — A multiple surface treatment which consists of the application of a chip seal followed by the application of either slurry seal or micro surfacing.

Cationic (Cation) — A positively charged ion in a solution; that portion of a compound which when dissolved (usually in water) tends to move toward the cathode under the influence of a direct current.

Cavitation — The formation of partial vacuums in a liquid by a swift moving body (as a propeller or asphalt emulsion mill rotor).

Chip Seal — See Single Chip Seal, Multiple Chip Seal and Surface Treatment.

Choke (Blotter) Aggregate — A light application of sand, screenings, or open-graded aggregate (usually smaller in size than the aggregate in the mixture being treated) applied to a compacted asphalt emulsion aggregate surface that prevents pickup of the mix by traffic and interlocks aggregate.

Clay — A natural earthy material, plastic when wet, resulting from the decomposition of certain minerals; fine sized mineral particles, smaller than 0.005 mm. Clay materials are usually characterized by their water sensitivity as measured by Plasticity Index. (AASHTO T90, ASTM D4318) See Sand Equivalent Value definition.

Coarse Aggregate — Aggregate retained on the No 8 (2.36mm) sieve.

Cold Mixed Asphalt — Asphalt emulsion and mineral aggregate mixed at or near ambient temperature.

Construction Seal — Light spray application of dilute recycling emulsion, applied to a newly constructed asphalt concrete surface. This process restores the chemical balance, lost primarily from the heat of the hot mix plant, to the asphalt at the surface and some shallow depth below. This seal may also help to seal or prevent the formation of surface pores.

Copolymer — A polymer produced by the simultaneous polymerization of two or more dissimilar monomers.

Curing — The development of the mechanical properties of the asphalt binder. This occurs after the asphalt emulsion has broken and the asphalt emulsion particles coalesce and bond to the aggregate.

Dense Graded Aggregate — Aggregate that is graded from the maximum size down through filler with the objective of obtaining an aggregate blend with a controlled void content and high density.

Dense Surface — Tight, relatively non-absorbent smooth textured surface.

Direct Non-Reducing Drive — A drive mechanism that connects the driving shaft directly to the driven shaft, maintaining the drive to driven speed ratio at 1: 1.

Discharge Head — A pumping condition when the discharge pressure of the pump equals the head pressure.

Elastomer — A polymer that can elongate (to at least twice its original length) at relatively low stress levels and rapidly return to approximately original size.

Emulsifier — See Surface Active Agent.

Emulsion Break — The initial separation of the water from the asphalt emulsion, which can be detected by a marked color change from brown to black, and often by the release of fairly clear to straw brown water. This break results in the deposition of the base asphalt on an aggregate or a paved surface.

Feeler Gauge — An instrument, usually consisting of a series of specific sized wires or blades used for measuring a dimension or for testing mechanical accuracy.

Fine Aggregate — Aggregate passing the No 8 (2.36mm) sieve.

Flush Coat — A fog seal applied for the purpose of increasing the asphalt content of under-asphalted, usually newly constructed chip seal surfaces. Flush coats are treated herein as fog seals.

Fog Seal — A light spray application of dilute asphalt emulsion used primarily to seal existing asphalt surfaces to reduce raveling and to enrich dry and weathered surfaces.

Fog Seals can also be used as a color coating and as a paint stripping surface preparation.

Heat Jacketed — A heating method where the object to be heated is encompassed by a ring-shaped space, through which water, steam, oil or any heat transfer medium can be circulated to heat the enclosed object.

High Tension Electric Power Lines — Primary electrical power lines capable of carrying or operating under current of high voltage, usually more than 600 volts.

Hot Asphalt Emulsion Mixes — Those emulsion aggregate mixtures (either open or dense-graded) which are mixed at temperatures greater than 220°F (104°C) and laid at temperatures substantially above ambient.

Hveem Design Method — A designing, and testing method used to evaluate asphalt aggregate mixtures. The method involves three principle tests: (a) The stabilometer test, which measures mix stability; (b) The cohesiometer test, which measures mix cohesion; and (c) The centrifuge kerosene equivalent (CKE) test, used to estimate asphalt content required by the mix.

Hydrophilic — Having an affinity for water.

Hydrophobic —Having no affinity for water.

Indirect Heat — A heating method where the actual heat source (i.e., steam, hot oil, water, open flame) does not come in direct contact with the material to be heated.

Ion(s) — Water soluble chemicals or substances which carry an electrical charge.

Ionic — See “Ions.”

Job Mix Formula (JMF) — The proportions of aggregate and asphalt emulsion used to produce a mixture. The proportions are determined by the engineer or the asphalt emulsion supplier using appropriate design methods and or specifications.

Latex — An aqueous stable, colloidal emulsion of a polymeric substance.

Lipophilic — Having an affinity for oils and fats.

Low Pressure Steam — Steam that is generated at pressures below approximately 100 psig.

Maintenance Mix — A mixture of asphalt material and mineral aggregate for use in relatively small areas to patch holes, depressions and distressed areas in existing pavements. Appropriate hand or mechanical methods are used in placing and compacting the mix.

Maltene (Maltene) — A relatively high boiling fraction of asphalt (oils and resins) that is soluble in low boiling saturated hydrocarbons, (e.g., n-pentane).

Marshall Design Method — A designing, and testing method used to evaluate asphalt aggregate mixtures. The method involves a density or void analysis and stability and flow tests.

Micro surfacing — A mixture of polymer modified asphalt emulsion, crushed dense graded aggregate, mineral filler, additives, and water. Micro surfacing provides thin resurfacing of 3/8 to 3/4in. (10 to 20mm) to the pavement and returns traffic use in one hour under average conditions. Materials selection and mixture design make it possible for micro surfacing to be applied in multiple applications and provide minor re-profiling. The product can fill wheel ruts up to 1.5 in. (40mm) in depth in one pass and produces high surface friction values. Micro surfacing is suitable for use on limited access, high-speed highways as well as residential streets, arterials, and roadways.

Mineral Dust — That portion of the fine aggregate passing the No 200 (0.075 mm) sieve.

Mineral Filler — A finely divided mineral aggregate; at least 70% of which will pass No 200 (0.075 mm) sieve. Pulverized limestone is the most commonly manufactured filler, although other stone dust, hydrated lime, portland cement, and certain natural deposits of finely divided mineral matter are also used.

Modified Binders — A bituminous material whose physical or performance characteristics, or both, are modified by addition of a polymer or other additives.

Multiple Chip Seal — Two or more successive applications of asphalt emulsion and cover aggregate followed by rolling of each application.

Natural Rubber — A naturally occurring polymer (poly cis-1-4-isoprene) found in some species of trees, shrubs, and plants.

Natural Rubber Latex — A naturally occurring latex containing polyisoprene (natural rubber).

Neoprene —A synthetic elastomer made by polymerization of chloroprene (2-chlorobuta-1,3-diene). A generic name for polychloroprene.

Nonionic — A hydrophilic compound that does not ionize in water.

OGAEM — Open Graded Asphalt Emulsion Mix.

Open Graded Aggregate — Aggregate containing little or no mineral filler or in which the void spaces in the compacted aggregate are relatively large and interconnected. Aggregate gradations vary.

Open Surface — An open, relatively porous rough textured surface. This type of surface will require a higher rate of application to compensate for the asphalt emulsion which flows into the large voids and cracks.

Outboard Bearing — A bearing, external to the pump, that supports the shaft.

Packing Gland — See packing seal.

Packing Seal — Material used to seal a pump rotor shaft from the fluid material being pumped. A typical packing material is a high temperature lubricant impregnated rope. The material is formed into a square shape that approximately fills the space between the pump shaft and housing. This area may take 3 to 10 rings of packing material.

Plastic — A polymer that exhibits flexible characteristics when subjected to heat and or pressure but does not have elastomeric properties.

Polarity — Quality of the electrical charge (i.e., positive or negative charge) on particles or electrodes.

Polymer — A large molecule made by the repetitive combination of a large number of simpler, identical units called monomers.

Polymer Modified Asphalt — A blend of asphalt and any compatible polymer.

Polymerized Asphalt Cement — A chemically modified asphalt produced by the controlled chemical combination of asphalt with monomers and polymers.

Pug mill — An asphalt and aggregate mixing device that proportions and mixes aggregate and asphalt emulsion to yield a uniform, properly coated mixture. A pug mill may be mobile or stationary. A stationary pug mill is usually supplied aggregate by a system of bins and conveyor belts.

Pump Head — A part of the pump housing opposite the shaft that supports various internal parts. It can usually be removed, allowing internal inspection.

Reclaimed Asphalt Pavement (RAP) — Asphalt pavement that has been scarified and pulverized or crushed. No attempt is made to control gradation, except for maximum particle size. The resulting asphalt aggregate mix may be recycled.

Restorative Seal — A light spray application of dilute recycling emulsion, applied to an existing asphalt concrete surface. This process restores the chemical balance, lost primarily from the heat of the hot mix plant, exposure to water and air, as well as deicing agents and other contaminates, to the asphalt at the surface and some shallow depth below. This seal may also help to seal hairline cracks and fill surface pores which develop due to aging.

Ring Staggered — A typical arrangement of packing which staggers the gap at the ends of the packing rings. The packing material is held in place by the packing gland. See Packing Seal.

Rotary Mixer — A rotary type mixer consists of a mobile mixing chamber mounted on a self-propelled machine. The mixing chamber is open at the bottom and has one or two transverse rotating shafts equipped with tines or cutting blades which cut the in-place material to a specified depth and mix it with asphalt emulsion. Rotary mixers are sometimes referred to as Stabilizers.

Rubber — A natural or synthetic polymer having unique properties of deformation (elongation or yield under stress) and elastic recovery after vulcanization with sulfur or other cross-linking agent, which in effect changes the polymer from thermoplastic to thermosetting.

Rubberized Asphalt — A blend of asphalt and elastomers.

Sand Emulsion Mixes — A mixture of asphalt emulsion and sand. Bank run poorly graded gravel and dune or sugar sands can be used, but generally sand mixes are restricted to granular sands and silty sands low in clay content. Sand asphalt emulsion mixes can be used for both base and surface courses.

Sand Equivalent Value — The relative proportion of detrimental fine dust, or clay-like materials, in fine aggregate used in paving mixtures and mineral aggregates or soils used for base courses; measured by the sand equivalent test. (ASTM D2419 or AASHTO T176)

Sand Seal — A surface treatment consisting of an application of an asphalt emulsion followed by the uniform application of fine aggregate.

Sandwich Seal — A surface treatment which consists of the uniform application of one course of aggregate to a prepared surface, followed by the application of an asphalt emulsion, which is then followed by the uniform application of a second course of smaller aggregate, which is then rolled.

SBR — Styrene-Butadiene Rubber; a synthetic polymer made by the random copolymerization of styrene and butadiene.

SBS — A synthetic block copolymer consisting of blocks of polystyrene and polybutadiene.

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

Shim Material — A thin strip of any material for filling in, leveling, or spacing, as for bringing one part in line with another.

SIS — A synthetic block copolymer consisting of blocks of polystyrene and polyisoprene.

Single Chip Seal — A wearing surface consisting of a uniform application of a rapid setting (RS or CRS), medium setting (MS or CMS), or high float (HFRS) asphalt emulsion to a prepared surface followed by a uniform application of cover aggregate, which is then rolled.

Slurry Seal — A mixture of well-graded fine aggregate, mineral filler or other additives, asphalt emulsion, and water. It is applied from 1/8 to 3/8in. (3 to 10mm) thick and used to renew pavement surfaces and retard moisture and air intrusion into underlying pavement. Slurry seal will fill minor cracks, restore a uniform surface texture, and restore friction values.

Stabilization — Changing of soils or aggregates by blending materials that increase the load bearing capacity, firmness and resistance to weather or displacement.

Steel Alloy — Steel that has been alloyed with other metals to produce variations in hardness, strength, elasticity, or chemical resistance.

Sub-base — A foundation course, that along with the base, helps distribute the load which is applied to the surface. The sub-base should consist of select materials such as natural gravels that are stable and drainable.

Sub-grade — The foundation course that supports the pavement system. Desirable properties that the sub-grade should possess include strength, drainage, ease of compaction, and permanency of strength and compaction.

Submerged Outlet—An outlet situated such that under all circumstances it is below the liquid level in the tank.

Suction Lift — The condition where a pump will pump a liquid that is below the level of the pump suction port. This condition exists when the pressure at the suction flange is below atmospheric.

Surface Active — Designation for substances that tend to concentrate strongly on surfaces.

Surface Active Agent — A substance that alters the energy relationship at interfaces; organic compounds displaying surface activity, including detergents, wetting agents, dispersing agents, and emulsifiers.

Surface Course — The top course of an asphalt pavement, sometimes called asphalt wearing course. This course must possess skid resistance, resist load and non-load associated fracture, and resist permanent deformation.

Surface Treatment — A chip seal applied to a prepared consolidated gravel, crushed stone, water bound macadam, stabilized soil, or similar base.

Surfactant — See Surface Active Agent.

Tack Coat — A spray application of asphalt emulsion (usually applied in a diluted state) to an existing asphalt or portland cement concrete surface prior to a new asphalt overlay or patch to provide a bond between new and existing pavement layers.

Thermoplastic Polymer — A polymer that softens and flows when exposed to heat and returns to its original consistency when cooled.

Thermoset Polymer — A polymer that softens and flows when subjected to heat. An irreversible chemical reaction also occurs, preventing it from softening and flowing when subjected to further heat.

Thermostatic Control — A temperature sensing device that controls a heating or cooling source using a set point temperature relative to the actual measured temperature.

Traced — A heating method where the object to be heated is wrapped, in contact with, or in close proximity to a heating source capable of transferring heat to the object. Typical heat sources are electrical resistance wires or tapes and small diameter pipes or tubes with circulating hot oil, steam, or hot water.

Travel Plant — Self-propelled pug mill plant that receives aggregate into its hopper from a haul truck, adds and mixes asphalt emulsion, and spreads the mix to the rear as it moves forward.

Virgin Aggregate — Aggregate which has not been used in pavement construction. In recycling, virgin aggregate is added to existing reclaimed material to adjust gradation, improve structural stability and adjust asphalt content.

Warm Asphalt Emulsion Mixture — Those emulsion aggregate mixtures (either open or dense-graded) which are mixed above ambient temperature but below 220°F (104°C) and laid at ambient or above ambient temperature.

Windrow — A long narrow bank of uncompacted material (treated or untreated on a road bed, yard or mix pads), shaped to size with a spreader box, windrow sizer, proportioning windrow box or a motor grader.

Young Method — A laboratory procedure that determines the pure asphalt requirement for mixes. This formula multiplies the retention of each sieve by a calibration factor to find the surface area. The surface area, in conjunction with the Centrifuge Kerosene Equivalent (CKE), California DOT 3038, will yield the amount of residual asphalt required. The percent asphalt emulsion requirement is generally between 6 and 15%.

SECTION 26

ASTM STANDARDS AND THEIR AASHTO DESIGNATIONS

(Standards May Not Be Identical)

ASTM	AASHTO	AGGREGATE STANDARD
C29	T19	Test Method for Unit Weight and Voids in Aggregate
C1252	T304	Test Method For Determining Uncompacted Void Content of Fine Aggregate
C88	T104	Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
C117	T11	Test Method for Materials Finer than 75 µm (No. 200) in Mineral Aggregates by Washing
C127	T85	Test Method for Specific Gravity and Absorption of Coarse Aggregate
C128	T84	Test Method for Specific Gravity and Absorption of Fine Aggregate
C131	T96	Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
C136	T27	Test Method for Sieve Analysis of Fine and Coarse Aggregates
C183	T127	Practice for Sampling and Testing Hydraulic Cement
D75	T2	Practice for Sampling of Aggregates
D448		Classification for Sizes of Aggregate for Road and Bridge Construction
D546	T37	Test Method for Sieve Analysis of Mineral Filler for Road and Paving Materials
D692		Specification for Coarse Aggregate for Bituminous Paving Mixtures
D1073	M29	Specification for Fine Aggregate for Bituminous Paving Mixtures
D2419	T176	Test Method for Sand Equivalent Values of Soils and Fine Aggregate
D3319	T279	Practice for Accelerated Polishing of Aggregates Using the British Wheel
D3398		Test Method for Index of Aggregate Particle Shape and Texture
D3744	T210	Test Method for Aggregate Durability Index
D4791		Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
D5106		Specifications for Steel Slag Aggregates for Bituminous Paving Mixtures
D5821		Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate

ASTM	AASHTO	BITUMINOUS BINDER STANDARD
D5	T49	Test Method for Penetration of Bituminous Materials
D70	T228	Test Method for Specific Gravity of Semi-Solid Bituminous Materials (Pycnometer method)
D92	T48	Test Method for Determining Flash and Fire Points by Cleveland Open-Cup
D113	T51	Test Method for Ductility of Bituminous Materials
	T300	Test Method for Force Ductility of Asphalt Materials
D36	T53	Test Method for Softening Point of Bituminous Material (Ring-and-Ball Apparatus)
D139	T50	Test Method for Float Test of Bituminous Materials
D140	T40	Practice for Sampling Bituminous Materials
D2042	T44	Test Method for Solubility of Bituminous Materials
D2872	T240	Test Method for Determining the Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)
D4402	T316	Test Method for Viscosity Determination of Asphalt Binder Using Rotational Viscometer
D5801		Test Method for Toughness and Tenacity of Bituminous Materials
D6084	T301	Test Method for Elastic Recovery of Asphalt Materials by Means of a Ductilometer
	R29	Practice for Grading of Verifying the Performance Grade (PG) of an Asphalt Binder
D6521	R28	Practice for Accelerated Aging Of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
D6648	T313	Test Method for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)

D7175	T315	Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
D7405	TP70	Test Method for Multiple Stress Creep Recovery (MSCR) of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
WK27550	MP19	Specification for Performance Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) Test
D7173		Practice for Determining the Separation Tendency of Polymer from Polymer Modified Asphalt