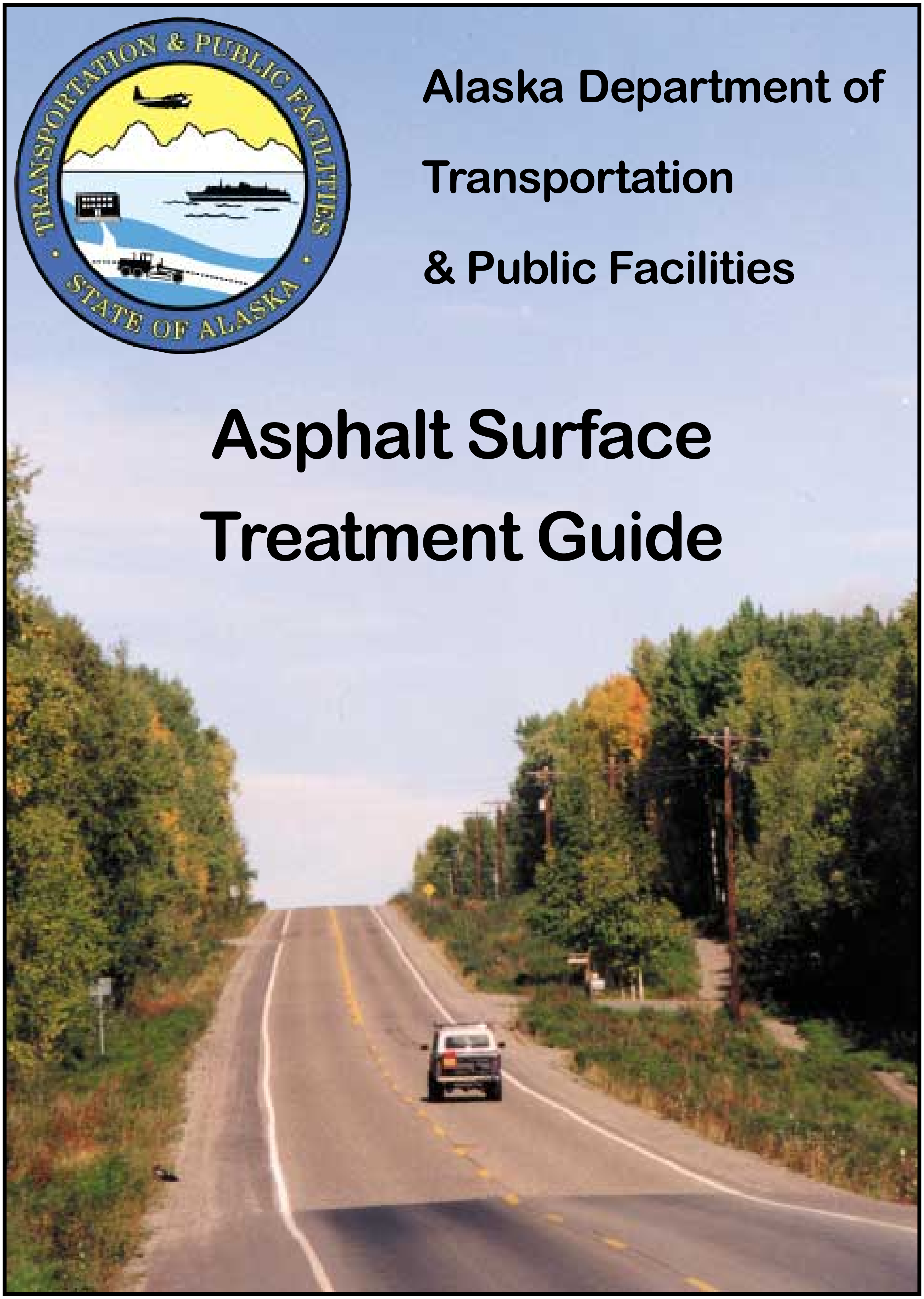

Alaska Department of Transportation & Public Facilities

Asphalt Surface Treatment Guide

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This guide is a field tool to assist workers in selecting and construction the right asphalt surface treatment (AST) for their specific situation. It describes how to construct three basic types of serviceable ASTs: seal coat AST, double-layer AST, and high float AST, using a specific selection of asphalt types and aggregate gradations that are found to work in Alaska. The guide covers materials selection and quality, construction methods, and troubleshooting. It also contains safety information. Before this guide, there existed no single, comprehensive document covering AST construction – workers used a varied combination of manuals from many sources, including personal "cheat sheets." This guide is a compilation of available information, drawing heavily from national sources as well as Canada's Yukon Government Community and Transportation Services. It contains specifications, detailed construction methods, and cautionary information that have never before been collected into a single document. It does not cover hot mix asphalt applications.

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Notes

Asphalt Surface Treatment Guide

This is:

- A guide, not a mandate or a step-by-step how-to manual.
- A guide that covers considerations and tools to select and build the three basic asphalt surface treatments that Alaska DOT&PF has experience with.
- A guide that will be revisited and updated when warranted.

Keep in mind that no two crews across the state have the exact same budget, expertise, equipment, and staffing size, nor are materials, existing surfaces, and other resources the same. Use this guide as a tool to supplement your judgement as you do your work. Learn who your counterparts are in other areas and regions, and call them.

This guide does not deal with:

- hot mix asphalt pavements, or
- asphalt surface treatments that haven't been tried in Alaska.

A future project will distill key AST information into a small pocket-sized handbook.

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Preface

Before this guide there was no single, comprehensive document covering Asphalt Surface Treatment (AST) construction that fully addressed DOT&PF needs. DOT&PF personnel performed AST work armed with a varied combination of manuals obtained from many sources. Sources include personal "cheat sheets" containing AST rules-of-thumb, some of which are derived from undocumented experimentation and/or other undefined (and sometimes unreliable) sources. The same can be said of the information used by designers working on AST jobs. The many and sometimes conflicting sources led to a commonly held view that successful AST construction may be more an art form than the result of sound engineering. This guide will help you build a better AST.

Sue and Russ Mitchell of Inkworks, Fairbanks, Alaska, provided technical editing and produced the guide document in its present form. Robert L. McHattie, an Inkworks contractor, assembled the guide from existing literature, through numerous personal contacts, and from nearly 27 years of experience as a DOT&PF engineer. Maintenance and Operations (M&O), Construction, and Design personnel of the Alaska DOT&PF who enthusiastically offered suggestions based on real observations deserve many thanks. Although standard technical references provided much of the general information contained here, many personal contacts enabled the writer to "calibrate" the guide to Alaska needs.

This guide borrows heavily from the Minnesota Seal Coat Handbook, AST manuals from The Asphalt Institute (TAI), and a wealth of technical advice provided to Alaska over the years by engineers of Canada's Yukon Government Community and Transportation Services. Those resources are a foundation for AST work recently done in Alaska. Canada's successful pioneering use of high float ASTs in the north fueled Alaska's interest in that pavement type. DOT&PF relies heavily on Canadian technical advice and specifications for its increasing investment in high float ASTs. Canadian influence is reflected throughout this guide—we are grateful for the help.

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Chapter 1. Introduction

An asphalt surface treatment (AST) consists of a thin layer of asphalt concrete formed by the application of emulsified asphalt or emulsified asphalt plus aggregate to protect or restore an existing roadway surface. Surface treatments are typically less than 1 inch (25 mm) thick. This guide describes how to construct three basic types of serviceable AST, using a specific selection of asphalt types and aggregate gradations that have been found to work in Alaska. The guide covers materials selection and quality, construction methods, and troubleshooting. It contains safety information as well. Unlike hot mix asphalt concrete pavements, ASTs must go through a curing process to attain final strength, so it is hard to overemphasize the importance of protecting a new AST. You will find that much of the guide's content relates to protecting the new AST against damage during and shortly after construction. Be aware that there are many other materials options than those described here—the ones covered are presently considered the most workable in Alaska. There are also many other types of AST pavements that are not covered—Alaska has little or no experience with these.

This guide originated from needs expressed from the lowest through highest levels of the Alaska DOT&PF. Project designers, construction personnel, and Maintenance and Operations (M&O) workers on AST projects wanted a comprehensive, reliable technical reference. The guide contains specifications, detailed construction methods, and cautionary information that have never before been collected into a single document. Use this manual as an everyday "working document" at the construction site. This is not an AST *design* guide per se, although design engineers will benefit from the information contained here when they must create plans, specifications, or other contract documents intended for AST jobs. This document can be found by selecting "Library" on the DOT&PF Statewide Design and Engineering Services' Research and Technology Transfer web site (www.dot.state.ak.us/external/state_wide/t2/).

Alaska DOT&PF has constructed many miles of new highway and maintenance rehabilitation projects involving applications of asphalt surface treatments. An AST provides a nonstructural but durable and highly functional pavement surface when constructed properly with good materials. Within certain limitations, surface treatments offer lower life cycle costs than competing paving options. Surface treatments give a long service life where traffic intensities are low and thicker pavements are inappropriate. Surface treatments provide a short but economically justifiable design life where traffic is heavy but foundation conditions are poor—places where the entire roadway will need releveling every two or three years. Last but certainly not least, M&O can patch or relevel and patch long stretches of roadway with low-cost, easily constructible ASTs.

Ranging between 0.5 inch (12 mm) and 1 inch (25 mm) in thickness, AST pavement types are much thinner than hot mix asphalt concrete pavements (usually 2 inches [50 mm] or more), and therefore are significantly cheaper, less equipment intensive, and easier to construct. ASTs are simple to describe in generalized terms of materials and construction. Conceptually, AST construction consists of spreading emulsified asphalt followed by a layer of mineral aggregate on a prepared surface. This basic process may be repeated to achieve the desired AST pavement type. There are often problems, though, and the devil is in the details. When the materials, construction methods, and weather are correct, these thin, dust-palliative pavements work. With poor materials, poor construction, or bad construction weather, AST pavements may have almost no service life. Combinations of materials, construction, and weather problems are even worse, sometimes resulting in immediate, complete failure. Unfortunately, AST construction errors can be much more crucial than similar errors made during hot mix paving. For example, successful hot mix pavements have been constructed during rain or snow events. Such weather will guarantee AST failure. AST failures also can stem from mistakes that are far more subtle than simply paving in the rain or snow.

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Chapter 2. Simple AST Descriptions and When to Use What

The maintenance or design engineer usually selects from one of three distinct types of AST: a seal coat, a double layer AST, or the high float AST. For the first two types, other common names are used. The seal coat is often referred to as a *single-shot AST* or a *single-shot chip job*. The double-layer AST is often called a *double-shot AST*, or more commonly, a *double-shot chip job*.

The term "chip" is used as an identifier for the nearly single-sized crushed aggregate used in seal coats and double-layer ASTs (but not in high float ASTs). Throughout the rest of this guide, the generalized term "cover aggregate" is used to describe processed aggregate materials used in all AST types.

Emulsified asphalt, commonly referred to as *oil* or *binder,* is used as the "glue" in the AST process. Emulsified asphalts are primarily composed of asphalt cement, water, and an emulsifying agent, although they may contain minor amounts of other additives. The terms *emulsified asphalt*, *oil,* and *binder* will be used interchangeably in this guide. Consider these as equivalent terms. However, *emulsified asphalt* is used more in the context of a particular type or grade of binder, while *oil* and *binder* is used generically throughout the guide.

Basic descriptions of the three AST types discussed throughout the guide follow. Note that the curing time briefly discussed below (and much more extensively later on) is likely the single most important factor in the ultimate failure or success of the AST. While a newly placed AST has almost no resistance to aggregate loss, the curing process allows the asphalt-aggregate bond become every bit as strong as in hot mix asphalt concrete.

A note concerning appropriate application: AST pavements discussed in this guide are intended for use as roadway surfacing materials. ASTs are generally not suitable for parking lots or similar locations where frequent, tight turning movements may destroy these thin pavements.

2.1. Seal Coat AST

The seal coat is placed on an existing, freshly cleaned asphalt concrete or AST surface. It seals and rejuvenates the existing pavement and improves the skid resistance of the old surface. The seal coat is constructed using a single layer of oil followed by a layer of coarse, single-sized, crushed cover aggregate material. The surface is then lightly broomed. Several days (or longer) may be allowed for the oil to cure, then aggressive brooming of loose aggregate from the surface finishes the job. The curing process leaves behind a highly viscous residue of asphalt cement that bonds well to the aggregate. The oil cures (the bond increases) as it loses water and other volatiles originally contained in the fresh emulsion. Curing time is profoundly important to AST success. With enough curing time, the residual asphalt cement develops considerable mechanical strength. The final effect is that cured oil bonds the AST cover aggregate materials together **much** better than uncured oil.

2.2. Double-Layer AST

The double-layer AST consists of a layer of oil then coarse, crushed, single-sized cover aggregate material. Roll the first layer and allow the oil to cure for a few days. Remove loose material by brooming. Then apply a second layer of oil and smaller, single-size cover aggregate material in much the same way as for the first layer. After several more days of curing, do a final brooming to clean the surface of loose material and produce the finished surface. Double-layer ASTs are placed on a smooth base course surface.

2.3. High float AST

The high float AST provides roughly the same service life and function as a double-layer AST. The high float AST comprises a single, heavily applied layer of special high float emulsified asphalt, followed by a single layer of well-graded crushed cover aggregate. The cover aggregate is similar in gradation to a common base course. The high float cover aggregate is rolled, and after several days (usually), broomed to complete the paving. As explained more later in this guide, the timing and amount of brooming depends on weather conditions and traffic, e.g., light brooming may be required after no more than 24 hours. High float ASTs are placed on a smooth base course surface.

2.4. Which AST Should I Use?

2.4.1. Selecting a Seal Coat

Select a seal coat if the job is to simply enhance and protect an existing pavement surface that is in reasonably good condition. Reasonably good condition means that the existing pavement should be acceptable in terms of smoothness, grade, and crown. The existing pavement should not be cracked to the point of impending disintegration—a seal coat has no ability to hold the pieces together. The seal coat can seal some small cracks. Expect that *all* large thermal cracks will reappear the first winter after seal coating. The seal coat will do nothing to repair rutting. A seal coat increases the tire-to-surface friction coefficient of tire-polished or over-asphalted surfaces and provides a visual cover for unsightly patches and sealing materials accumulated on the old surface. It also retards further weathering (oxidation) of the old surface.

2.4.2. Selecting Between Double-Layer and High Float ASTs

Select either a double-layer or a high float AST when the job is to cover an unpaved surface with a light-duty pavement. According to the Alaska DOT&PF Preconstruction Manual, chapter 11, subsection 1180.01, high float and double-layer ASTs are considered appropriate for most roads with an average daily traffic (ADT) volume of less than 2,000. For roads with ADTs less than 2,000 but with high truck percentages and for some high-ADT roads, an AST pavement type may or may not be appropriate, depending on DOT&PF management decisions and factors including pavement structure and foundation quality. As mentioned previously, both double-layer and high float AST pavements give approximately the same level of service. They provide approximately the same pavement thickness and both need to be applied on a smooth, firmly compacted surface, properly set for crown and grade. So what's the difference? How do I choose one over the other? The following information will help you make that decision.

Decision Based on Appearance

Plan a field trip to visit several double-layer and high float AST paving sites. Appearance is a subjective quality and, in complete fairness, shouldn't be discussed between the observers during the field trip, lest it influence an otherwise unbiased inspection. However, there are several things to look for that will help you asess the pavement's appearance. Is the pavement surface of uniform color and texture? Is longitudinal streaking visible? How much patching is present, and does the patching material tend to match the color of the AST? Take pictures to discuss in the office.

To the average observer, a new double-layer AST will often have a better appearance than a new high float AST. The new high float will produce more dust than a double-layer AST, although both types are comparatively dust-free within a few weeks (see additional comments below). As several years go by, the two kinds of AST tend toward a similar appearance. When constructed properly, older double-layer and high float ASTs can become almost indistinguishable from one another or from a hot mix asphalt concrete pavement.

Decision Based on Ride Quality

During the field trip, drive the full length of all AST sites visited and form an opinion of the overall ride quality. Drive each section at the posted speed limit to get a realistic sense of roughness. It helps to have a second person along to help judge ride quality and with whom you can discuss ride quality immediately after driving a particular AST section. For this subjective ride quality test to have any real validity, you must be able to recognize and disregard that element of road roughness caused by poor foundation conditions. In other words, you will attempt to "feel" (mostly through vehicle vibrations) the quality imparted by the texture of the road surfacing material while disregarding heaves, dips, major rutting, and cracking. This takes some practice and, hopefully the company of an experienced "road rater," someone who has done a lot of this previously. Also pay attention to the vehicle noise generated from different AST types—it will be necessary to stand at the side of the road for a while and listen to various types of vehicles passing.

In addition to field trip observations, you can obtain objective roughness data collected by the DOT&PF Statewide Materials Section pavement management engineer, phone 907-269-6200. These profilometer data are in the form of mile-by-mile International Roughness Index (IRI) numbers. IRI data can be requested for paved road sections of interest in most areas of Alaska. IRI numbers are influenced by a variety of roughness-generating problems. Therefore, the most useful information will come from those AST sections that have *not* been damaged by heaves, dips, ruts, and major cracking. From field observations, you must be able to separate useful from unusable data.

Decision Based on Constructability

Double-layer ASTs require two good construction days for applications of two layers of oil and cover aggregate. Since the first layer of materials must cure enough to be broomed, you need at least a few days of warm (+60˚F [+15˚C]), dry weather between the two construction days. Near the end of the construction season or during a wet, cold summer period, there may be no interval of time long enough to be ideal for doing a double-layer AST.

A high float job is a one-step process. Therefore, only one good day is necessary for the construction process. Also, DOT&PF experience shows a high float savings of about 40% in time and equipment over the double-layer AST. DOT&PF Maintenance and Operations personnel report that a high float application requires slightly more time than applying the first layer of a double-layer AST because of the higher materials application rate. High float AST doesn't require a second period of traffic control or the additional brooming, construction personnel, time, and equipment required for the second layer of the double-layer AST.

Both AST types of course require a similar period of warm, dry weather for curing after construction is completed. Because only a single day is required for application of high float (instead of two different days for the double layer AST), a few extra curing days are available.

Decision Based on Capital Cost

There are no shortcuts here; you must assess materials costs for each job. Past estimates are not necessarily indicative of future costs (remember the stock market warnings?); this is certainly the case with old estimates or with estimates made for areas of Alaska distant from the intended new AST location.

However, data collected by Northern Region DOT&PF Maintenance and Operations personnel gives some insight into recent average costs within the Northern Region. Maintenance records show total material costs for a high float AST to be about 40% less than for a double-layer AST. In terms of individual AST components, the total cost of double-layer AST cover aggregate is about 50% more than for high float cover aggregate. The cost of oil used for the double-layer AST has run almost 20% higher than high float oil. Further, the double-layer AST can require a total amount of oil 25 to 30% above that required for a high float AST. On the other hand, comparative estimates for some locations have occasionally found the materials costs of double-layer and high float ASTs to be about the same. Relative costs may shift one way or the other, depending on variables that include time frame, shipping costs, availability of materials, ownership of materials, size of job, etc.

The high float AST surface may have a rough finished texture and may need to be monitored with an eye toward extra traffic control and patching during the first week after construction. If the surface texture becomes too much of a problem, a seal coat may be needed at a later date. Extra monitoring and seal coating may increase the total cost of a high float AST to nearly that of a double-layer AST, but the end result would be about 0.5 inch (12 mm) thicker and perhaps slightly more durable.

Northern Region Maintenance and Operations estimated average costs, including surface preparation, for AST work done in Alaska's southcentral area. Records from 2000 show costs varying from about $3.60 per square yard for seal coats (one layer of single-size aggregate) to about $5.50 per square yard for double-layer ASTs (two layers, using two different sizes of single-size aggregate). The cost of high float ASTs averaged about $4.50 per square yard. They noted that thick fills or other extensive work to correct major deformations could increase costs significantly.

Use a lot of care in applying cost estimate data from one project location to another location. Keep in mind that materials sources may drastically change the economic picture and may make the usually most expensive pavement type the best choice. For example, consider that in some parts of Alaska, the CRS-2 emulsified asphalt for the double-layer AST may be much more readily available than the HFMS-2s used for high float. The difference in availability will likely heavily influence cost. Although less likely, cover aggregate for a double-layer AST may be no more expensive than for a high float AST aggregate. For example, local materials may not meet high float quality specifications because of too much clay in the fines. On the other hand, materials suitable for making the well-graded high float cover coat aggregate are usually easier to find than a material source suitable for producing single-sized "chips." If both materials must be barged from a long distance, end costs per ton may be about the same. In comparing costs, also consider that the production of chips, i.e., aggregates for double-layer ASTs can deplete a materials source much faster than making aggregate for a high float AST. This factor can greatly increase basic materials costs. For state-owned materials sources, this additional cost may remain hidden for awhile, and not realized until the materials source nears depletion.

Decision Based on Location

A high float AST will be a dustier surface than a double-layer AST for perhaps several weeks after placement. High float ASTs also tend to produce significantly more vehicle tire noise over the life of the pavement. Therefore, a high float AST may be a poor choice in urban or other residential areas where the initial dust and long-term increased noise may be a problem.

The Final Decision

Since maintenance and operating costs are roughly the same, a first assumption would be to select the AST type having the lowest initial cost. This choice usually (but not always) satisfies management and is the one usually favored by public opinion. If your role is to help management decide between a double-layer and high float AST, be prepared to discuss all of the above decision factors, including comparative costs. Lay all your cards on the table and be prepared to justify your views, but realize that there is no single, "correct" decision. Your goal is to present enough information to promote a reasonable consensus. Note that a life cycle cost analysis could be useful decision tool.

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Chapter 3. The AST is Part of a Much Thicker Pavement Structure

Pay attention to the materials under your AST or it may not survive its first spring thaw. This is the only chapter where important pavement design concepts will be covered. While a complete discussion of these design methods is beyond the scope of this guide, some information is vital for anyone wanting a successful AST. Pavement design references and software are described at the end of this chapter. The following information is meant to be a useful but general guideline. That should work in most cases.

One basic question cannot be addressed here: what's the longest pavement design life I can expect from an AST installed at a particular location? The answer requires detailed pavement design analysis, with due consideration of traffic (equivalent single axle loads [ESALs], average daily traffic [ADT], and seasonal traffic distribution), estimates of local climate factors, and detailed knowledge properties of materials below the AST. If your objective is to obtain the maximum service life from your new AST, your regional materials personnel (or other pavement structure design specialist) should do a complete pavement design.

Keep the following in mind!

ASTs **DO** provide a dust palliative driving surface for the design life of the project. ASTs **DO** protect the base from rain and other forms of water damage.

ASTs **ARE NOT** a structural pavement layer (see pavement structure description below). Even well-cured ASTs have only a tiny fraction of the total strength of thick hot mix pavements. Therefore, you should place them on high quality, compacted materials that are as good as or better than materials used under hot mix pavements. Failure to pay attention to the quality of base and subbase materials under the AST may cause rapid failure.

With respect to materials under the AST, some things are obvious. For example, you must place the AST on a smooth, firmly compacted surface, properly set for crown and grade. Remember that all base course surface flaws will show through the thin AST. Preparation of the surface is covered in Construction (chapter 7) of this guide, under Road Surface Preparation. However, vehicles are not supported by the AST surface alone. Essentially all of the support comes from some thickness of unbound material under the AST. The questions to be asked are:

1. What total thickness of material supports the load?
2. What quality of material is required within this thickness?
3. What happens if poor quality materials are used within this thickness?

The AST is the top layer of the pavement structure. Pavement structure is an important concept, defined for our purpose as the total thickness of material that "feels" significant compression and bending stresses under the load of a heavy truck—the material that must support the truck's live load. Material at the surface (AST) and material close to the surface (base course) will feel relatively strong compression and bending stresses, while materials at a depth of, say, 33 feet (10 meters) will feel almost no live load stress. Materials to a depth of 42 inches (about 1.1 meter) carry the bulk of the live load. The pavement structure is therefore defined in this guide as the AST layer plus all other material layers to a total depth of 3.5 feet. Material beneath the pavement structure comprises the foundation.

Quality of materials within the pavement structure is mostly controlled by the percent of fines (weight percent of particles finer than #200 sieve [0.075 mm]). In Alaska, the fines content usually controls the material's ability to support vehicular load, especially during the springtime thaw period. The general relationship is: low fines content gives good support and high fines content gives poor support. The fines content matters less as depth increases; at a depth greater than 3.5 feet, high fines are acceptable. For generally good results, a simplified rule of thumb is:

Bottom of AST to 8 inch (0.2 meter):	≤ 6% #200 sieve (0.075 mm)
8 to 20 inch (0.2 to 0.5 meter):	≤ 8% #200 sieve
20–42 inch (0.5 to 1.1 meter):	≤ 12% #200 sieve
>42 inch (more than 1.1 meter):	No limit

The listing does not represent a particular pavement structural design. However, this general guideline and some inexpensive sieve testing of materials from various depths will quickly tell you whether existing materials will contribute to AST success or not.

Depending on traffic intensity, weather, and groundwater level, excess fines will cause springtime softening in layers supporting the AST. If softening occurs, visualize the situation as a cracker (the AST) on a thick layer of cream cheese—the AST is unsupported and highly vulnerable. Even a small amount of truck traffic can quickly destroy the AST as damage progresses from cracking to potholing and finally to complete loss of the AST surface. The chance of poor AST performance increases enormously as the fines content increases above the amounts listed above.

Canada's Yukon Government Community and Transportation Services developed 1999 estimates of AST pavement life as part of its management system for AST pavements on Yukon highways (see Yukon Road Surface Program information at www.gov.yk.ca/depts/cts/highways/BST.htm). AST life estimates are based on the quality of the pavement structure under the AST surface. The management system defines three classes of pavement structure quality:

1. Class 1—Includes all roads on which the AST has been applied to an unimproved road structure that has not been designed to any particular standard.
2. Class 2—Includes roads on which a 3 to 6 inch (75 to 150 mm) thick layer of crushed gravel base course is placed on the subbase prior to AST application.
3. Class 3—Includes roads with fully designed base and subbase layers on which AST has been applied as a substitute for hot mix asphalt concrete.

Estimates of average AST life are shown in Table 1.

Canadian engineers also addressed the question of putting seal coats on older AST pavements. They found, in terms of overall economics, it is best not to seal coat older, damaged AST pavements. The seal coat adds nothing to the life of existing ASTs that were damaged because of a poor pavement structure. In the Yukon, older ASTs are not seal coated; they are "ripped and reshaped," then a new AST is applied. Therefore, seal coating would be considered viable only on newer ASTs showing very minor damage, located where the overall pavement structure is strong enough to permit a reasonably long pavement life.

DOT&PF pavement design requirements are outlined in chapter 11, section 1180 of the DOT&PF Preconstruction Manual. Computational methods normally used by the Alaska DOT&PF are available, free of charge, in the form of three computer programs available through the office of DOT&PF Technology Transfer, 907-451-5320. Request latest versions of programs titled Akpave98, Akod98, and Paveinfo. These programs can be found by selecting "Software" on the DOT&PF Statewide

Table 1. Canadian Estimates of AST Life*

For Class 1 Conditions	Expect 2 Years of Routine Maintenance	Expect 5 Years Before Reconstruction
For Class 2 Conditions	Expect 4 Years of Routine Maintenance	Expect 7 Years Before Reconstruction
For Class 3 Conditions	Expect 6 Years of Routine Maintenance	Expect 10 to 12 Years Before Reconstruction

*Although Canadian estimates are for high float ASTs, life expectancy of a double-layer AST should be similar.

Design and Engineering Services' Research and Technology Transfer web site (www.dot.state.ak.us/external/state_wide/t2/). The first program includes the simplified "excess fines" pavement design method. The latter two programs cover the more sophisticated "mechanistic" pavement design methods. No user's manuals are available for these programs, and discussion of these programs is beyond the scope of this guide. For general pavement design concepts, recommended references are:

Yoder, E. J. & Witczak, M. W. *Principles of Pavement Design.* John Wiley & Sons, second edition, 1975.

Yang and Huang. *Pavement Analysis and Design.* Prentice Hall, 1993.

Ullidtz, Per, *Pavement Analysis.* Elsevier, 1987.

Ullidtz, Per, *Modelling Flexible Pavement Response and Performance.* Polyteknisk Forlag, Narayana Press, Gylling, Denmark, 1998.

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Chapter 4. Materials Properties and Handling

4.1. Liquid Asphalt

Asphalt is used in pavement applications because it is waterproof and adheres to stone. At normal ambient temperatures, most Asphalt materials are much too stiff to be workable for application. Workability requires that the viscosity be reduced by:

- heating (for hot mix asphalt concrete pavements),
- making a cutback asphalt (used only for prime coat in Alaska), or
- making an emulsified asphalt (for AST pavements in Alaska).

Cutback Asphalts

In Alaska, a medium-curing cutback asphalt (MC-30) is used as a prime material in AST construction. Cutback asphalts (liquid asphalts) are asphalts that are dissolved in a petroleum solvent (cutter). Typical solvents include naptha (gasoline) and kerosene. The type of solvent controls the curing time of the cutback and thus when it will obtain its ultimate strength. Rapid-curing cutbacks use naptha while medium-curing cutbacks use kerosene. The amount of cutter affects the viscosity of the cutback asphalt. The higher the cutter content, the lower the viscosity, and the more fluid it will be. The solvent softens the asphalt cement and allows it to be pumped and sprayed at fairly low temperatures. As the solvent evaporates into the atmosphere, only the asphalt cement remains. Once the solvent has evaporated, the cutback has fully cured. The use of cutbacks has declined rapidly over the years due to concerns over pollution and health risks as the solvents evaporate into the atmosphere. Until about 35 years ago, rapid-curing cutback asphalt (RC-800) was the material of choice in Alaska for constructing ASTs. That material became unavailable due to the costly and harmful solvents used in its manufacture. There is speculation that MC-30 cutback may one day become unavailable for economic and environmental reasons. For AST paving, one advantage cutbacks have over emulsions is a much higher residual asphalt percent, typically over 80%. This compares with just over 65% for emulsified asphalts. The result is more asphalt cement left on the roadway after curing for the same volume of material originally applied.

Emulsified Asphalts

The Minnesota Seal Coat Handbook provided much of the following discussion. Find more detailed introductory information in The Asphalt Institute's publication *A Basic Asphalt Emulsion Manual,* Manual Series No. 19, third edition.

Emulsified asphalts (CRS-2, CRS-2P, and HFMS-2s) are used for constructing AST pavements in Alaska. Emulsified asphalt consists of three primary components and may contain other additives such as stabilizers, coating improvers, anti-strips, or break control agents. The primary components are:

- asphalt cement,
- water, and
- emulsifying agent (surfactant, i.e., soap-like material).

It is well known that water and asphalt will not mix, except under carefully controlled conditions, using highly specialized equipment (an emulsion mill) and chemical additives. When asphalt is milled into microscopic particles and dispersed in water with a chemical emulsifier, it becomes an asphalt emulsion. As shown in Figure 4.1, tiny droplets of asphalt remain uniformly suspended until the emulsion is used. In an emulsion state, the emulsifier molecules orient themselves in and around droplets of asphalt. The chemistry of the emulsifier/asphalt/water system determines the dispersion and the stability of the suspension. When emulsions are used in the field, the water eventually evaporates into the atmosphere, and the chemical emulsifier is retained with the asphalt.

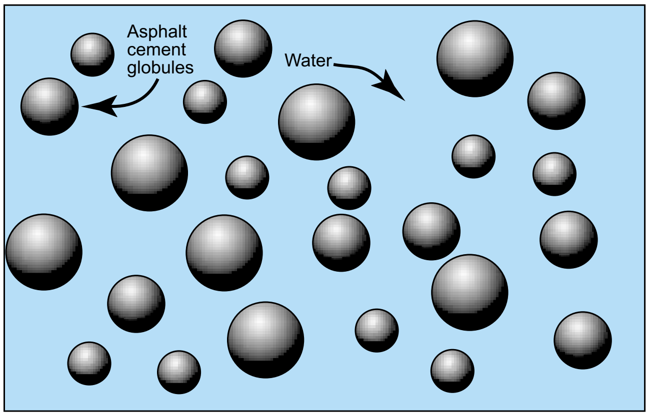

Figure 4.1. Asphalt emulsion

Asphalt cement makes up about two thirds of the volume of the emulsion. In Alaska, emulsions are made with an AC-5 or AC-2.5 base asphalts—the same asphalt cements used for hot mix pavements within the state. In some cases, a polymer is added to the emulsified asphalt as a modifier. Polymer modified emulsions are used to improve early chip retention and seal coat durability and flexibility.

Water is the second largest ingredient in the emulsion. It provides a medium for the suspension and transfer of the asphalt particles. When the asphalt and water separate from each other, the color of the emulsion will change from brown to black. When this process has occurred, the emulsion is said to have "broken." The aggregate chips must be applied and rolled *before* this occurs—normally only a few minutes after the emulsion is applied. After the asphalt separates from the water, the water evaporates, leaving the asphalt bonded to the aggregate. Initial attraction and bonding between the asphalt and aggregate is enhanced by charge compatibility, explained below. After the emulsion breaks, it begins the long process of curing. The oil cures as water and other volatiles originally contained in the fresh emulsion evaporate. Curing is a process that develops the mechanical properties of the asphalt binder. Curing eventually transforms the combination of emulsified asphalt and aggregate into a tough asphalt concrete material. Several days may pass before the emulsion has cured so that construction brooming can be done. Weeks, or in extreme cases even months, may pass before the oil cures completely. The curing process leaves behind a tough residue of asphalt cement. Curing time is a profoundly important determiner of AST success.

The emulsifying agent, or surfactant, has two primary roles. First, it allows the asphalt particles (created by a milling process) to remain stable as tiny droplets suspended in water. This is accomplished by the surfactant's ability to lower the surface tension between the asphalt and water. In emulsion form, the asphalt can be applied at much lower temperatures than would otherwise be possible. Second, the emulsifying agent determines the electrical charge on the surface of the asphalt particles (cationic [+], anionic [-], or nonionic). Usually, an emulsion is chosen with an electrical charge opposite to that of the aggregate—considered good charge compatibility. The theory is that like charges repel, and the emulsion will not bind well to aggregates with the same charge—charge incompatibility. Most aggregates used in Alaska have a negative charge (possible exceptions would be limestone type materials), and are therefore compatible with the cationic (+) emulsions, such as CRS-2 or CRS-2P (polymer modified) used for seal coats and double-layer ASTs. An exception to this charge compatibility is Alaska's combining of anionic emulsified asphalt HFMS-2s with common aggregates for high float AST pavements: both are negatively charged materials. This combination *does* work: although asphalt/aggregate bonding occurs without the aid of charge compatibility, the bond is more gradually established during the curing process.

Classification of Emulsified Asphalts: Emulsions are divided into three grades for classification: cationic, anionic, and nonionic. In practice, only the first two types are used in roadway construction and maintenance. In designating cationic emulsified asphalt, the first letter of the designation is "C." No similar designation is used for anionic emulsions.

In addition to being classified by their electrical charge, emulsions are further classified according to how quickly the asphalt particles leave the emulsion state and revert back to asphalt cement. The terms RS, MS, and SS have been adopted to simplify and standardize this classification. They are relative terms only and stand for rapid setting, medium setting, and slow setting.

High float emulsions are also available. High float emulsions, so designated because they pass the float test (AASHTO T-50 or ASTM D-139), permits a thicker asphalt film on the aggregate particles with a minimum probability of drainage because of the addition of certain chemicals. This property allows high float emulsions to be successfully used with somewhat dusty aggregate.

Finally, emulsions are subdivided by a series of numbers identifying the viscosity of the emulsion and the hardness of the base asphalt cement. The numbers 1 and 2 are used to designate the viscosity of the emulsion. The lower the number, the lower the viscosity and the more fluid the emulsion. When the number ends with the letter *h* or *s,* the emulsion contains harder or softer base asphalt. Lately, a "P" has been added as a suffix if the emulsion contains a polymer modifier. For example: HFMS-2sP means anionic (no "C" prefix), high float ("HF"), medium set ("MS") emulsified asphalt of relatively high viscosity ("2"), with a relatively soft base asphalt ("s"), and a polymer additive ("P").

Table 4.1. Examples of Emulsion Types (from The Asphalt Institute's MS No. 19)

Anionic Emulsified Asphalts (ASTM D 977, AASHTO M 140)	Cationic Emulsified Asphalts (ASTM D 2397, AASHTO M 208)
RS-1	CRS-1
RS-2	CRS-2
HFRS-2	—
MS-1	—
MS-2	CMS-2
MS-2h	CMS-2h
HFMS-1	—
HFMS-2	—
HFMS-2h	—
HFMS-2s	—
SS-1	CSS-1
SS-1h	CSS-1h

Emulsifiers: Emulsifiers are chemical solutions that give asphalt particles the ability to stay suspended in water. The two types of emulsifiers, cationic and anionic, are both comprised of salts.

Anionic emulsifiers are comprised of acids reacted with a base such as caustic potash or caustic soda to form a salt. It is this salt that is the active emulsifier. The emulsifier attaches to the asphalt particles. The number and density of these emulsifier molecules determine how much negative (-) charge is on the surface of the asphalt particles. Figure 4.2 is a simplified illustration of an anionic emulsified asphalt particle.

Cationic emulsifiers are also made of acid salts. Cationic emulsifiers give a positive (+) charge to

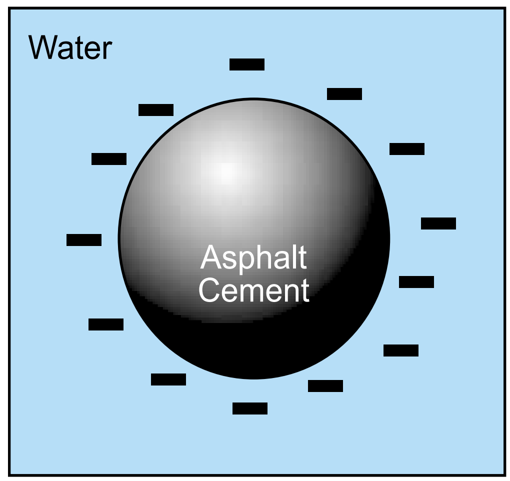

Figure 4.2. Anionic (-) emulsion

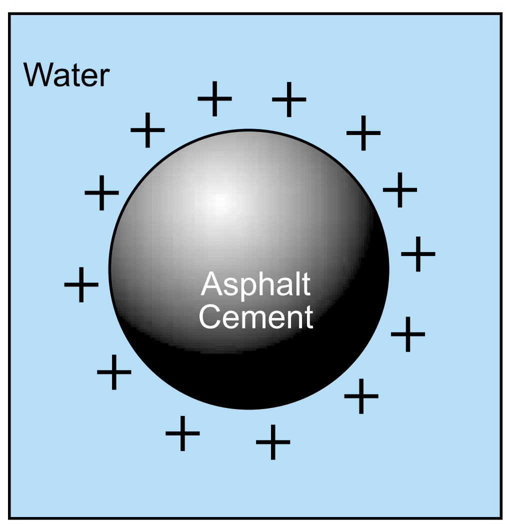

Figure 4.3. Cationic (+) emulsion

the asphalt particles. Most aggregates have a negative charge and thus attract cationic emulsifiers, causing a good initial bond. Figure 4.3 illustrates a cationic emulsified asphalt particle.

Cationic Versus Anionic: Overall, cationic emulsions perform more reliably in the field and set up more quickly than anionic emulsions, provided the correct handling and application procedures are used.

In addition:

- Cationics are less sensitive to weather because they have a more dependable break.
- Cationics can be stabilized without making break times longer.
- Cationics have to be handled more carefully.
- Cationics need close attention to storage procedures.
- Cationics are suitable for use with most aggregates, silica aggregates included.
- Cationics cure faster initially.

Properties of Emulsions: All the properties of emulsions and their behavior under various conditions are directly related to the type and strength of emulsifier used.

Anionic emulsions have a negative charge, as does almost every mineral. There will be no electrostatic attraction between the emulsion and the aggregate surface since like charges repel each other. For an anionic emulsion to break, the particles must get so close to each other that the surface charges are overcome by the attractive forces that exist between most things (as happens with high float ASTs). This occurs by forcing the particles together in some way. During AST construction, the original bond develops following compaction as the water evaporates out of the emulsion. Initial bond development may require three or more days, depending on the exact properties of a specific emulsion and as influenced by environmental conditions. The final bond is developed when all volatile components of the anionic emulsion have evaporated. In Alaska, the anionic emulsion HFMS-2s is used for high float ASTs.

Cationic emulsions have a positive charge and since opposite charges attract, they are drawn toward most aggregate particles. Thus, a direct and very rapid bonding between the emulsion and an aggregate or pavement is possible, as shown in Figures 4.4 and 4.5. The size of the charge affects stability. The larger the charge, the more rapid the reaction. The other mechanism that affects curing is evaporation. After the chemical break is completed, the water must still be completely evaporated for the residual asphalt to achieve full strength. In Alaska, the cationic emulsion CRS-2 is used for seal coat and double-layer ASTs.

Polymer Modified Emulsions: Certain properties of asphalt emulsions can be enhanced by the addition of polymers. The common polymer used

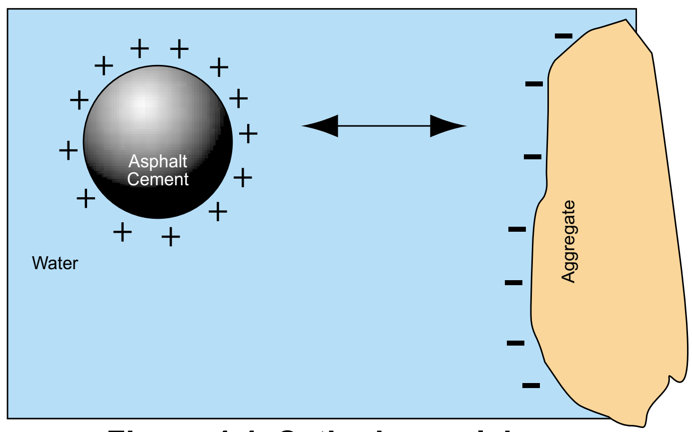

Figure 4.4. Cationic emulsion before breaking

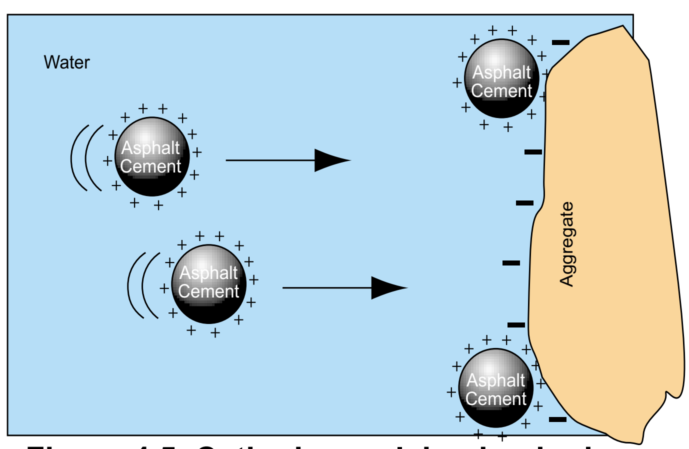

Figure 4.5. Cationic emulsion beginning to break

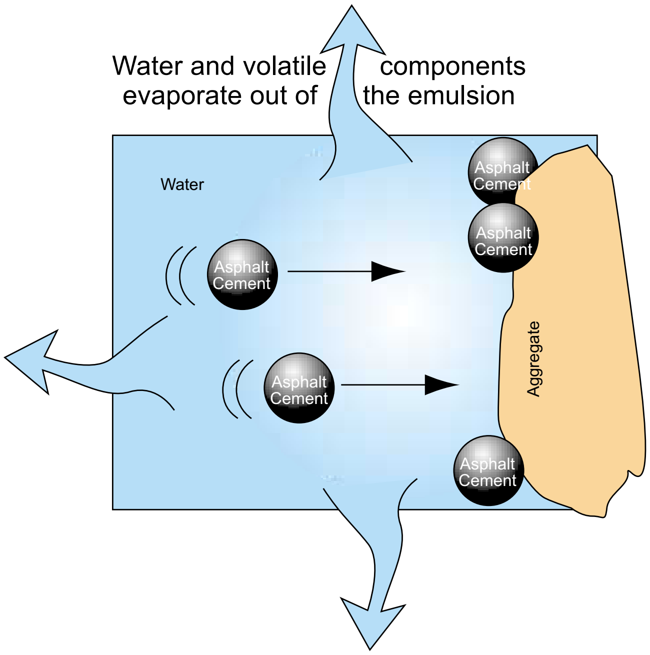

Figure 4.6. Anionic emulsion beginning to break

in Alaskan emulsions is styrene butadiene rubber (SBR). Typically, about 2 to 3% polymer by weight is added to the emulsion.

Advantages of using polymers are:

- Increased viscosity of the residual asphalt which helps to minimize bleeding
- Better early chip retention due to increased early stiffness
- Enhanced flexibility over time

The main disadvantage of using polymer-modified emulsions is the additional cost. Modified emulsions typically cost about 30% more than conventional emulsions. Alaska DOT&PF is gaining experience with polymer-modified emulsified asphalts used for seal coating and double-layer ASTs (using CRS-2P). The added cost appears to be warranted based on observed performance improvements. Following Canadian recommendations, Alaska does not presently use a polymer-modified version of HFMS-2s for high float ASTs.

General Factors Affecting Breaking and Curing: Some of the factors affecting breaking and curing rates of emulsified asphalts include:

- Water absorption—A rough-textured, porous aggregate speeds the setting time by absorbing water from the emulsion.
- Aggregate moisture content—While damp aggregate may facilitate coating, it tends to slow the curing process by increasing the amount of time needed for evaporation.
- Weather conditions—Temperature, humidity, and wind velocity all have a bearing on water evaporation rate, emulsifier migration, and water release characteristics. While breaking usually occurs faster at warmer temperatures, that is not always the case. Hot weather can cause skin formation on seal coats and double-layer ASTs, trapping water and delaying curing. There are some recently developed chemical formulations that break rapidly at cool temperatures.
- Mechanical forces—Roller pressure and, to a limited extent, slow-moving traffic forces water from the AST and helps attain AST cohesion, cure, and stability.
- Surface area—Greater aggregate surface area, particularly excessive fines or dirty aggregate, accelerates the breaking of the emulsion.
- Surface chemistry—Intensity of the aggregate surface charge, combined with the intensity of emulsifier charge, can impact setting rate, particularly for cationic emulsions. Calcium and magnesium ions on the aggregate surface can react with and destabilize certain anionic emulsifiers, accelerating setting.
- Emulsion and aggregate temperature—Low emulsion and aggregate temperatures retard breaking and subsequent curing.
- Type and amount of emulsifier—The surfactant used in the manufacture of the emulsion determines its breaking characteristics.

The Asphalt Institute recommends that the above factors be considered to determine working time after the emulsion has been sprayed. The emulsion supplier is the best source of advice.

4.1.1. Specifications and Test Methods

4.1.1.1. Cutback Asphalt for Prime

A prime coat may be applied before placing double-layer or high float ASTs. A properly applied and penetrating prime coat can effectively increase the total thickness of the AST by up to about 0.5 inch (12 mm). Prime provides a uniform surface in terms of adhesion. It also creates a gradational boundary of varying stiffness between the relatively soft base course and relatively stiff AST layer, which has some structural benefit. Prime coat is sprayed onto the base course surface and allowed to cure for about 24 hours before placing the AST.

Since prime coat can enhance the structural quality of the AST, shouldn't it always be used? The answer depends on whether you value the structural enhancement more than the cost of the prime. Given ideal conditions, a good prime coat may increase the life by more than 30%. The extra life potential can be wasted if the AST life expectancy is only two or three years because of a poor pavement structure or bad foundation conditions. Costs associated with priming include not only the purchase price of the material itself, but costs of additional equipment and storage capacity as well (an additional distributor may be required on the job). The prime itself can also cause problems. If the AST is placed before the prime is sufficiently cured, considerable curing time will be needed for the combined thickness of prime coat plus AST. The new AST will remain vulnerable to vehicle damage for perhaps months. Prime application will require additional traffic control since vehicles cannot be allowed on a freshly primed surface. The desirability of prime decreases if the job is already pushing the limits of weather or construction season.

If the job includes a prime coat, require that the surface be tight bladed immediately before applying the prime and that a penetrating prime be used. Tight blading consists of very lightly scarifying or roughening the compacted base course surface with a grader blade to a depth not exceeding about 0.25 inch (6 mm).

Specify the medium-curing, cutback emulsified asphalt MC-30.

MC-30 must meet the quality requirements of AASHTO M 82, Table 1, with the following exceptions:

- Maximum absolute viscosity of residue from distillation at 140˚F (60˚C) = 1000 Poises (100 Pa-s)
- Maximum distillate percentage by volume of total distillate to 437˚F (225˚C) = 35

Specify storing MC-30 at 140˚F (60˚C) maximum and spray application at 86+˚F (30+˚C).

4.1.1.2. For Seal Coats and Double-Layer ASTs

Specify the cationic, rapid-setting emulsified asphalt CRS-2 or the polymer-modified, cationic, rapid-setting emulsified asphalt CRS-2P.

CRS-2 must meet the quality requirements of AASHTO M 208, Table 1.

Specify storing CRS-2 at between 104 and 176˚F (40 and 80˚C) and spray application at between 122 and 176˚F (50 and 80˚C).

CRS-2P must meet the quality requirements of AASHTO M 316, Table 1, with the following exception:

- Maximum Saybolt Furol viscosity at 122˚F (50˚C) = 1,000 seconds

Specify storing CRS-2P at between 100 and 176˚F (38 and 80˚C) and spray application at between 160 and 190˚F (71 and 88˚C).

Special Manufacturing Requirements for CRS-2P: Require that polymer solids used in the manufacture of CRS-2P be introduced into the asphalt material by means of a high-speed colloid mill at an established emulsified asphalt production facility. Do not allow job-site addition of polymer additives to normal emulsified asphalts.

4.1.1.2. For High Float ASTs

Specify high float, anionic, medium-setting emulsified asphalt HFMS-2s:

HFMS-2s must meet the quality requirements of AASHTO M 140.

In addition to the AASHTO M 140 test series, Canada's Yukon Government Community and Transportation Services recommends the non-standard "tipped can test." This simple laboratory test examines the coating tenacity of the emulsion's base asphalt component. Indirectly, it addresses the question of whether the asphalt will remain in place as a thick coating on the cover aggregate or tend to drain from the aggregate. First, asphalt cement is extracted from the emulsion by distillation methods described in AASHTO test method T 59. The extracted material is poured into a standard asphalt cement penetration tin and allowed to cool to room temperature (tin dimensions are described in AASHTO T 49). After cooling, the tin is placed on its side (no lid) and observed occasionally for 12 hours. Expect poor long-term coating performance if most of the asphalt drains from the tin in less than three hours. Expect adequate long-term coating if most of the asphalt remains in the tin for 12 hours.

Specify storing HFMS-2s at between 126 and 185˚F (52 and 85˚C) and spray application at between 149 and 180˚F (65 and 82˚C).

4.1.2. Storing and Handling Emulsified Asphalts

These handling, storing, and sampling guidelines are extracted from The Asphalt Institute's MS-19, third edition. They are based on a long history of successful field use of asphalt emulsions; the guidelines should be followed. Questions about the handling, storage, or sampling of asphalt emulsions should be referred to your emulsion supplier.

4.1.2.1. Storing Emulsified Asphalt

Emulsified asphalt, a dispersion of fine droplets of asphalt cement in water, has both the advantages and disadvantages of the carrier medium, water. When storing emulsified asphalts:

DO store at the temperature specified for the particular grade and application. See below for normal storage temperature ranges.

DO NOT permit normal asphalt emulsions to be heated above 185˚F (85˚C). Elevated temperatures evaporate the water, changing the characteristics of the asphalt emulsion.

DO NOT let the emulsion freeze. This breaks the emulsion, separating the asphalt from the water. The result will be two layers in the tank, neither of which will be suited for the intended use, and the tank will be difficult to empty.

DO NOT allow the temperature of the heating surface to exceed 212˚F (100°C). This will cause premature breakdown of the emulsion on the heating surface.

DO NOT use forced air to agitate the emulsion. It may cause the emulsion to break.

Storage tanks should be insulated for protection from freezing and most efficient use of heat. A skin of asphalt can form on the surface of emulsions when exposed to air. Therefore, it is best to use tall, vertical tanks that expose the least amount of surface area to the air. Most fixed storage tanks are vertical, but horizontal tanks are often used for short-term field storage. Skinning can be reduced by keeping horizontal tanks full to minimize the area exposed to air.

Side-entering propellers located about 3.3 feet (about one meter) up from the tank bottom may be used to prevent surface skin formation. Large diameter, slow-turning propellers are best and should be used to roll over the material. Over-mixing should be avoided. Tanks may also be circulated top to bottom with a pump. Avoid over-pumping. The following temperature ranges are presently used in Alaska and are taken from the latest specifications (see Appendix C).

- Store CRS-2 at temperatures between 104 and 176˚F (40 and 80˚C)
- Store CRS-2P at temperatures between 100 and 176˚F (38 and 80˚C)

- Store HFMS-2s at temperatures between 126 and 185˚F (52 and 85˚C)

Handling Emulsified Asphalt

DO blow out lines and leave drain plugs open when they are not in service.

DO use pumps with proper clearances for handling emulsified asphalt. Tightly fitting pumps can bind and seize.

DO warm the pump to about 149˚F (65˚C) to facilitate start-up.

DO when diluting emulsified asphalt, check the compatibility of the water with the emulsion by testing a small quantity.

DO if possible, use warm water for diluting, and always add the water slowly to the emulsion (not the emulsion to the water).

DO avoid repeated pumping and re-circulating, because the viscosity may drop and air may become entrained, causing the emulsion to be unstable.

DO place inlet pipes and return lines at the bottom of tanks to prevent foaming.

DO pump from the bottom of the tank to minimize contamination from skinning that may have formed.

DO remember that emulsions with the same grade designation can be very different chemically and in performance.

DO haul emulsion in truck transports with baffle plates to prevent sloshing.

DO agitate emulsions that have been in prolonged storage. This may done by recirculation.

DO NOT mix different classes, types, and grades of emulsified asphalt in storage tanks, transports, and distributors. See Table 4.2 for recommendations. Also check with the manufacturer for their recommendations.

DO NOT apply severe heat to pump packing glands or pump casings. The pump may be damaged.

DO NOT dilute rapid-setting grades of asphalt emulsion with water. Medium and slow setting grades may be diluted, but always add water slowly to the asphalt emulsion. Never add the asphalt emulsion to a tank of water when diluting.

DO NOT load asphalt emulsion into storage tanks, tank cars, tank transports, or distributors containing remains of incompatible materials. See Tables 4.2 and 4.3.

DO NOT subject emulsified asphalt or air above it to an open flame, heat, or strong oxidants.

DO NOT breathe fumes, vapors, and mist. Adequate ventilation is required.

DO NOT work without a copy of the supplier's material safety data sheet (MSDS). Read the MSDS carefully and follow it.

Table 4.2. Guide for Condition of Emptied Tanks Before Loading Asphalt Emulsions

	Last Product in Tank					
Product to be Loaded	**Asphalt Cement (Includes Industrial Asphalt)**	**Cutback Asphalt and Residual Fuel Oils**	**Cationic Emulsion**	**Anionic Emulsion**	**Crude Petroleum**	**Any Product Not Listed**
Cationic Emulsion	Empty*	Empty to no measurable quantity	OK to Load	Empty to no measurable quantity	Empty to no measurable quantity	Tank must be cleaned
Anionic Emulsion	Empty*	Empty to no measurable quantity	Empty to no measurable quantity	OK to Load	Empty to no measurable quantity	Tank must be cleaned

* Any material remaining will produce dangerous conditions

Table 4.3. Possible Causes of Contamination of Asphalt Materials or Samples and Suggested Precautions

Haulers and Hauling Vehicles

Field observations and studies of test results indicate that materials often get contaminated during transportation.

Possible Causes	Precautions
Previous load not compatible with emulsion being loaded	Examine the log of loads hauled or check with the supplier to determine if previous material hauled is detrimental. If it is, make sure vehicle tanks, unloading lines, and pump are properly cleaned and drained before being presented for loading. Provide a ramp at the unloading point at the plant to ensure complete drainage of vehicle tank while material is still fluid.
Remains of diesel oil or solvents used for cleaning and flushing of tanks, lines, and pump	When this is necessary, make sure all solvents are completely drained.
Flushing of solvents into receiving storage tank or equipment	Do not allow even small amounts to flush into storage tank; entire contents may be contaminated.

Mixing Plant Storage Tank and Equipment

Many investigations and test results point to mix plant storage tanks and associated equipment as the source of contamination.

Possible Causes	Precautions
Previous material left over in tank when changing to emulsion.	Any material allowed to remain must be compatible with the emulsion, and the amount remaining in the tank must be insufficient to cause emulsion to become out of specification. If in doubt, check with your supplier. To be on the safe side, tank should be drained or cleaned before using tank for each different type or grade of asphalt. Be sure to discharge the line connects at low point of storage tank to ensure complete emptying when changing type or grades of asphalt or cleaning tank.
Solvents used to flush hauling vehicle tank discharged into storage tank.	Observe unloading operations and caution the driver about flushing cleaning materials into storage tank. If possible, provide place for hauler to discharge cleaning materials.
Flushing of lines and pump between storage tank and mixing plant with solvents and then allowing this material to return to tank.	If necessary to flush lines and pump, suggest providing bypass valves and lines to prevent solvents from returning to tank. A better solution

	is to provide insulated, heated lines and pump, thereby eliminating the necessity of flushing.
Cleaning of distributor tank, pump, spray bar, and nozzles with solvents.	Be sure all possible cleaning material is drained off or removed before loading.
Dilutions from hot oil heating systems.	Check reservoir on hot oil heating system. If oil level is low, or oil has been added, check system for leakage into the asphalt supply.

Non-Representative or Contaminated Sample

Test results are greatly dependent upon proper sampling techniques. The sampler must take extra care to obtain samples that are truly representative of the material being sampled. This will do much to eliminate the possibility of erroneous test results by reason of improper sampling. Make sure samples are taken only by authorized persons who are trained by the Western Alliance for Quality Transportation (WAQTC) in sampling procedures.

Possible Causes	Precautions
Contaminated sampling device (commonly called a "sample thief").	If the sampling device (described in ASTM D 140 or AASHTO T 40) is cleaned with diesel oil or solvent, make sure that it is thoroughly drained and then rinsed out several times with the emulsion being sampled before taking sample.
Samples taken with sampling device from top of tank where, under certain conditions, contamination can collect on the surface.	In taking a sample from the top of a tank, lower the sampling device below the extreme top before opening the inlet of the device. Note: This sample may come from the top one-third of the tank.
Contaminated sample container.	Use only new, clean containers. Never wash or rinse a sample container with solvent. Wide-mouthed plastic jars or bottles or plastic-lined cans should be used.
Sample contaminated after taking.	DO NOT submerge container in solvent or wipe the outside of the container with a solvent-saturated rag. If necessary to clean spilled emulsion from outside of container, use a clean, dry rag. Make sure container lid is tightly sealed before storage or shipment. Ship to testing laboratory promptly.
Samples taken from spigot in lines between storage tank and mixing plant.	If the sampling spigot is in a suction line between the tank and pump, this requires stopping the pump before taking a sample. Samples thus taken are by gravity and only representative of emulsion localized in the pipe area of the spigot.

	DO NOT take a sample while the hauling vehicle is pumping into storage tank. DO NOT take a sample without allowing enough time for circulation and thorough mixing of emulsion. DO drain off sufficient material through spigot before taking a sample to ensure removal of material lodged in spigot. DO take a sample slowly during circulation to be more representative of the emulsion being used.
Samples taken from unloading line of hauling vehicle.	Drain off sufficient emulsion through the spigot before taking a sample to ensure removal of any material lodged there. Sample should be taken after one-third and not more than two-thirds of the load has been removed. Take the sample slowly to be sure it is representative of the emulsion being used.

4.1.3. Sampling Emulsified Asphalt

The purpose of any sampling method is to obtain samples that will show the true nature and condition of the material. The general procedure is described below. The standard procedure is further detailed in "Standard Methods of Sampling Bituminous Materials," ASTM D 140 or AASHTO T 40. Containers for sampling asphalt emulsion must be wide-mouth jars or bottles made of plastic, or wide-mouth plastic-lined cans with lined screw caps, or plastic-lined triple-seal friction-top cans. Fill the sample containers about 95% full to prevent sloshing. Sample the asphalt emulsion at the point of manufacture or storage whenever practical. If that is not practical, take samples from the shipment immediately upon delivery. Take three samples of the asphalt emulsion. Send the samples to the laboratory for testing as soon as possible.

Sampling Precautions

- Use new containers. Do not use washed or rinsed containers. If they contain evidence of solder flux, or if they are not clean and dry, discard the containers. Verify that the top fits the container tightly.
- Do not allow the samples to become contaminated. (See last section of Table 4.3.) Do not submerge the sample container in solvent, nor wipe it with a solvent-saturated cloth. If there is residual material on the outside of the container, wipe it away with a clean, dry cloth immediately after the container is sealed and removed from the sampling device.
- Do not transfer the sample to another container.
- Tightly and positively seal the filled container immediately after the sample is taken.

Safety Precautions

Safety precautions are mandatory at all times when handling asphalt materials. These safety precautions include, but are **not** limited to:

- Wear gloves that provide protection against hot, fluid materials. Roll sleeves down and fasten them over the gloves at the wrist while sampling and while sealing containers.
- Wear a face shield while sampling.
- Do not smoke while sampling asphalts.
- Avoid prolonged breathing of fumes, vapors and mists.
- During sealing and wiping, place the container on a firm level surface to prevent splashing, dropping, or spilling the material.

Protection and Preservation of Samples

- Immediately after filling, sealing, and cleaning, properly mark the sample containers

Table 4.4. Aggregate Gradation Requirements (Determined by Alaska Test Method [ATM] T-7)

	Grading % Passing by Weight		
Sieve, inches (mm)	**For Seal Coat AST (DOT&PF "E" chip)**	**For First Layer of Double-Layer AST (DOT&PF "B" chip)**	**For Second Layer of Double-Layer AST (DOT&PF "E" chip)**
1.0 (25 mm)		100	
0.75 (19 mm)		90-100	
0.50 (12.5 mm)	100	20-55	100
0.375 (9.5 mm)	90-100	0-15	90-100
#4 sieve (4.75 mm)	10-30	—	10-30
#8 sieve (2.36 mm)	0-8	—	0-8
#200 sieve (0.075 mm)	0-1	0-1	0-1

for identification with a permanent marker on the container itself, not on the lid.

- Package, label, and protect samples of emulsions from freezing during shipment.
- Limit shaking of the full containers as much as possible.
- Limit thermal cycling of the sample, i.e., store and ship materials in an environment with minimum temperature variation—near room temperature if possible.
- All samples should be packaged and shipped to the laboratory the same day they are taken. The containers must be tightly sealed and packed in protective material to reduce the probability of damage during shipment.
- Identify each sample with this information:
  - —— Shipper's name and bill of lading or loading slip number
  - —— Date sampled
  - —— Sampler's name
  - —— Product grade
  - —— Project identification
- Include a note with the samples reminding testing personnel to stir—not shake—the materials before pouring from the containers.
- Other important information as necessary.

4.2. Cover Aggregate

Keep records concerning materials sources and rock types used.

Do not use frozen cover aggregate materials.

AASHTO T-2 and ASTM D-75 test methods discuss correct methods for sampling aggregate materials. Obtain the most representative samples of aggregates from output-material belts during aggregate production. However, when it is necessary to sample from the stockpile, you will need to use special care to get a representative sample. The recommended way of sampling a stockpile is to obtain and average the test results from three samples. Obtain these samples from each of three bucket-loads of material extracted from the stockpile by a front-end loader. Request that the loader dig deeply (aggressively) into the side of the stockpile and at a different level for each sample. For process control, obtain samples representing about every 300 tons (270 megagrams) of aggregate production. For acceptance-for-payment, obtain samples representing about every 500 tons (450 megagrams) of production.

Table 4.5. Standard Aggregate Quality Requirements for Seal Coat and Double-Layer ASTs

Name of Test	Property Measured	Test Number	Required Value
Tests for Aggregate Soundness			
Percent of Wear	Dry Abrasion Wear	AASHTO T 96	45 max.
Degradation Value	Wet Abrasion Characteristics	ATM T-13	50 min.
Percent Sodium Sulfate Loss	Resistance to Freeze/Thaw Cycle Disintegration	AASHTO T 104	9 max. (after 5 cycles)
Tests for Aggregate Shape			
Percent Fracture	Roundness	ATM T-4	90 min. (single face)
Flakiness Index (%) *	Flatness/Elongation	Appendix D	30 max. **
Test for Aggregate/Emulsified Asphalt Compatibility			
Anti-Strip Test (percent)	Asphalt-to-Aggregate Adhesion	ATM T-14	70 min.

* The flakiness index is obtained as part of the mix design process (see Appendix D). This gives a percentage, by weight, of the aggregate that consists of flat and elongated pieces.

** On high-volume roadways, the flakiness index should not exceed 20%.

4.2.1. Specifications and Test Methods

4.2.1.1. Aggregate for Seal Coats and Double-Layer ASTs

Importance of Using Clean Aggregate

Aggregates containing dust should not be used for seal coating unless certain precautions are taken. To avoid dusty aggregate, the guide's specification requires 1% or less passing the #200 sieve (0.075 mm). Some states require 0.5% or less passing the #200 sieve. Dust coatings on the aggregate particles prevent a good bond between asphalt and aggregate and will result in extensive chip loss.

If clean aggregate is not available, do one or more of the following:

- Wash the aggregate using clean, potable water.
- Use polymer-modified emulsified asphalt (CRS-2P). Although more expensive than the normally used CRS-2, the modified oil is extremely tacky and will bond more tenaciously to any aggregate. Keep in mind that the additional tackiness of polymer-modified asphalts may increase the problem of vehicle coating if too much oil is applied.
- Precoat the chips with asphalt cement. This technique involves putting the aggregate through an asphalt plant and coating it lightly with asphalt. This will bond the dust to the aggregate. Precoated aggregate is slated for a trial in Alaska, but proven Alaska specifications are not available at the time of this writing.
- Precoat the chips with a lime/water solution.

Importance of Aggregate Strength (Soundness)

The AST aggregate is the load-bearing component of the AST. The aggregate must therefore be "tough." It must withstand years of traffic abrasion, and it must resist disintegration during the freeze-thaw cycling it is subjected to in Alaska. Soundness requirements ensure that the aggregate has sufficient long-term strength against mechanical breakage.

Soundness specifications qualify material sources as being acceptable or unacceptable for use on a particular project (as opposed to use as an acceptance-for-payment testing during construction. The contractor may call soundness test results (percent wear, degradation value, and percent sodium sulfate loss) into question whenever materials from a particular source do not pass the specification. These tests determine whether a contractor will be allowed to use a particular materials source or not, and are therefore packed with economic consequence. Specification limits set for soundness are derived from empirical evidence of good versus poor performance, and are therefore intended as general limits separating acceptable from unacceptable performance. These are referred to as "index-type" tests because they predict an index, i.e., category of performance. There is no continuous quantitative function between test value and performance! Therefore, if the contractor questions the performance ramifications of violating soundness specifications by some specific amount, you (the project owner) will ***not*** **be able to predict the amount of performance degradation. If such measures become absolutely necessary, soundness specifications should be lowered or eliminated only after consultation with Regional and/or Statewide Materials personnel.**

Importance of Aggregate Shape

To a large extent, the stability of the AST is controlled by the shape of the individual cover aggregate particles. Aggregate particle shape is characterized by:

- flatness and/or elongation of the particle, and
- degree of rounding of the particle's edges and corners.

Impact of Aggregate Flatness or Elongation

Traffic will determine the final chip orientation of ASTs constructed with flat and elongated aggregate. The flatter the aggregate, the more susceptible the AST will be to either bleeding in the wheelpaths or excessive aggregate loss in the nonwheelpath areas. In the wheelpath, traffic

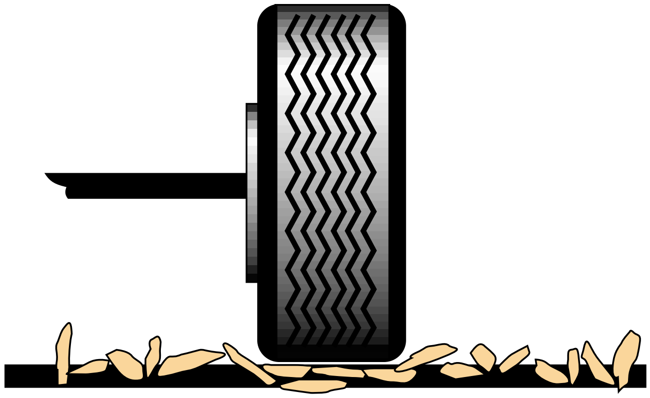

Figure 4.7. Traffic causes flat and/or elongated aggregate in wheelpath to rotate until long axis is horizontal

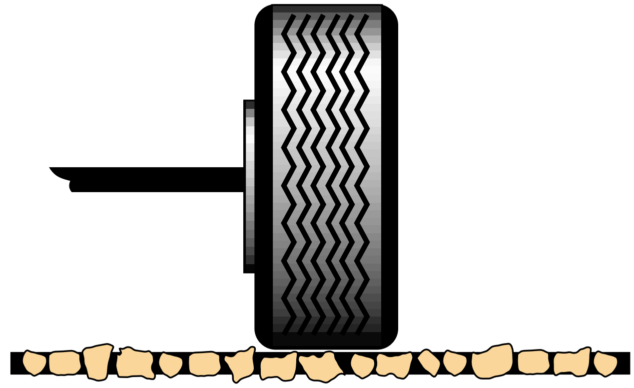

Figure 4.8. Cubical aggregate does not rotate under traffic

causes flat particles to lie on their flattest side. The AST therefore becomes thinner in the wheelpath than in the nonwheelpath areas, as shown in Figure 4.7. If the oil is applied too thick in the wheelpaths, bleeding will result when the chips lie on their flat side. If too little oil is applied, cover aggregate in the nontraffic areas will be dislodged by traffic and snow plow blades.

On low volume roads, these differences in AST thickness may not become a problem because it requires repeated applications of traffic to reorient aggregate particles their flattest side. If the traffic volume is very low, or the traffic is not confined to a specific wheelpath (unlikely except on very wide road surfaces, parking lots, etc.), there may not be a large enough difference in particle height to cause a problem.

Table 4.7. Standard Aggregate Quality Requirements for High Float AST

Name of Test	Property Measured	Test Number	Required Value
Tests for Aggregate Soundness			
Percent of Wear	Dry Abrasion Wear	AASHTO T 96	50 max.
Degradation Value	Wet Abrasion Characteristics	ATM T-13	30 min.
Percent Sodium Sulfate Loss	Resistance to Freeze/Thaw Cycle Disintegration	AASHTO T 104	9 max. (after 5 cycles)
Tests for Aggregate Shape			
Percent Fracture	Roundness	WAQTC TM-1	70 min.
Thin-Elongated Pieces (percent)	Flatness/Elongation	ATM T-9	8 max.
Test for Aggregate/Emulsified Asphalt Compatibility			
Anti-Strip Test (percent)	Asphalt-to-Aggregate Adhesion	ATM T-14 This test is called for in some DOT&PF specifications, but DO NOT USE IT !	No Requirement
Test for Clay in the Aggregate			
Plasticity Index *	Deleterious Plastic Nature of Material	AASHTO T-90	3 max.

* Prepare material for AASHTO T 90 according to the wet preparation method (AASHTO T 146).

Traffic will not have a pronounced effect on final chip orientation with cubical aggregate. No matter how the particles are oriented, the average aggregate height will be essentially the same so asphalt embedment remains uniform.

Tips for Using Flat Aggregate:

- In the mix design process (Appendix D), calculate the amount of binder required for both the wheelpath and non-wheelpath areas. This will give you a feel for the difference in AST thickness between these two areas.
- Flat aggregate should not be used on high volume roadways! There will be too much binder in the wheelpaths or not enough between them. For high volume roadways, only cubical aggregate with a flakiness index of 20% or less should be used.
- Use a little extra aggregate (5 to 10%) in the wheelpaths to prevent the flat aggregate particles from sticking to the tires of the aggregate spreader and dump trucks while the binder is curing. This can be done by increasing the opening of the spreader gates in these areas. Remember, if enough oil is applied to hold onto the tall particles in the nontraffic areas, flat materials in the wheelpath will likely be covered with oil. The excess aggregate will help to prevent asphalt-coated aggregate from sticking to vehicles.
- Modify the spray bar on the asphalt distributor so that it has smaller nozzles in the wheel-paths than it does in the areas between them. If done properly, this technique places slightly more binder in nonwheelpath areas than in wheelpath areas.

Impact of Aggregate Roundness

The roundness of the aggregate will determine AST susceptibility to damage by turning and stopping movements. In AST specifications, the degree of roundness is characterized in terms of percent fracture. Round aggregates (low percent fracture) are much more susceptible to rolling and displacement by traffic than angular aggregates (high percent fracture).

Importance of Compatibility Between Aggregate and Emulsified Asphalt

An unsettlingly frequent problem on Alaska AST projects is loss of aggregate shortly after construction. The word usually goes out that the oil has unusually poor adhesion qualities. This is most often blamed on dirty aggregate, aggregate-oil surface charge incompatibility, or some sort of emulsion supplier quality control problem, although poor weather conditions (slow curing) probably plays a hand in many if not most cases. The bottom line is that forensic studies of Alaska AST failures often cannot pin down the specific problem source. The anti-strip test reduces some of the variables by verifying (at least in the laboratory) that your project's emulsified asphalt will stick to your project's aggregate. Poor anti-strip test results alert the emulsified asphalt manufacturer that the emulsion composition needs changing or that anti-strip additive might be necessary.

4.2.1.2. Aggregate For High Float ASTs

Table 4.6. Aggregate Gradation Requirements for High Float AST (Determined by AASHTO T-27 and T-88)*

Sieve, inches (mm)	Grading % Passing by Weight
0.75 (19 mm)	100
0.50 (12.5 mm)	63–89
0.375 (9.5 mm)	54–76
#4 sieve (4.75 mm)	36–56
#8 sieve (2.36 mm)	18–38
#16 sieve (1.18 mm)	12–30
#50 sieve (0.30 mm)	4–18
#200 sieve (0.075 mm)	0–5
0.0002 inch (0.005 mm)	0–3**

* Determine the gradation by AASHTO T 27 and T 88 except dry the material for the T-88 test within a temperature range of 90 to 100˚F (32 to 38˚C).

** Verify compliance with the minus 0.0002 inch (0.005 mm) size fraction at least once for each source used. This requires a hydrometer-type gradation test.

Importance of Using Clean Aggregate

High float cover aggregate is well graded, so a small percentage of fines is actually desirable. To avoid overly dirty aggregate, the specification shows 5% or less passing the #200 sieve (0.075 mm). Excess minus #200 sieve (0.075 mm) material absorbs too much of the emulsified asphalt while also preventing the best possible bond between asphalt and aggregate. An ideal amount of #200 sieve (0.075 mm) size material is about 2 to 4% even though the gradation specification allows up to 5%.

Any appreciable amount of clay-size material in the high float aggregate is bad! The gradation specification limits clay content to 0 to 3% minus 0.0002 inch (0.005 mm). An overly moist, well-graded material containing clay will tend to clump and cannot be evenly distributed by the aggregate spreader. Such aggregates retain excess moisture after placement, causing stability problems. Furthermore, the clay can form a hard caking at the AST surface that makes brooming very difficult.

- Do not use clayey aggregates if other aggregates are available.
- If you must use clayey aggregates, take every care to keep the moisture content below 3% in the stockpile, during transport, and during construction. After construction and before a week of warm, dry curing weather, a single heavy rainstorm plus traffic action will likely ruin the AST.

A Quick Field Test for the Presence of Clay

To determine if the high float cover aggregate contains a significant amount of clay, obtain about 2 to 4 lbs (1 to 2 kg) of the aggregate. Then sieve out and retain a generous handful of material from the minus sand size fraction. Add tap water to a handful of material until it is saturated. Mold and squeeze the wetted material in your hands until the water is uniformly mixed throughout the mass (add water as necessary to keep material saturated). The idea is to work the wetted material until it thickly coats the palms and fingers. Then place your hands under gently running water (protect the drain). See how much of the coating rinses off *without rubbing your hands together.* If any appreciable amount of sticky, greasy-feeling coating remains, you have a potential construction problem. If no coating remains there is very little or no clay—good.

Importance of Aggregate Strength (Soundness)

Same as above comments for seal coat and double-layer AST aggregate.

Importance of Aggregate Shape

Similar to above comments for seal coat and double-layer AST aggregate, although not as critical. Aggregate shape for high float cover aggregate particles is defined using a different test method than that used for seal coats and double-layer ASTs (compare in Tables 4.5 and 4.7).

Importance of Compatibility Between Aggregate and Emulsified Asphalt

Until recently, the anti-strip test was required for determining compatibility between high float emulsified asphalt and cover coat material used for high float ASTs. This was a long-standing requirement regardless of the fact that most aggregates used in Alaska are known to carry a negative surface charge and that high float HFMS-2S oil is an anionic (-) material. Limestone and dolomite are examples of possible aggregate types that would carry a positive surface charge, but these materials are not normally a major component of high float cover coat aggregate in Alaska. Recent Northern Region DOT&PF testing has confirmed that common aggregate types used in Alaska will almost always fail if subjected to anti-strip testing. Therefore, laboratory and Statewide Research personnel are of the opinion that anti-strip testing is irrelevant with respect to high float AST components.

4.2.1.3. AST Blotter Material

At times weather or materials-related problems may become apparent during AST construction that make the new AST surface unstable. You can often minimize development of such damage by applying a thin layer of blotter material (the method of application is covered in Chapter 7).

Specify clean sand that passes the #10 sieve (2.0 mm), and contains no more than 0.5% material passing the #200 sieve (0.075 mm) (use Alaska Test Method [ATM] T-7 to determine gradation).

4.2.2. Stockpile for Cover Aggregate

Use care when locating and protecting the stockpile. If possible, place the stockpile on a hard surface that is well graded for drainage. A hard surface minimizes the chance that foreign materials stirred up and tracked about by the loader will contaminate the stockpile. Good drainage keeps the lower part of the stockpile from becoming saturated (especially important with high float cover aggregate), and helps minimize contamination.

Be aware that repeated storm action washes fines from material on the surface of the stockpile and deliver those fines deeper into the core of the pile. During the job, periodically verify that the aggregate at various locations within the pile is within gradation specification. Belt-washed aggregates can also drop excess fines into the pile at locations directly below the belt discharge.

Do not use frozen cover aggregate materials.

4.2.2.2. Loader

A standard front-end loader is required to load aggregate from the stockpile into delivery trucks. The one exception to this would be when aggregate is obtained directly from an aggregate supplier. In that case, the trucks would be loaded at the pit or quarry.

- Special training requirement—special training on mixing and loading stockpile materials, and any necesary Mining Safety and Health Administration (MSHA) training
- Reliable loader needed or backup readily available
- Select bucket type for most efficient loading from a stockpile
- Use an adequate size loader for the job
- Use a bucket having a smooth lip—no teeth

4.2.2.3. Moisture Control for High Float Cover Aggregate

The moisture content of high float cover aggregate stockpiles is critical. With a moisture content of near 0%, the material will not absorb the high float emulsified asphalt (overly dry material will likely *never* be a problem under Alaska conditions). When the moisture content is too high, the aggregate may not spread uniformly and may actually form clumps. High moisture content also greatly increases curing time (overly moist material will be a concern on almost every Alaska project). Be aware that within the timeframe of your project, you may not have enough time to dry materials that are too wet at the source; think about this when you choose your source and/or plan your project schedule. Always avoid any conditions that cause an increase in curing time!

The latest DOT&PF specifications require a narrow moisture content range of between 2 and 4%. Plan on sticking with this range if at all possible. Although the requirement seems strict, it has proven necessary for most Alaska aggregates. High float construction personnel recounted problems on one project when the moisture content exceeded 3%. Moisture content will be most critical for cover aggregates that exceed the allowable fines content (#200 sieve [0.075 mm] content) of 5%. The situation only becomes worse if the material contains clay. The #200 sieve (0.075 mm) and 0.0002 inch (0.005 mm) limits shown in Table 4.6 ensure that the moisture sensitivity of the cover aggregate is minimized.

Strongly Recommended: Plan on having available some method of covering the stockpile.

4.2.2.4. Handling Stockpiled Materials

Stockpile materials should be moved around as little as possible. Once the stockpile is created, every additional step in handling breaks larger particles into smaller particles. Stockpiles composed of some metamorphic rock types or freshly crushed, weathered materials are particularly susceptible to generation of fines during handling. Quality requirements in Tables 4.5 and 4.7 minimize this problem.

Segregation is the enemy of a well-mixed, uniform stockpile. Segregation occurs when the course particles have separated from the fine particles. Poor handling technique will always tend to segregate stockpile materials (very important with high float cover coat).

For high float cover coat stockpiles, the following information is critical for keeping the material within gradation specification. For stockpiles of seal coat or double-layer AST aggregate, the guidelines still apply but are less critical.

When adding material to the stockpile, minimize particle-to-particle impact and segregation:

- Minimize drop height from belts.
- Do not build up a high, steep-sloped cone at one location—layer material into the stockpile by moving the belt discharge or by filling the stockpile layers using a loader.
- The ideal maximum height for a stockpile is no higher than the loader bucket can reach.

When removing materials from the stockpile, minimize segregation:

- Do not skim material from around the periphery of the stockpile; enter the pile aggressively with the loader.
- Do not load material from the bottom of the stockpile.
- Enter into the side of the pile with the loader bucket held in a fairly high position.

When loading the trucks, minimize segregation:

- Minimize drop height into trucks.
- Do not drop aggregate into the truck in a single pile—use the loader to layer the aggregate into the trucks in two or three piles, e.g., "front-back-middle" load technique.

When loading trucks, require a screening-out of oversize contamination that may be present in the stockpile. This prevents clogged chip spreader gates.

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Chapter 5. General Safety and Traffic Control

WARNING! This section contains general guidelines for doing an efficient and safe job. INFORMATION CONTAINED IN THIS SECTION DOES NOT REPLACE THE NEED FOR A TRAFFIC ENGINEER OR A QUALIFIED TRAFFIC CONTROL SUPERVISOR. CONSULT WITH YOUR REGIONAL TRAFFIC SAFETY ENGINEERING STAFF TO VERIFY THAT YOU ARE PLANNING ADEQUATELY FOR SAFETY.

If you are a contractor working for DOT&PF, you MUST refer to your plans and specifications for traffic control requirements. The information in this chapter does not replace requirements in the plans and specifications.

ANY M&O employee who develops TCPs or flags must attend appropriate training and obtain any certifications required by Department policy.

SAFETY STANDS ABOVE ANY OTHER ASPECT OF THE JOB IN IMPORTANCE. Grief and monetary damages from injury or death caused by safety oversights/shortcuts will have a profound effect on you and the department.

Traffic control devices used during construction and maintenance must conform with the Alaska Traffic Manual. The Alaska Traffic Manual is composed of the Alaska Traffic Manual Supplement and the FHWA *Manual on Uniform Traffic Control Devices* (MUTCD). Part 6 of the MUTCD addresses work zone traffic control and is available as a small booklet.

Traffic Control Plans (TCPs) should be approved by your Regional Traffic Engineer before work begins.

You must:

- Have your Traffic Control Plan approved by your regional traffic engineer before starting work. Develop a traffic control plan in consultation with your regional DOT&PF regional traffic safety engineer. Adhere to your traffic control plan at all times and make sure that traffic control devices keep up with the project. Nothing less will do.
- Follow all manufacturer-recommended safety precautions with respect to equipment.
- Inspect equipment daily for safety and acceptable operation.
- Follow established safety requirements with respect to handling materials (see section 5.6).
- Radios allow operators and supervisors to keep the job running smoothly, but they are essential tools for job safety as well.

5.1. Training Level for Safe, Efficient Operations

Allowing for closely supervised on-the-job training is an acceptable and necessary part of construction. However, management should have enough well-trained personnel to closely supervise trainees on every item of project equipment (including pilot vehicles). Operators directly involved in the paving materials application (emulsion distributor, aggregate spreader, aggregate haul trucks) should have advanced training to maintain a safe, efficient operation.

Flagger requirements are in the Alaska DOT&PF Highway Construction Specification manual, subsection 643-3.04, Traffic Control Devices. M&O flaggers should attend an approved flagger class. In addition to training, verify that flaggers remain alert and exhibit safety consciousness. By providing the illusion of safe traffic control, a lazy or otherwise impaired flagger may be worse than no flagger. Flaggers often provide the sole public relations interface between the job and the traveling public. Because of this function, flaggers need to be kept informed of delay times and unusual conditions within the working areas.

For long delay times, it is useful if flaggers are reasonably personable yet strict and can deliver a brief description of the project if asked. Except for small jobs such as small maintenance patches, flaggers must have radio communications with other flaggers, pilot cars, and worksite management.

5.2. Work Zone Traffic Maintenance

For small jobs—in-house maintenance work, etc.—traffic management can be simpler than on larger projects. Before small-job activities, contact the regional traffic safety engineer for advice concerning barriers, signing, and flagging requirements. Realize that safety requirements change with time. Abnormal conditions are the rule in work zones, making traffic particularly dependent on proper design, placement, and uniformity of traffic control devices. The consistently shifting and changing nature of work zones require frequent readjustment of traffic control devices.

Signs useful on smaller jobs include but are not limited to:

- Road Work Ahead
- Be Prepared to Stop
- Flagger Ahead (text sign)
- Flagging icon (a pictorial sign)
- Fresh Oil
- Loose Gravel
- Speed Limit signs
- Truck Crossing

The following information was modified slightly from documentation used by Northern Region M&O personnel on small to moderate-sized AST jobs:

Worksite Traffic Supervisor

The foreman and his appointed traffic supervisor are responsible for maintaining traffic operations in accordance with the traffic control plan and for accommodating traffic safety at the work site.

The traffic supervisor must understand the requirements of the Alaska Traffic Manual, Traffic Control Plan (TCP), and specifications. The foreman will make sure that a TCP is approved by the regional traffic engineer and that all devices are in place and maintained before and during construction operations. The foreman will periodically verify that the plan is working and be prepared to modify it as necessary.

Public Notification

Public notice of major changes, detours, delays, lane restrictions, or road closures should be given to local officials, including but not necessarily limited to:

- Alaska State Troopers
- Local Police
- Emergency Services
- School Transportation
- Railroads
- Pipeline Security
- Major Tour Operators
- Alaska Carriers Association

Emergency equipment must be given immediate passage through the project.

Traffic Control Plan

The TCP must be in conformance with the Maintenance & Operations manual and, if applicable, TCPs in the design documents for the project before work begins. Minor modifications to the TCP must be approved by either an American Traffic Safety Services Association (ATTSA) or an International Municipal Signal Association (IMSA) certified work site traffic supervisor. A minor revision is one that does not chance the basic concept of the plan. The regional traffic safety engineer must approve major traffic control plan revisions before work begins. A major revision to the work zone changes the basic concept of the TCP.

The work traffic supervisor will attach a copy of the new TCP to his foreman's daily report.

Work during daylight hours unless otherwise approved on the TCP. Open all lanes of traffic at night with proper delineation.

Devices

Devices must comply with the approved TCP, the Alaska Traffic Manual (ATM), and specifications. In the event of conflict, use ATM requirements. Remove or modify signs as soon as they are no longer applicable. Keep devices properly positioned and clean at all times.

Keep traffic off the new AST surface until rolling is complete. After compaction, route traffic over the AST at 15 MPH (25 km/hr) or less.

Flaggers

Flaggers are responsible for public safety and for the safety of the workers. They must be trained in safe traffic control practices.

- Locate flaggers away from stationary objects such as signs, equipment, vehicles, or workmen if possible. M&O operations may require flexibility in this respect.
- Equip flaggers with approved hand-held signs as indicated in the Alaska Sign Design Specifications (ASDS).
- Equip flaggers with high-visibility vests and other clothing. Flaggers should be visible from a distance of at least 1000 feet (300 meters) approaching the work zone. Vests must be a vivid fluorescent color and also must be highly reflective if used during nighttime hours. Increase visibility further by requiring fluorescent hats and gloves.
- Flaggers are responsible for inspecting their equipment daily and for proper storage.
- Maintain flagging stations at all times that the construction project is open to the traveling public.
- Flaggers must maintain their position until relieved by another qualified person.
- Locate flaggers as specified in Part VI of the Manual of Uniform Traffic Control Devices (MUTCD).
- Under normal conditions, do not hold traffic longer than 20 minutes.
- At all times during flagging operations, one flagger will be the designated lead flagger (the traffic supervisor designates the lead flagger). The lead flagger directs all other flaggers and synchronizes their traffic control actions with construction activities. Flaggers must be in radio communication with one another when not mutually visible.
- Provide frequent breaks for the flaggers, using alternate flaggers who are also fully qualified.

Dust Control

Place water for dust control as necessary. A water removal permit is required from the Department of Natural Resources if the job requires water from lakes, streams, or other natural bodies of water. You must also comply with the Alaska Department of Fish and Game screening requirements for all water removal operations—so make sure you have the correct fish-protective intake device at refilling sites. M&O personnel can obtain the proper permits through their respective regional DOT&PF Environmental Sections.

Interim Pavement Markings and Devices

Interim markings and devices are covered in Alaska DOT&PF Highway Construction Specifications, subsection 643-3.09. Traffic control devices must remain in place and be maintained until all hazards have been corrected. This includes but is not limited to items such as guardrail adjustment, erosion repairs, excavations, loose gravel, pavement breaks, and pavement edge drop-off.

On new AST projects, apply permanent pavement striping as soon as possible, i.e., after final sweeping. After speed limit restrictions are lifted but before final sweeping, the surface of the new AST is equivalent to a gravel road. **The TCP (approved by the regional traffic engineer) must address signing or other traffic control devices required during this period!** Realize that an unexpected stretch of gravel road encountered by a motorist on an otherwise paved highway can pose a hazardous condition including dust, flying rocks, and decreased traction.

Large contracted construction projects must have an approved comprehensive TCP. Learn the TCP, and make sure the contractor sticks to it.

5.3. Pilot Vehicles and Piloting

Pilot vehicles serve two purposes: they keep public traffic safely moving through the project and they help protect the AST.

Special Training Requirement

Pilot vehicle operators must be trained to safely lead traffic through a sometimes confusing maze of construction operations. The pilot must have enough general knowledge of construction operations to anticipate equipment movements and keep the traffic moving whenever possible. The pilot vehicle operator must also know something about the AST pavement itself and how to route the traffic to help compact rather than damage the new pavement.

Pilot vehicle operators should attend orientation meetings at each new stage of construction so that they will know generally what to expect as well as any special precautions necessary during the upcoming phase of work.

Limit piloted traffic to 15 MPH (25 km/hr) for 2 to 24 hours, and alternate the wheelpaths (serves as additional rolling) until legal traffic speed will not damage the AST surface. This time period may need to be extended if the weather turns cold and/or rainy after construction (see discussion about extended curing in Chapter 8). For smaller paving operations, M&O sometimes pilots traffic for no more than a half hour or so after the aggregate has been applied. Short patches are usually not piloted at all unless there are several patches grouped together.

As with all other vehicles on the job, pilot vehicles should make no sharp turns on the new AST.

The pilot vehicle must have:

- Clean, highly visible signs
- Strobe lights
- Tow strap(s)
- First aid kit and fire extinguisher
- Radio for communicating with flaggers and other job-site safety personnel

5.4. Safety Precautions for Handling Asphalt Materials

Safety precautions are mandatory at all times when handling asphalt materials. These safety precautions include, but are **not** limited to:

- Obtain a copy of the supplier's material safety data sheet (MSDS). Read the MSDS carefully and follow it.
- Avoid prolonged breathing of fumes, vapors, and mists.
- Wear gloves capable of protecting while handling hot liquids. Roll sleeves down and fasten them over the gloves at the wrist while sampling and while sealing containers.
- Wear a face shield while sampling.
- Do not smoke while sampling asphalts.
- During sealing and wiping, place the container on a firm level surface to prevent splashing, dropping, or spilling the material.

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Chapter 6. Weather for Construction and Curing

Bad paving weather, bad weather during a period shortly after paving, and/or a late or early paving date spell disaster for your new AST. Analyses of Alaska AST failures often point back to weather-related problems. Weather-related problems tend to magnify problems related to any other AST variables. “Bad” weather is a catchall term that generally includes precipitation, low temperatures, and, depending on specific conditions, wind. The AST paving season is the period between early and late allowable paving dates.

6.1. In General

ASTs are affected greatly by weather conditions, especially during construction. The ideal conditions are a warm, sunny day with low humidity. Humidity and cool weather will delay the curing time and cause the AST to be tender for a longer period of time, making it more susceptible to damage by traffic. Rain can cause immediate, major problems.

6.2. Precipitation

If the asphalt binder has not cured, it can become diluted and rise above the top of the cover aggregate. After the water evaporates, asphalt may cover the entire surface, causing tires to pick up aggregate or track the binder across the surface. Even a light rain will cause a “skin” of hardened asphalt to form on the surface of the AST. The skin is a thin waterproof covering that retards water evaporation from underneath and therefore retards curing. **Do no AST paving in the rain! Do no AST paving when showers are threatening!**

6.3. Fog, Mist, or Imminent Rain

High humidity will retard evaporation of water from the broken emulsion and slow the early stages of curing. DOT&PF has no specific requirements regarding humidity. A common sense guideline for successful AST work is: do not pave during local fog or mist conditions or if rain seems imminent.

6.4. Low Air Temperature

This retards evaporation, and in fact, the entire curing process. Measure air temperature in the shade and away from any heat source.

- Minimum air temperature for construction of seal coat and double-layer ASTs is 60˚F (15˚C).
- Minimum air temperature for construction of high float AST is 50˚F (10˚C).

A warning:

Based on Alaska experience—**DO NOT VIOLATE AIR TEMPERATURE RESTRICTIONS!**

If you do AST paving at a temperature below these minimums, **expect slow curing or no curing** until the temperature rises. Curing times do not increase linearly with falling temperature. A rule of thumb is that an 18˚F (10˚C) drop in temperature decreases the curing rate by at least half. As the temperature nears freezing, the curing process stops. Low AST paving temperatures can produce odd results. For example, if paving is done late in the year and the temperature drops below freezing before appreciable curing, the frozen AST may provide reasonably good service through the winter and then can be destroyed by high-speed traffic in the spring when curing actually begins.

Even if the AST is constructed at a temperature above the required minimum, remain aware of the air temperature for at least several days after construction. If you planned on the usual 2 to 24 hours of post-paving piloted, limited speed traffic, but the air temperature takes a large drop, change your traffic control plan—assume that curing has stopped for the remainder of the low temperature period. Post-construction weather is a dice roll that can turn any AST project sour. It is the one uncontrollable factor that can make alternative use of hot mix asphalt concrete paving attractive in some areas of Alaska that have constantly bad or consistently unpredictable weather. Use the long-range forecasting available on the Internet (discussed near the end of this chapter) as a best guess about post-construction weather. Protect the new AST until aggregate cannot easily be removed with the bare hand and/or full-speed traffic does not cause obvious significant loss of aggregate.

6.5. Low Aggregate Temperature

This factor is often overlooked. DOT&PF has no specifications controlling aggregate temperature, although the sight of frozen aggregate chunks should bring any AST paving operation to a screeching halt. It could be very difficult to meet specific aggregate temperature limits if they existed. The assumption (the hope) is that the temperature of the aggregate is not far below air temperature. During application, cold aggregate immediately “shocks” the emulsified asphalt, leading to irregular breaking and poor initial bonding of asphalt to the aggregate surface. This is just one more factor that can affect curing.

Ideal 50 to 60˚F (10 to 15˚C) cover aggregate may be impossible without heating, but you can use solar heating to the extent possible. Some possibilities include locating the stockpile in a sunny area, working the stockpile from the south side, and shaping the stockpile to maximize sun exposure (consider spreading and flattening the pile).

Some special comments are in order concerning stockpiling of larger, single-size aggregate such as the largest size used for double-layer ASTs. A stockpile of large, single-size aggregate contains enough void space so that cold air will circulate within the pile during the winter. The effect is that such a pile can lose more heat in the winter than it gains in the summer, and the core of the pile can remain very cold, even frozen, through the summer. How is this information useful? Consider the possibility of a very cold stockpile in deciding whether to crush and stockpile coarse aggregate in the fall, in preparation for the next construction season. There may be some advantage to producing and using coarse aggregate stockpiles the same construction season. If the crushed material is to go through one or more winter cycles, leaving all natural snow cover in place or perhaps adding additional snow cover may keep the temperature of the material higher. Put the snow cover to best use with the following “tricks.” You can maximize thermal protection of single-sized aggregate stockpiles if you make sure the snow cover is disturbed and compacted to some extent. Otherwise, cold air can circulate through the fluffy snow layer and mix with air circulating through voids within the stockpile (verified by research data). Conversely, protect a high float cover aggregate stockpile by leaving the snow cover in an undisturbed state as much as possible. Air does not circulate within this densely graded stockpile material and so will not draw cold air through the undisturbed snow layer.

6.6. Wind

Aside from obvious oil distributor problems, AST construction on a windy day can cause rapid evaporation at the AST surface, leading to formation of an asphalt skin. Once formed, the skin will retard additional evaporation and therefore delay curing of the AST. Windy conditions the first few days after construction will either aid or retard curing, depending on wind velocity and post-construction air temperatures.

6.7. Allowable Paving Season

If the weather on the day of construction is ideal, why does the calendar date matter? The reason is curing time—sufficient post-construction curing time so that the AST does not remain tender for too long. Pave too early in the year, and the air temperature may drop for a considerable time before warm weather comes to stay. Pave too late, and a temperature drop could easily extend through the winter. The results are the same; essentially all of the curing occurs with no traffic control. Seasonal limits have been established for several general areas of Alaska. Schedule your AST jobs according to Table 6.1.

Table 6.1. Seasonal AST Paving Window

General Location	Earliest AST Paving Date	Latest AST Paving Date
Southeastern Region	May 1	September 15
North of the Yukon River	June 15	July 15
Southern Coastal Areas of Interior and Central Regions	May 15	August 15
Other Areas	May 15	August 15

A warning:

In the annual drive to get the job done before winter, there is often a lot of pressure (from all directions) to violate the seasonal paving window. Based on Alaska experience—do not violate the seasonal paving window!

6.8. The Daily Weather Watch

Each day during the construction process, supervisory personnel must agree that weather conditions are conducive to AST construction. Threatening weather conditions often result in a "wait and see what happens" posture. If rainfall occurs, no AST paving should be done until:

For seal coats—the roads are totally dry and clean (resweeping with a pick-up sweeper may be required before resuming seal coating).

For double layer and high float ASTs—the base course surface has dried to the point where no areas are saturated (certainly no standing water anywhere). Tight blading and or visual observation will verify that the base course surface is reasonably dry (see section 4.1.1.1 of this guide for brief discussion of tight blading).

The Internet is a great source of weather information. Use it to check the short or long-range forecast. There are many Internet sites that you can use for this purpose. One of the easiest to use is the "Yahoo Weather" site at **www.weather.yahoo.com.** A lot of information is also available at the Accuweather site at **www1.accuweather.com**

Simply follow the several-step path required by both of these sites to take you from country to local area of interest.

If the weather turns sour during AST paving:

- If an unexpected rainfall occurs, discontinue the AST application immediately. Inspect areas that have not yet cured for puddles of brownish water bleeding to the surface. Where this condition is found, apply a thin layer of AST blotter material (see Section 4.2.1.3 for material requirement) then immediately roll the surface using the rubber-tired roller available on the job (see Chapter 7 for roller requirements and the increased tire pressure used for rolling blotter material).
- If the rain is severe enough that blotting does not help, you will have to evaluate each of the damaged areas after the storm. You may be able to save lightly damaged areas with a supplemental coating of oil and aggregate, although attempting this form of patching may prove unsightly. Most likely you will have to remove most or all of the originally applied AST in the damaged areas and start over.

Some final words regarding AST success: **BAD WEATHER OR LATE OR EARLY AST PAVING CAUSES CURING PROBLEMS. IF YOU ALLOW A NORMAL FLOW OF HIGH-SPEED TRAFFIC WITHOUT SUFFICIENT CURING TIME THERE WILL BE NO SUCCESS!**

Notes

Chapter 7. Construction

7.1. Prepaving Meetings

Prepaving meetings will confirm that every involved person knows the what, when, and how of the upcoming construction work. The information given here is directed at full-scale construction projects. Maintenance personnel and others involved in small AST projects should be aware of the following procedure and adapt parts of it applicable to the scale of their operation.

7.1.1. Management-Level Meeting

Once the project has been awarded, conduct a management-level prepaving meeting, normally a week before construction. The purpose of the meeting is to review the project parameters and timeline and establish quality expectations.

Who Attends?

- DOT&PF construction project manager (or M&O manager)
- Personnel representing the contractor
- DOT&PF's resident project engineer and assistant engineer (or M&O foreman)
- A recording secretary to take minutes of the meeting

What Occurs?

The DOT&PF construction project manager (or M&O manager):

- Verifies the contract documents are in order and approval to proceed is given.
- Discusses the method of measurement and payment, contract approval process, and a general overview of the project.
- Reviews/approves subcontractor(s) if any, and materials to be used on the project.

DOT&PF resident project engineer or assistant project engineer (or M&O foreman):

- Reviews anticipated starting date and working hours.
- Discusses completion date for AST application and pick-up sweeping process.
- Reviews material delivery schedules.
- Distributes maps of the area(s) to receive AST application.
- Points out road sections not to receive AST application as a part of the project.
- Describes the work and reviews the contractor's responsibilities.
- Discusses emulsified asphalt application process, application rate (and allowable range), and equipment calibration requirements.
- Discusses cover aggregate and application process, application rate (and allowable range), and equipment calibration requirements.
- Approves equipment scheduled for the project and indicates areas where overnight parking is allowed.
- Discusses pre-sweeping (for seal coats) and pick-up sweeping requirements, including a schedule.
- Reviews protection of existing structures and preferred method to cover manholes, gate valves, etc.
- Discusses daily commencement of work parameters and traffic control.
- Reviews traffic control plan.
- Reviews materials documentation requirements.
- Discusses materials specifications and compliance.

The resident engineer (or M&O foreman) also inspects and approves the material to be used, determines sites to stockpile the aggregate, and location(s) for the oil transport trucks to park during the operation before commencement of the project.

7.1.2 Operations-Level Meetings

Conduct orientation meetings for operations-level personnel about one day before construction. If the project is large enough to be done in stages, call a meeting before beginning each stage. Everyone with significant involvement in that stage of construction should attend, including the DOT&PF and contractor field management, inspectors, materials people, operators, and safety personnel. Subjects covered in these meetings will include safety, communications, project layout (who's working where), equipment/operator preparedness, equipment/personnel scheduling, materials handling, and anticipated problems.

7.2. Road Surface Preparation

Safety is important above all other aspects of the job. Follow all manufacturer-recommended safety precautions with respect to equipment. Develop a traffic control plan based on information from Chapter 5 and consultation with DOT&PF regional traffic safety engineer. Adhere to your traffic control plan at all times.

Seal coat ASTs protect or improve the surface quality of existing pavements. Seal coats are applied on existing pavements that are structurally sound and in good condition. Surface preparation is minimal and consists of a good cleaning to promote bonding of the new AST to the old asphalt concrete surface.

Double-layer and high float ASTs are another matter entirely. These ASTs are intended for roads where the surface preparation costs often exceed the cost of the AST application itself. Without careful surface preparation, a good AST job is impossible. The AST pavement is much too thin to repair any problem of grade, crown, superelevation, etc. Since the AST is not a structural layer, it is not strong enough to compensate for poor quality or insufficient compaction of underlying layers.

According to an old saying, the three most important things to consider in road construction are drainage, drainage, and drainage. The AST pavement will not survive if you do not provide for good drainage from the road surface and adjacent to or immediately below the pavement structure. If you anticipate unusual or difficult drainage problems, consult with your regional engineering hydrologist and geotechnical engineer.

Appropriately protect utilities and monuments located in or near the work area from coverage by the AST material.

7.2.2. Selecting, Operating, and Maintaining Equipment

Except for the power broom and water truck, the following equipment types are used for surface preparation on double-layer and high float AST jobs. The broom is used for cleaning an existing pavement surface in preparation for a seal coat. Water trucks will be needed on all AST jobs.

7.2.2.1. Reclaimers

Recycling lessens hauling costs, eliminates waste, and reduces crushed aggregate needs. If you intend to recycle damaged pavement material before applying a double-layer or high float AST, you will probably use a reclaimer or similar equipment. This equipment attacks the existing asphalt concrete with a powerful rotating toothed drum and breaks the material into pieces of asphalt concrete "aggregate." The material can be gathered by other equipment for further crushing or recycled on the grade, as is. This recycled material supplements existing base course and can be used for reshaping the roadway surface.

Other Important Points

- Special training requirements—Require qualification training for the specific reclaimer used on the project.
- Contract timing—Rental charges of reclaimer equipment are high. Make sure the equipment will be available at the proper time and place, then released for other jobs. Consider the following example. When properly compacted, the recycled asphalt material can function as a pavement for extended periods of time. Be aware, though, that compacted recycled materials can set up to become nearly as hard as the original surface. Therefore they will probably need scarifying and grading if left in place for some time

before the final AST is applied. This kind of scheduling might allow all reclaiming work to be done efficiently as a continuous operation until compled.

- The equipment must be in good condition. Inspect for proper operation and safety.
- Select a machine suitable for the job—Size and power are important. The unit should have the power to cut completely through the existing pavement layer in a single pass. The need to make even two passes will require more than twice as much recycling time and it is very hard on cutting teeth. If the old pavement contains a very large number of thick asphalt concrete patches, reclaimer operations may become impractical. Patched areas may have to be ripped with a dozer and that material discarded.
- Mechanics—Pavement milling equipment requires a lot of maintenance. Have knowledgeable mechanics constantly available during the recycling operation. Schedule regular maintenance work after hours to ready the unit for the next day.
- Extra parts—Milling operations require a ready supply of replacement parts. In particular, the project should have on hand a supply of cutter teeth and brackets.
- Specify depth of cut—On thin pavements (existing ASTs), the milling depth should reach 1 to 2 inches (25 to 50 mm) below the bottom of the pavement. This will mix processed asphalt concrete with existing base course to produce an easily gradable material. Temper this suggestion with judgement, depending on milling equipment capability and the quality of the base course encountered.
- Specify size of reclaimed material—Control the speed and cutting depth of the equipment so that the resulting size of the product is no larger than about 2 inches (50 mm). For a still better product, require that 95 to 100% by weight passes the 1.5 inch (38.1 mm) sieve. The rule of thumb is that aggregate material is difficult to compact if the particle size is more than half the lift thickness.

For recycling existing thin AST pavements, consider the possibility of using less expensive types of equipment, such as farm disk-types used on Canadian AST projects in the Yukon.

7.2.2.2. Graders

In surface preparation, the grader operator is the project's resident "artist." Technically, grading is the most demanding of surface preparation activities. Grading imperfections cannot be improved by any subsequent activity of the AST job. Ideally, use automated (computerized) grader controls. Computer controls help ensure an accurate profile and crown. Experience shows that these controls save time and money and minimize base course needs.

Other Important Points

- Special training requirement—Ideally, the grader operator for AST surface preparation should have advanced training. The operator should be capable of "tight blading," that is, readying the surface immediately before prime or AST application (see section 4.1.1.1 of this guide for a brief discussion of tight blading).
- The grader must be in good condition. Inspect for proper operation and safety.
- Radio communication—Maintain communication between grader operator, on-grade foreman, and materials haulers.

For finish work:

- Use a straight blade. On a regular basis, check the bottom of the cutting edge with a chalk line and trim with a torch as necessary.
- Verify that the circle is adjusted and shimmed as required.
- Use grader tires without traction lugs to obtain the smoothest possible surface.

7.2.2.3. Steel Wheel Rollers

Use steel wheeled, vibratory rollers to compact the base course material before AST paving. Use rollers suitable for compacting earthen embankments.

Rollers must be in good condition; inspect for proper operation and safety.

For compacting base course materials containing pieces of recycled asphalt concrete, require a minimum static weight in the 10-ton (11-megagram) class, capable of exerting a minimum dynamic force of 22 tons (200 kN) per vibration cycle, delivered at a minimum frequency of 16 cycles per second.

Operate the roller no faster than 5 mph (8 km/hr).

7.2.2.4. Brooms

Power brooms are used before a seal coat application to clean dirt and debris from the existing pavement surface. Brooming provides a clean surface for the asphalt binder to adhere to. Once the seal coat has been applied, the brooms are used to remove aggregate not embedded into the binder. Two different types of power brooms are available for seal coat preparation. Front mounted rotary sweepers can be used in rural areas where dust is not a problem. Use pick-up sweepers wherever dust must be minimized. In either case, though, keep water available for dust control.

Regarding traffic control for brooming operations—keep in mind that broom-generated dust can substantially reduce visibility, so plan accordingly. Again, have plenty of water available for dust control.

7.2.2.5. Water Trucks

Water trucks will be used for dust control during surface preparation activities on all AST jobs.

Other Important Points

- Have permits for all water sources. Keep a copy at the job office site and a copy with each water haul truck.
- Size the unit for the intended application. Tankers holding more than 8,000 gallons (30,000 liters) will cover most needs on small AST jobs. If recycling is to be done, plan on an additional tanker dedicated as a water supply for pavement reclaimer operations.
- Inspect tankers for general mechanical condition and the presence of leaks.
- Radio communication—Maintain communications between the water truck and the on-grade foreman.
- Have an approved suction end on hand and use it for all filling operations.
- Know each of the job's allowable filling locations and plan for efficient filling.
- Have sufficient suction hose and fittings on hand.
- Verify that the discharge pump is adequately sized to deliver the required flow (no gravity feeds) and operates at a constant pressure.
- Check that the spray unit provides a uniform spray pattern.
- Use a fish-protective pump screen inlet.

7.2.3. The Surface Preparation Operation

7.2.3.1. For Seal Coat

Before beginning construction of a seal coat AST, verify that the existing pavement condition warrants the seal coat. This step may sound like a waste of time, but some projects are in the planning stage so long that the condition of the existing pavement may have deteriorated a lot. Roadways to be seal-coated should be in relatively good condition. This means that there should be little, if any, load related distress such as alligator cracking, rutting, and potholes. If these conditions exist, do all patching and crack sealing before placing the seal coat. If surface damage is severe, postpone seal coating and report the surface condition to the project designer or M&O management (depending on project origination).

Seal coating is a good maintenance technique for pavements with the following:

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

Protect Utilities and Monuments

When seal coating in urban areas where manholes and gate valves in the street are common, the asphalt binder will stick to these structures unless precautions are taken. Monument cases present the same kind of problem. To prevent the binder from adhering to the utilities, cover them. Examples of appropriate covers include roofing paper, kraft paper, or sand. Some agencies use the same type of aggregate for covering the utilities as they do for the seal coat, only much smaller. Since the material must be disposed of properly, using sand is the preferred method. Place the covering material immediately before seal coating.

Patching and Crack Sealing

As mentioned above, do all patching and crack sealing before placing the seal coat. Damage caused by active mechanisms will reappear quickly. For example, if low-quality materials within the pavement structure caused the original alligator cracking, expect the cracks to reappear within about a year. Expect the same quick return of large transverse and longitudinal thermal cracks. Less severe thermal damage such as hairline block cracking may remain sealed (or at least camouflaged) for years. Make sure that patching materials have had time to cure before placing the seal coat. M&O recommends 7 to 14 days of curing time for patches.

About Using Tack Coat

Do not apply a tack coat before seal coating! A tack coat is only required if you are overlaying an existing pavement with a new layer of hot mix asphalt concrete.

7.2.3.2. For Double-Layer and High Float ASTs

If there is an existing pavement surface and that material is to be recycled, do that work first. Then do necessary construction to bring the existing roadway to the required profile, cross-section, and crown. All lifts of embankment and selected materials must be compacted and the base course surface made smooth before applying the AST. For double-layer ASTs, the surface of the base course is usually tight bladed, then primed just before the AST is applied. (See section 4.1.1.1 of this guide for a brief discussion of tight blading.) Prime is not normally used on high float AST jobs in Alaska.

- If recycling is to be done, take advantage of the prepaving meeting to make sure everyone knows where it will be done.
- Reclaimer operations are discussed in section 7.2.2.1 above.
- Establish profile and cross section according to geometric requirements of the design traffic. For contracted projects, this information is available in the project's plans and specifications package. For maintenance projects, profile and cross section can be reestablished using as-built plans from previous designs in the area or the information can be interpolated from nearby undamaged sections of roadway that must be matched.
- Make sure the surface drains well. In non-superelevated areas, use a 3% crown. Be sure that the construction process does not produce berms along the edge of the roadway (such berms are very common). Any form of impediment to free water flow across the roadway surface will cause ponding.
- If the roadway is severely deformed, reestablish correct grade by placing and compacting materials in a series of individual layers not over 8 inches (200 mm) thick and no less than twice the largest aggregate size (see Figure 7.1).

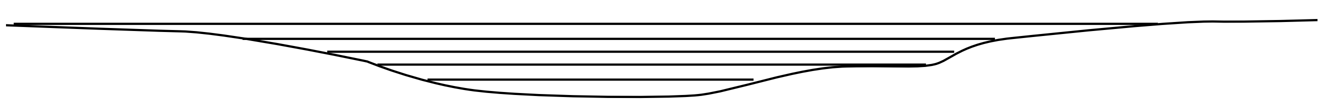

Figure 7.1. Deep repairs should be done in layers or "lifts" of no thicker than 8 inches and no less than twice the size of the largest aggregate.

- Compact materials under the base course according to DOT&PF Highway Construction Specification, subsection 203-3.03 if moisture and density control are required. A simplified compaction requirement is contained in Subsection 203-3.04 for embankments not constructed with moisture and density control. The simple method involves compaction by routing construction equipment and/or rollers uniformly over the entire surface of each layer before the next layer is placed—compact until the material does not rut under the loaded hauling equipment.
- Compact normal aggregate base course materials according to DOT&PF Highway Construction Specification, subsection 301-3.02. **Inadequate compaction of the base course will ruin the AST. Acceptable base course density can be verified by single "proof rolling" coverage with pneumatic rollers before applying the AST.**

When the base course material contains a significant amount of recycled asphalt concrete pieces, the compaction standard used in DOT&PF Highway Construction Specification, subsection 301-3.02 cannot be used. Therefore, establish a test-strip standard according to subsection 308-3.04 or simply require about five complete steel wheel roller coverages using the roller described previously in section 7.2.2.3 of this guide.

- Ensure correct final surface shaping; use a finish grader equipped with an automatic grade and cross slope control system (ideal equipment type; not all crews will have this).
- Apply the AST within 72 hours after the finished grade has been approved.
- Roll the surface with a steel wheeled roller immediately before applying asphalt materials if the surface is not to be primed.

If prime coat is to be applied before double-layer AST:

- A prime coat is usually applied before a double-layer AST.
- Loosen the surface to be primed by tight blading. An expert grader operator will be needed to do this task without making a mess of the shaped and compacted base course surface. (See section 4.1.1.1 of this guide for a brief discussion of tight blading.)
- Apply MC-30 prime coat according to DOT&PF Highway Construction Specification Section 403.
- Apply MC-30 at a starting rate of 0.20 gal/yd^2 (0.91 L/m^2). Be aware that this application rate may prove to be too heavy and will need downward adjustment based on observation.
- Do not apply any more prime than can be covered by the following day's paving.
- Make sure blotter material is available in case excess prime material is applied or spilled.

7.3. AST Application

Safety is important above all other aspects of the job. Follow all manufacturer-recommended safety precautions with respect to equipment. Follow established safety requirements with respect to handling materials (see Chapter 5, section 5.6). Develop a traffic control plan based on information from Chapter 5 and consultation with DOT&PF regional traffic safety engineer. Adhere to your traffic control plan at all times.

7.3.1. Application Rates for Emulsified Asphalt and Cover Aggregate

Application rates determined by the methods discussed below may need some adjustment once AST paving has started. Remember, this is an "eyeball" adjustment that should be based on a **lot** of experience. Questions are:

1. Who is qualified to change materials application rates?
2. How much can the application rates be changed without ruining the AST?

Regarding question 1: Qualified individuals include those who have actually attended AST paving on at least two previous successful AST jobs like the one being done, i.e., double-layer or high float AST. Expertise from unsuccessful jobs can also be of value, provided the "expert" learned from what went wrong.

Regarding question 2: A change in the materials application rate of more than about ± 10% (ballpark estimate but reasonable) from the mix design amount should be discussed with whomever did the mix design. Large changes in application rate are justified if the material characteristics have changed (a new aggregate source for example)—if this is not the case, be very careful.

Alaska experience has shown that cold, damp, and/or windy weather, i.e., any conditions that retard early curing, may reduce short-term aggregate retention. The response to this has too often been to increase the oil application rate. Records from several AST failures indicated that the emulsified asphalt application rate was raised more than 50% above the mix design amount. On one of these projects, miles of new AST had to be completely removed and replaced the spring following construction. Do not fall into this trap.

The Minnesota Seal Coat Handbook offers the following "wave test" for determining if the application rates are about right: This method is intended for seal coat but should work for double-layer ASTs. It determines if your application rates are appropriate to the road surface condition.

1. Allow the paved area to cure for several hours or until aggregate is totally dry and dusty.
2. Place your hand on the road with fingers spread and in a rapid waving motion lightly brush any loose chips until you see the remaining aggregate that stuck into the binder.
3. Visibly check to see if the aggregate is uniformly covering the binder, compacted into the binder consistently, and there is adequate aggregate coverage.
4. This procedure will help you judge if you need to adjust application rates up or down.

Excessive aggregate or "float" after curing takes place indicates that aggregate application rates should be reduced to the point where you are getting single layer coverage and minimal excess float remaining.

Binder "bleeding" out of the aggregate consistently after rolling indicates you should *reduce the application rate of binder rather than increase the application rate of the aggregate*.

Used in combination with the above technique, another simple test is to simply pull some of the aggregate from the surface and inspect the coating. DOT&PF personnel have normally used this test.

If after doing a "wave test," you see that rock chips are not staying in place, you should increase the emulsified asphalt application rate.

7.3.1.1. For Seal Coat

Chapter 4 contains materials requirements for the emulsified asphalt (section 4.1.1.1) and aggregate (Tables 4.4 and 4.5) used for a seal coat AST.

The amount of CRS-2 (or CRS-2P) and cover aggregate is determined by the McLeod method described in Appendix D. Table 7.1 gives the general range of application rates to expect from the McLeod mix design. The table also contains the allowable tolerances from the mix design application rates or from new application rates set in the field.

Table 7.1. Expected Range of Application Rates and Allowable Tolerances for Seal Coat AST

Material Type	Expected Range of Application Rate	Allowable Tolerance
CRS-2 or CRS-2P*	0.20–0.35 gal/yd^2 (0.9–1.6 L/m^2)	0.04 gal/yd^2 (± 0.18 L/m^2)
Cover Aggregate	20–26 lb/yd^2 (11–14 kg/m^2)	1.3 lb/yd^2 (± 0.7 kg/m^2)

* depending on the amount and type of polymer used, application rates for both emulsified asphalt and cover aggregate may be significantly outside the ranges indicated.

7.3.1.2. For Double-Layer AST

Chapter 4 contains materials requirements for the emulsified asphalt (section 4.1.1.1) and aggregate (Tables 4.4 and 4.5) used for a double-layer AST.

The amount of CRS-2 (or CRS-2P) and cover aggregate is determined by the McLeod method described in Appendix D. Using the McLeod mix design method, the amount of emulsion requirement for each size aggregate is calculated separately and then the two amounts are added together for the total emulsified asphalt requirement. Apply 40% of the total requirement for the first layer of cover aggregate, and the remaining 60% for the second layer of cover aggregate.

Table 7.2 gives the general range of application rates to expect from the McLeod mix design. The table also contains the allowable tolerances from the mix design application rates or from new application rates set in the field.

Table 7.2. Expected Range of Application Rates and Allowable Tolerances for Double-Layer AST

Material Type	Expected Range of Application Rate	Allowable Tolerance
For the First Layer:		
CRS-2 or CRS-2P	0.35–0.51 gal/yd² (1.6–2.3 L/m²)	0.04 gal/yd² (± 0.20 L/m²)
Cover Aggregate	41–50 lb/yd² (22–27 kg/m²)	2.4 lb/yd² (± 1.3 kg/m²)
For the Second Layer:		
CRS-2 or CRS-2P	0.51–0.60 gal/yd² (2.3–2.7 L/m²)	0.04 gal/yd² (± 0.20 L/m²)
Cover Aggregate	20–26 lb/yd² (11–14 kg/m²)	1.3 lb/yd² (± 0.7 kg/m²)

7.3.1.3. For High Float AST

Chapter 4 contains materials requirements for the emulsified asphalt (section 4.1.1.2) and aggregate (Tables 4.6 and 4.7) used for a high float AST.

The amount of HFMS-2s and cover aggregate is prescribed by DOT&PF based on Canadian experience. Table 7.3 gives the "starting" application rate normally prescribed in Alaska. The starting application is then adjusted in the field as needed. The table also contains the allowable tolerances from the starting application rate or from a new application rate set in the field.

Table 7.3. Expected Application Rate and Allowable Tolerances for High Float AST

Material Type	Prescribed (starting) Application Rate	Allowable Tolerance
HFMS-2s	0.75 gal/yd² (3.4 L/m²)	0.04 gal/yd² (± 0.18 L/m²)
Cover Aggregate	75 lb/yd² (41 kg/m²)	2.6 lb/yd² (± 1.4 kg/m²)

7.3.2. Selecting, Calibrating, Operating, and Maintaining Equipment

Pay attention to the type and condition of the equipment. However, the experience of the equipment operator is of utmost importance. Even new, well-calibrated equipment, using the finest materials, will not produce a quality seal coat project without experienced and qualified operators.

7.3.2.1. Spreaders for Cover Aggregate

The aggregate chip spreader must apply a uniform, even layer of cover aggregate across the full width of an emulsified asphalt covered surface. It must be calibrated properly and in good working order. A self-propelled chip spreader is desirable. This type of spreader pulls the aggregate trucks as it travels down the road. When the truck is empty, the spreader releases it, and another truck then backs into place. If done correctly, no work stoppage occurs while refilling the spreader.

The newer chip spreaders are equipped with computerized controls that allow the gates to open and close hydraulically to compensate for the speed of the spreader. This feature is recommended; it ensures a constant application rate, regardless of travel speed.

Other Important Points

- Special training requirement—Spreader operators should be thoroughly trained on the type of equipment used on the job.
- Radio communication—Maintain communications with aggregate supply trucks, the rollers, the asphalt distributor, and

the paving foreman. Supply the operator with a hands-free, voice-activated headset to communicate over noise generated by the aggregate spreader itself and nearby trucks.
- Check that the aggregate spreader is in good condition and has sufficient capacity. The spreader must have a feed system that can maintain cover aggregate in the spreader hopper at all times.
- Check that the gate controls work properly.
- Check that the scalping screen is functioning properly.
- Segregation control—First, verify that the cover aggregate being fed to the spreader is not already segregated. Periodically inspect the stockpile and stockpile loading operations (see section 4.2.2 of this guide).

For all AST aggregate types, verify that the spreader hopper is equipped with augers to prevent segregation. For high float cover aggregate, DOT&PF Northern Region M&O personnel install a diffuser plate in the spreader to minimize segregation. At one time, Alaska and Canadian high float paving operations used a comb device externally mounted across the width of the aggregate spreader. The comb was supposed to actually cause a specific kind of segregation and allow some of the coarser aggregate to hit the ground before finer material. Aggregate combs are often considered unnecessary now. Comb devices have not seen recent use in Canada. However, Alaska M&O crews are expressing renewed interest, and combs are being used on some DOT&PF Northern Region high float cover aggregate spreaders.

- The spreader must deliver the aggregate onto the fresh emulsion surface almost immediately after the emulsion is applied (before the emulsion breaks).
- The speed of the aggregate spreader must be kept low enough so that aggregate does not bounce or roll after it contacts the emulsified asphalt.
- Calibrate the spreader to deliver the required application rate before use, according to the following information.

Calibrate Cover Aggregate Spreader (from Minnesota Seal Coat Handbook)

Calibrating and maintaining the cover aggregate spreader is an important step in achieving good results. Poorly calibrated equipment can negate what would otherwise be a quality AST project. Calibrating the cover aggregate spreader ensures that:

- All chip spreader gates are applying the same amount of aggregate across its entire width.
- The chip spreader is applying the desired amount of aggregate per unit area.

The recommended procedure for calibrating an aggregate chip spreader is ASTM D5624-95.

Calibrating a chip spreader requires the following:

1. A 12 to 16 foot (3.7 to 4.9 meter) length of a grooved rubber mat, depending on the width of the spreader, typically used as stair runners. They can be purchased from building supply stores and come in 27 or 36-inch widths (approximately 69 or 91 cm). The mat is then cut into 12-inch-wide (30.5 cm) strips. The result will be mats that are either one-fourth or one-third of a square yard (approximately 0.21 to 0.28 square meter), depending on the width of the original strip.
2. A scale of some type to weigh the chips. A reasonably accurate spring-loaded scale will suffice.
3. Twelve to sixteen 1 gallon (4 liter) size plastic food bags to be used for holding the contents of each rubber mat during weighing.
4. Wide masking or duct tape to prevent the rubber mats from slipping on the pavement surface.
5. A notepad and pen or pencil for recording the results.
6. A 5-gallon (20-liter) bucket for storing and carrying all of the above.

One way to speed up the calibration procedure is to adjust as much as possible before loading the hopper with aggregate. With the hopper empty and all the gates opened, the distance between the roller and the bottom edge of each gate should be the same.

Step 1

Lay the rubber mats side by side on the roadway until they extend the entire width of the spreader. To prevent the mats from slipping, use wide masking tape on the upstream end of the mats as shown in Figure 7.2.

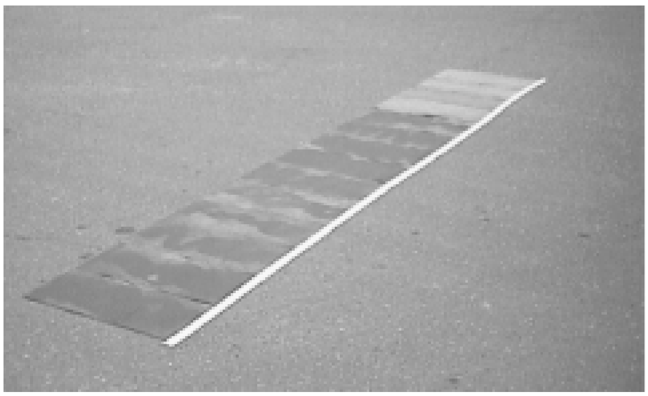

Figure 7.2. 12 inch (30.5 cm) wide rubber mats are placed in position.

Step 2

Drive the spreader over the mats. The spreader should begin dropping chips about 6 to 8 feet (roughly 2 to 3 meters) before the mats to ensure the gates are open and functioning properly. **It is critical that the spreader travel speed and**

Figure 7.3. The rubber mats are covered with aggregate from the aggregate spreader.

tachometer be monitored to ensure they are the same as those used during construction. The inspector should record these values to make sure this is done. If the spreader is traveling too fast or slow during calibration, it will not provide the same yield as the actual yield obtained during production.

Figure 7.4. The aggregate on each mat is emptied into plastic bags.

Step 3

Carefully empty the aggregate dropped on each mat into the 1-gallon (4-liter) plastic bags. The order of the bags must be kept straight, so the gate openings match the proper mat.

Figure 7.5. The contents of each bag are weighed and recorded.

Step 4

Weigh the content of each bag and convert it to pounds per square yard (or kilograms per square meter). Record this amount on the notepad, along with the position of the gate relative to the outer edge.

Step 5

The first adjustment made is to get all of the gates to drop the same amount of aggregate, even if it is not the desired amount. This will involve adjusting individual gate openings on the front of the spreader.

Repeat the test until all of the gates are placing the same amount of aggregate, plus or minus 1 lb/yd^2 (about 0.5 kg/m^2). Once all of the gates are dropping the same amount of aggregate, adjust the main feed until the correct amount of aggregate is being placed. Normally the spreader must be adjusted two or three times before all the gates drop the same amount and the amount they drop is the target amount.

Figure 7.6. Adjusting a spreader gate opening.

The calibration can be done the day before construction to reduce any delays. If possible, do the calibration off-site so that all of the equipment and personnel are not waiting on the roadway until the calibration is complete. This procedure will normally take 30 and 60 minutes.

7.3.2.2. Distributors

The asphalt distributor must be able to apply a uniform layer of emulsified asphalt at the correct thickness and width. If the emulsion is applied too heavily, flushing of the asphalt in the wheel paths will result. If applied too thin, excessive chip loss will result. Most distributors used today have computerized controls that regulate the pressure of the material to compensate for the speed of the vehicle. This results in a constant application rate, regardless of travel speed. Using two distributors on larger AST jobs allows work to continue while one is being refilled.

Other Important Points

- Special training requirement—Distributor operators should be thoroughly trained on the type of equipment used on the job.
- Use appropriate safety placards.
- Radio communication—Maintain communications to the aggregate spreader, emulsion supply trucks, and the paving foreman.
- Check that equipment is in good working order. Use equipment that is designed, equipped, maintained, and operated so that the emulsion remains at an even temperature.
- Require computer controls that ensure constant, accurate delivery of the emulsion at the specified spread rate. The controls must be capable of maintaining the spray bar at a constant height during spraying. Beware that radio communications may cause problems with computer controls.
- Require computer monitoring of spread rate, truck speed, and distance traveled.
- Require controls that enable the distributor to maintain a constant speed during emulsion application.
- Equip with a thermometer for temperatures of the tank's contents, readily visible from outside the truck cab.
- Cleaned for oil compatibility—Be careful when using different emulsion types on the job (see section 4.1.2 of this guide).

- Environmental considerations—Refer to section 4.1.2 of this guide. Also, make sure the spray bar has a positive shutoff to prevent dribbling.
- Have an efficient and safe method set up for transferring oil from tanker to storage to distributor—refer to section 4.1.2.
- Have all necessary connectors, hoses, and pumps at job site and ready to use—Refer to section 4.1.2 of this guide.
- Spray capacity for seal coats and double-layer ASTs—Use equipment capable of applying the specified application rate with uniform pressure and within the tolerances shown in section 7.3.1 of this chapter.
- Spray width—For two-lane roads, require that the distributor be able to apply a uniform application up to the width of the cover aggregate spread plus 6 inches (150 mm).
- Adjust the nozzles to about 30 degrees from the spray bar's long axis.
- Adjust the spray bar height to get a triple overlap pattern (see calibration procedure below).
- Calibrate nozzles as a set and then use them as a set. All nozzles should be of the same manufacturer, type, and size, except that special end-nozzles should be included in the set and installed (one end-nozzle for each end of the spray bar).
- Calibrate the distributor to deliver the required application rate according to the following information before use.
- Install a driving aid on the distributor to assist the driver in aiming the line of asphalt application. This could be as simple as a length of chain hanging from a pipe extended from the front bumper.
- Check strainers on the distributor before each "shot."

Calibrate Asphalt Distributor

Calibrating and maintaining the asphalt distributor is an important step in achieving good results. Poorly calibrated equipment can negate what would otherwise be a quality AST project. Calibrating the asphalt distributor ensures that:

- The distributor spray bar nozzles are all adjusted to the same angle, resulting in uniform coverage of the binder across the entire lane.
- None of the spray bar nozzles are plugged with debris.
- The spray bar height is correct. If it is too high, the fans will overlap too much. If it is too low, there will be areas with insufficient binder. Both conditions will cause streaking.

Several calibration procedures or adjustments should be done to the asphalt distributor before it is used. While these adjustments are very simple and quick, failure to perform them can lead to a nonuniform application of binder that not only affects the appearance of the AST but also its performance.

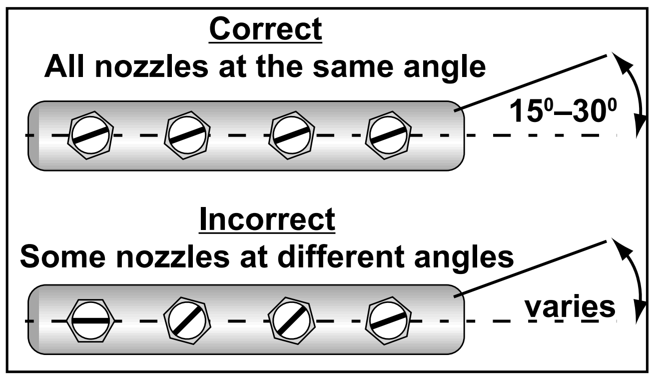

Figure 7.7. Spray bar nozzle alignment

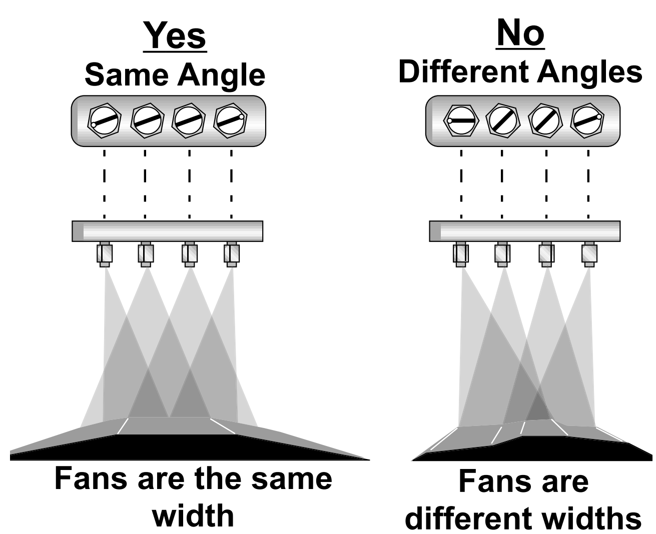

Figure 7.8. Spray bar nozzle alignment

Spray Bar Nozzle Alignment

The first thing to do to the distributor is to check the spray nozzles. In order for the distributor to spray a uniform layer of binder, the angle of each nozzle must be the same (Figures 7.7 and 7.8). The nozzles at the very ends of the spray bar should be special end-nozzles, although these will be turned to the same angle as all the other nozzles. Before beginning a seal coat project, the angle of each nozzle should be checked and adjusted as needed. Adjustment is very easy to do, typically only involving the slight turn of a wrench or other tool provided by the distributor manufacturer. In addition, each nozzle opening should be checked for grass or other debris that may be obstructing the opening.

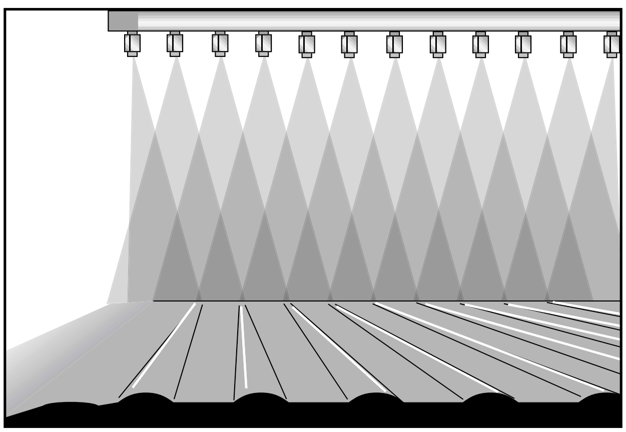

Figure 7.9. Spray bar is too high (ridges)

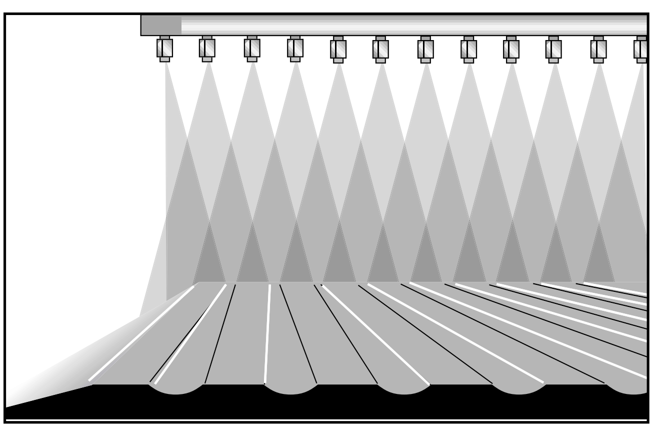

Figure 7.10. Spray bar is too low (gaps)

Spray Bar Height Adjustment

The next step in adjusting the distributor is to determine if the spray bar is at the correct height. Do this by shutting off certain nozzles and examining the point at which the fans hit the pavement surface. For a triple lap application, two nozzles should be shut off for every one that is open. For a double lap application, every other nozzle should be shut off. The distributor operator then sprays for a very quick moment. If the fans do not hit the pavement surface at the same point, the spray bar is either too high or too low and should be adjusted accordingly. As the distributor becomes less full, the spray bar will rise slightly due to the decreased weight on the vehicle. However, this is normally a minimal height increase and can be ignored.

If the spray bar is not adjusted to the proper height above the pavement, one of two situations will result. Either the spray bar will be too high, in which case the fans will overlap too much in certain areas, resulting in ridges, or it will be too low, in which case there will be gaps between the fans. In either case, undesirable streaking will occur.

To determine if the spray bar is at the correct height, the following test should be done before any work begins.

For a Triple Lap Application (recommended for all DOT&PF AST work)

To determine if the spray bar height is correct for a triple lap application, conduct the following test:

1. Make sure all of the nozzles are aligned to the same angle.
2. Shut off *two consecutive nozzles* for each that is left open (Figure 7.11).
3. Spray binder for a brief moment and examine the point where the fans hit the pavement surface. If they do not meet at the same point, the spray bar is not at the correct height.
4. If the fans overlap, the spray bar is too high.
5. If they are too far apart, the spray bar is too low.

6. Adjust the bar as needed and repeat until the edges of the fans meet the pavement at the same point.

For a Double Lap Application

To determine if the spray bar height is correct for a double lap application, conduct the following test:

1. Make sure all of the nozzles are aligned to the same angle.
2. Shut off *every other* nozzle (Figure 7.12).
3. Spray binder for a brief moment and examine the point where the fans hit the pavement surface. If they do not meet at the same point, the spray bar is not at the correct height.
4. If the fans overlap, the spray bar is too high.
5. If they are too far apart, the spray bar is too low.
6. Adjust the bar as needed and repeat until the edges of the fans meet the pavement at the same point.

7.3.2.3. Trucks

Dump trucks used in AST work must have the proper hitch type, and the hitch must be mounted at the proper height for compatibility with the aggregate spreader. Practice hooking, dumping, and unhooking before actual road work. When approaching the aggregate spreader, trucks should alternate wheel patterns to provide additional rolling. Never turn sharply on a fresh AST surface! Use enough trucks to keep the job moving smoothly. Check the mud flap heights on the front tires so they will not drag on the AST.

Other Important Points

- Special training requirement—The aggregate haul truck operator must be able to work smoothly with the aggregate spreader. This requires training in making and breaking connection with the aggregate spreader, proper truck box angle during delivery, and steering during the delivery.
- Trucks must be in good condition. Inspect for proper operation and safety.
- Balance the number of trucks with the job. The aggregate spreader cannot be allowed to empty.
- Radio communication—Truck operators must be able to communicate with the aggregate spreader and paving foreman.
- Standardize hand signals.
- Equip trucks with the proper gate type (or overhanging lip) and skirting to allow a clean,

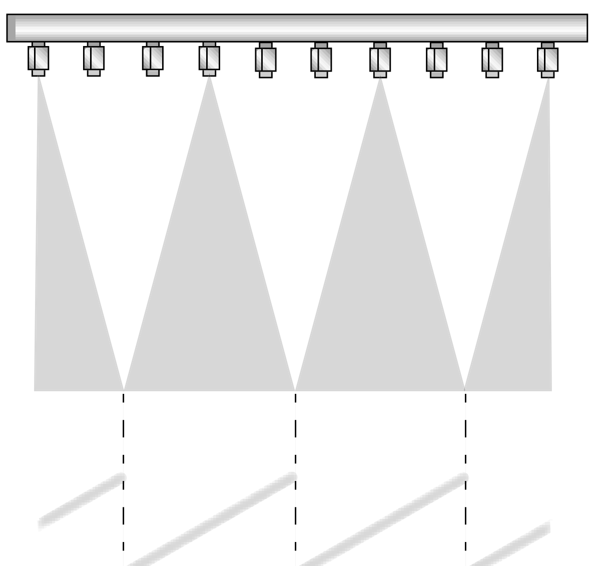

Figure 7.11. Spray bar height test for a triple lap application

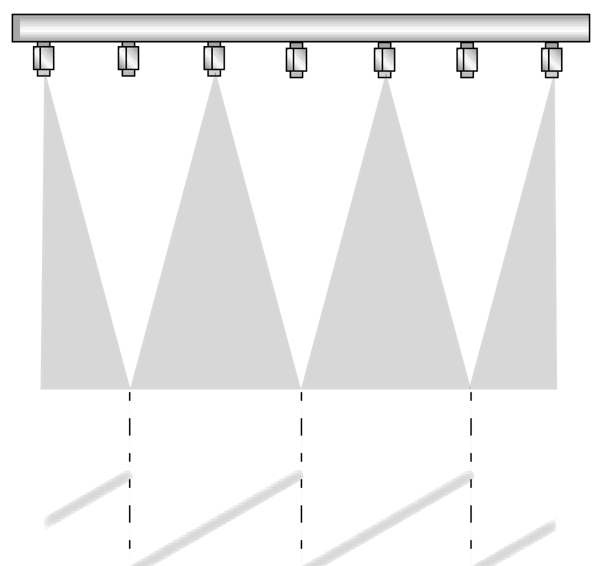

Figure 7.12. Spray bar height test for a double lap application

- controlled attachment to the aggregate spreader. Consider modifying trucks to use the hydraulic, vertical-action dump gate (Figure 7.13). This modification eliminates several problems associated with swinging dump gates. There is a feature article on the new style dump gate in the DOT&PF Research Section newsletter *Technology for Alaskan Transportation,* vol. 25, no. 1, Spring 2000.
- New AST pavement is fragile—Always do gradual turns, starts, and stops.

A constant supply of emulsified asphalt is required. Carefully plan for a sufficient number of asphalt tanker trucks, as well as where they should be located and when to schedule them to arrive. Proper placement and delivery of emulsified asphalt is essential for a smooth AST paving operation.

7.3.2.4. Rubber-Tired Rollers

Perhaps the most overlooked pieces of equipment are the pneumatic tired rollers. Their primary function is to embed the aggregate into the asphalt binder and orient the chips so that maximum bonding will occur. The number of rollers used, roller speed, and the required coverages control the production rate of the entire AST. It is important to have enough rollers to complete the rolling quickly. The aggregate needs to be embedded into the binder before it "breaks." Normally, a minimum of three rollers will be required. The first two drive side by side, rolling the outer edges. The third roller follows closely behind, rolling the center of the lane. It is very important for the rollers to travel slowly, no more than 5 mph (8 km/hr), so the chips are correctly embedded into the binder.

Figure 7.13. hydraulic, vertical action dump gate

Other Important Points

- Special training requirement—The operator must know how to roll an AST pavement, taking special care to stay close to the AST paving operation. The operator must know how to operate the roller without damaging the tender AST surface. Skills include making smooth directional changes and turning movements.
- The rollers must be in good condition. Inspect for proper operation and safety.
- Roller weight—Recent DOT&PF specifications require rollers weighing not less than 10 tons (9 megagrams). DOT&PF Northern Region M&O now prefers a roller weight of about 20 tons (18 megagrams) (the claim is more production and a better AST).
- Require scrapers plus cocoa-mat scrubbers with enough of a water supply to keep these attachments wet during roller operation.
- Require that the roller have a minimum of nine tires, staggered back and front.
- Check that *all* tires are inflated to 60 to 90 psi (414 to 621 kPa), and equip rollers with gauges for verifying the tire pressure.
- Radio communication—Roller operators should be able to communicate with the aggregate spreader and paving foreman.
- The rollers should operate very closely behind the aggregate spreader. As much of the total required rolling as possible must be done before the emulsion breaks.

- Always use care when starting, stopping, reversing, and turning. Never turn sharply on a new AST!
- Maximum speed—5 mph (8 km/hr)

7.3.2.5. Steel Wheel Rollers

A steel wheel roller is sometimes used on a double-layer AST job as a finishing roller. The steel wheel roller will operate closely behind the rubber-tired rollers. It will make a single pass after the rubber-tired rollers are finished.

Other Important Points

- Special training requirement—The operator must know how to roll an AST pavement, taking special care to stay close to the AST paving operation. The operator must know how to operate the roller without damaging the tender AST surface. Skills include making smooth directional changes and turning movements.
- Use steel wheel rollers that are specifically designed to compact asphalt concrete pavements.
- Rollers must be in good condition. Inspect for proper operation and safety.
- Roller weight—Recent DOT&PF specifications require steel wheel rollers for AST work weighing between 10 and 12 tons (9 and 11 megagrams).
- Operate only in nonvibratory mode.
- The roller must be capable of reversing without backlash.
- Always use care when starting, stopping, reversing, and turning. Never turn sharply on a new AST!
- Maximum speed—5 mph (8 km/hr)
- Stop using steel wheel rollers if crushing or fracturing of the cover aggregate is evident.

7.3.2.6. Brooms

Obtain the broom manufacturer's advice on available broom materials, and use the type recommended for sweeping excess "pea gravel" size material from a highly textured surface. Canadian AST crews use graders with rubber-edged blades before sweeping.

Do not begin sweeping until the AST has cured enough to hold the embedded aggregate solidly in place. In Alaska, adequate curing will normally require between four days and two weeks, depending on weather and temperature conditions. If the AST is broomed prematurely, much of the nonexcess aggregate will be removed and a patch will be necessary.

Other Important Points

- Power brooms must be in good condition. Inspect for proper operation and safety.
- Inspect broom bristles for wear. Bristles shortened by wear effectively become stiffer and may remove more than just excess aggregate.
- Use care in the amount of down-pressure used. Too much down-pressure will remove more than the excess aggregate.
- Brooming on damp or rainy days minimizes dust production.
- Regarding traffic control for brooming operations—Keep in mind that broom-generated dust can substantially reduce visibility, so plan accordingly. Brooming at night will minimize dust annoyance for most drivers. Using a vacuum broom is a good idea. Make sure the brooms are well lighted for nighttime use.
- Steel versus plastic bristles and bristle stiffness—The choice depends somewhat on operator experience. Depending on selected bristle stiffness, steel bristles are normally more aggressive and move loose aggregate more efficiently, but can damage the new AST with a heavy-handed operator. Steel bristles will probably last the longest.
  Bristles are available in varied degrees of stiffness. As per the discussion above, a higher degree of stiffness can make the sweeping operation more efficient, but operator experience becomes more important to prevent removing more than just the excess aggregate.

- Down pressure, rotational speed and forward speed of the broom—The operator must adjust these variables to get efficient sweeping while not removing too much material. Adjust so that the required amount of material is removed in one to three passes. The combination of stiff bristles, very high down pressure and high rotational speed will quickly grind away any new AST.
- Brooming sequence—General operation of the broom involves moving parallel to the centerline while gradually pushing material toward (and finally past) the edge of the roadway. However, do the shoulders first to remove the small berms of excess aggregate that will have collected before brooming. After removing excess material from both shoulders, then move the broom to the center of the roadway and begin working excess aggregate outward until brooming is completed (Figure 7.14).
- Sweep past the pavement edge. Make sure no berms remain on any area of the road surface.
- Sweeping must be completed and approved before permanent markings are painted on the road surface.

A few comments about sweeping operations on larger projects: The field inspector should inspect the equipment for leaks. Fuel or hydraulic leaks will destroy the bond between the asphalt material and the aggregate for double-layer and high float ASTs and, for seal coats, the bond between the seal coat and old pavement. Do not allow leaky sweepers or trucks on the project. Make sure they are repaired or replaced.

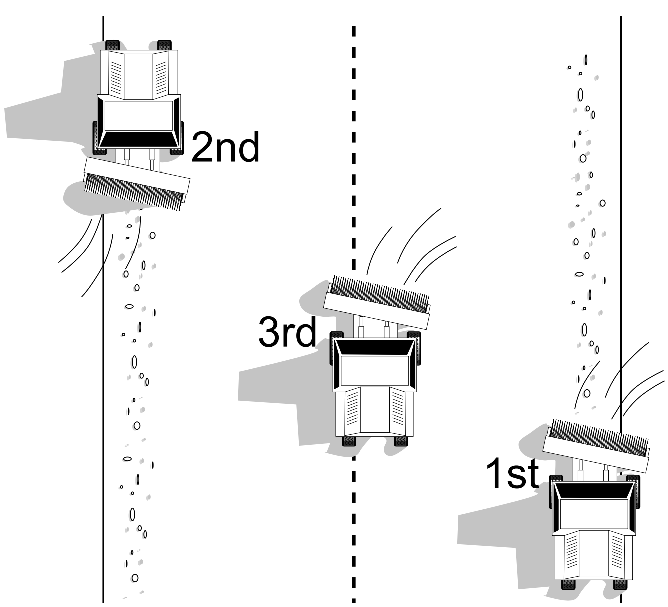

Figure 7.14. Brooming sequence

The sweeping operation includes the following:

- A location to stockpile sweepings.
- Full-width sweeping attaining at least 85% pickup of loose chips.
- Minimizing turning movements of sweepers and trucks at low speeds to avoid damage to the AST.

The field inspector should do a windshield inspection behind the sweeping operation to ensure that:

- all AST paved areas are swept,
- defects that require more attention are noted,
- all structures are uncovered (for seal coats), and
- the progress and quality of the sweeping operation is as required.

7.3.2.7. Miscellaneous Hand Tools

Use hand tools to touch up areas where the AST does not fully cover the pavement surface, such as cul-de-sacs and corners of parking areas, particularly where curbs and gutters are present. Tools such as push brooms, shovels, and squeegees are normally used. An asphalt rake is necessary for smoothing uneven coverage or ripples. Roller operators will typically be the ones who do the touch-up work, so it is common to tote these tools on the rollers.

7.3.3. The Paving Operation

7.3.3.1. General Tips

- Record distributor and spreader application rates, quantities, length of paving, and materials identification information throughout the paving operation.
- Sweep pavement ends by hand when patching.

- Transverse joints—Use the proper startup method. Use building or tar paper to start and stop the oil and aggregate spreading operations on the transverse joints. A well-trained crew can eliminate the need for the paper. Repair defects immediately; rake off excess aggregate at joints, cover exposed emulsion, or add emulsion and aggregate to bare spots. Do this before curing prevents hand raking.
- Longitudinal joints—These joints are often a problem, either because a ridge is formed during construction or because potholing occurs soon after the AST is completed. Use special care so not too much and not too little emulsion is deposited along the joint line. Verify that the distributor is dispensing the required application rate at the ends of the spray bar. For the distributor, an overlap of 4 to 6 inches (10 to 15 cm) along longitudinal joints is considered good control. Construct longitudinal joints only along the centerline and lane lines.

Figure 7.15. Cleaning for transverse joint area

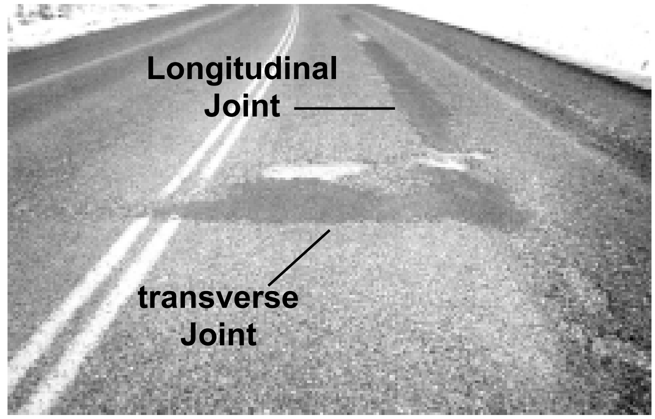

Figure 7.16. Poor construction of transverse and longitudinal joints

- Limit forward progression of paving operations to about 200 to 300 feet/minute (60 to 90 meters/minute). The distance between the emulsion distributor and aggregate spreader should generally be no more than about 200 feet (60 meters).
- Maintain uniform oil coverage and uniform application of cover aggregate.
- Pave in an uphill direction when placing AST on grades of more than about 6 percent.
- *Do not* create side berms of excess materials at any time during construction—These produce watertraps!
- Complete emulsified asphalt and cover coat applications full width by the end of each shift.

7.3.3.2. Special Requirements for Seal Coat ASTs

Applying Emulsified Asphalt

1. Apply the seal coat within 24 hours of completing surface preparation.
2. Do not extend the length of the spread of asphalt material beyond what can be immediately covered with aggregate.
3. Do not allow equipment or other vehicles on sprayed emulsion before cover aggregate is applied.
4. Do not spread emulsion more than 6 inches (150 mm) wider than the width covered by the aggregate spreader.

5. At the beginning of each spread, use a strip of building paper at least 1 meter wide and with a length equal to that of the spray bar plus 1 foot (0.3 meter). Remove and safely dispose of the used paper when finished.
6. Make sure the distributor is moving forward at the proper application speed at the time the spray bar valve is opened.
7. Apply CRS-2 at a temperature between 122 and 176˚F (50 and 80˚C). Apply CRS-2P at a temperature between 160 and 190˚F (71 and 88˚C).
8. Do not allow emulsion to chill, set up, dry, or otherwise impair retention of the cover aggregate.
9. Do not allow emulsion to drip from the distributor onto the surface of the roadway nor drip at any other unapproved location when the asphalt distributor is not spraying.
10. Correct skipped areas or other deficiencies. Make longitudinal joints of spreads carefully to prevent applying too much emulsion along the joints.

Applying Cover Aggregate

1. If necessary, moisten the cover aggregate with water the day before the aggregate is to be used.
2. Do not apply cover aggregate at a speed greater than 300 feet/minute (90 meters/minute).
3. Apply the cover aggregate within 1.5 minutes after application of the asphalt material or, depending on weather conditions, as directed. Keep this time increment as constant as possible, but adjust as needed to meet changing conditions. Whenever it is apparent that the time limit above will be exceeded, make a transverse joint by placing construction paper (roofing felt or similar product) on the prepared surface and ending the seal coat operations on the paper. Remove the paper and dispose of the paper properly. Touch up the edges of the applied seal coat before restarting operations.
4. Spread cover aggregate so that the tires of the trucks and aggregate spreader never contact the uncovered and newly applied asphalt material.
5. Immediately after the cover aggregate is spread, repair deficient areas using additional cover coat aggregate. Then, immediately compact the aggregate with at least three complete coverages using the rubber-tired tire rollers. Operate rubber-tired rollers at a speed less than 5 mph (8 km/hr).
6. After compacting the cover aggregate, sweep excess cover aggregate from the entire surface after sufficient curing—usually several days (see section 7.3.2.6). Be prepared to maintain the seal coat at least four days after construction. Temporary maintenance will include the distribution of cover aggregate over the surface to absorb any free asphalt material and cover any area deficient in cover aggregate. Conduct this maintenance so as not to displace embedded aggregate. Repair failed areas before striping.

Applying Blotter Material

Due to weather, construction, and/or materials problems, it is possible that the finished surface treatment may become unstable. To minimize damage to the surface, blotter material may be required (see specifications in section 4.2.1.3). If blotter material is required, apply a thin layer of blotter material and roll immediately with a rubber-tired roller with tire pressures adjusted upward to 90 to 100 psi (620 to 690 kPa).

Traffic Control

Do not operate construction equipment at speeds exceeding 15 mph (25 km/hr) on the freshly applied AST for up to 24 hours, or until there is no threat of damage to the seal coat.

If the roadway remains open to traffic throughout the paving operation, do not allow traffic on freshly sprayed asphalt or on cover aggregate that is not fully compacted. As soon as all required rolling has been completed for a seal-coated area, controlled traffic may be permitted to operate on that surface. Use flaggers and pilot cars to control traffic on the new seal coat. Do not permit traffic

Figure 7.17. Emulsified asphalt distributor in action on the second coat of a double-layer AST

Frigure 7.18. Emulsified asphalt distributor in action

speed to exceed 15 mph (25 km/hr) for a period of 2 to 24 hours until legal speed traffic will not damage the surface. Repair any damage to the surface caused by construction equipment or public traffic as soon as possible.

7.3.3.3. Special Requirements for Double-Layer ASTs

Applying Emulsified Asphalt

1. Apply the AST within 72 hours of the time that surface preparation is completed.
2. If you use a prime coat, do not prime an area larger than can be covered by the following day's paving. Keep primed surfaces in good repair during the period between prime application and AST application. Repair holes or raveled areas with MC-30 cutback asphalt.
3. If you do not use a prime coat, the surface should not be completely dry. If dry, you can *dampen* the surface with a fine spray of water. Make sure that no standing water remains on the surface if you do spray.
4. These requirements are the same as items 2–10 for section 7.3.3.2 above, "Applying Emulsified Asphalt" for seal coats.

If no prime is used and if the texture of the surface is such that the initial application of asphalt material penetrates the surface, a prelimi-

Figure 7.19. Applying second layer of aggregate

Figure 7.20. Loading aggregate spreader

Figure 7.21. Cover aggregate spreader in action

nary emulsion application of 0.05 to 0.10 gal/yd^2 (0.23 to 0.45 L/m^2) may be required.

Applying Cover Aggregate

1. Moisten the cover aggregate with water the day before it is to be used.
2. Do not apply cover aggregate at a rate greater than 300 feet per minute (90 meters per minute).
3. Apply the cover aggregate within 1.5 minutes after application of the asphalt material (existing Alaska DOT&PF Highway Construction Specifications requirement) or, depending on weather conditions, as directed. Keep this time increment as constant as possible, but adjust as needed to meet changing conditions. Whenever it is apparent that the time limit above will be exceeded, make a transverse joint by placing construction paper (roofing felt or similar product) on the prepared surface and ending the seal coat operations on the paper. Remove the paper and dispose of it properly. Touch up the edges of the applied seal coat before restarting operations.
4. Spread cover aggregate so that the tires of the trucks and aggregate spreader never contact the uncovered and newly applied asphalt material.
5. Immediately after the first cover aggregate application is spread, cover deficient areas using additional material. Then, immediately compact the first application of cover aggregate by at least three complete coverages using rubber-tired rollers. A roller coverage is defined as the roller passing over a given location one time. Following compaction of the first cover aggregate application, sweep excess cover aggregate from the entire surface after sufficient curing—usually several days (see section 7.3.2.6).
6. Spray the second application of emulsified asphalt at the required application rate and according to application methods described at the start of this section. Follow this second emulsion application with the second course of cover aggregate, using the same equipment and methodology as for the first course of cover aggregate. After deficient areas are covered with additional material, compact the second cover aggregate application by at least two coverages using rubber-tired rollers, followed (optional step) by a third and final coverage by steel wheel rollers. Operate rubber-tired rollers at a maximum speed not exceeding 5 mph (8 km/hour). Operate steel wheel rollers in static (nonvibratory) mode only, and at a maximum speed not exceeding 5 mph (8 km/hour). Stop using steel wheel rollers if crushing or fracturing of the cover aggregate is evident. Complete all rolling required for each cover aggregate application the same day as that application.
7. After the second layer of cover aggregate has been compacted, sweep excess cover aggregate from the entire surface after sufficient curing—usually several days (see section 7.3.2.6).
8. Be prepared to maintain the AST at least four days after construction of each layer. Temporary maintenance will include the distribution of cover aggregate over the surface to absorb any free asphalt material and cover any area deficient in cover aggregate. Conduct this maintenance so as not to displace embedded aggregate. Repair any failed areas before installing striping.

Applying Blotter Material

Same as for section 7.3.3.2 above, "Applying Blotter Material" for seal coats.

Traffic Control

Do not operate construction equipment at speeds exceeding 15 mph (25 km/hour) on a freshly applied surface treatment for a period of up to 24 hours or until there is no threat of damage to the AST.

Unless otherwise specified, keep the highway open to traffic at all times. Do not allow traffic on freshly sprayed emulsified asphalt or on cover aggregate material that is not fully compacted. As soon as all required rolling has been completed for each AST layer, controlled traffic may be permitted to operate on that surface (this includes allowing traffic operation on the first layer of cover aggregate if all required rolling has been completed for that layer). Control traffic on the AST through use of pilot cars, to a speed not exceeding 15 mph (25 km/hour) for a period of 2 to 24 hours, until legal speed traffic will not damage the surface. Repair any damage to the surface caused by construction equipment or public traffic as soon as possible.

7.3.3.4. Special Requirements for High Float ASTs

The ideal aggregate moisture range during application is 2 to 3 percent, although a moisture content of up to 4 percent is allowed.

Distance between distributor and aggregate spreader: Place the cover aggregate for high float ASTs within 200 feet (60 meters) of the distributor. Do not move the high float operation too fast or you can create a large wave in front of the cover aggregate spreader. At times, problems may occur where the timing between emulsion and aggregate application (normally 1.5 minutes) requires special reconsideration. Sometimes it's better to delay placement of cover aggregate past the normal 1.5 minute recommendation given under "Applying Cover Aggregate" in order to minimize problems. This situation is discussed later under "Wave Control."

Control oil application to minimize overlap along longitudinal joints. With too much overlap, you will produce a substantial ridge along the logitudinal joint.

Applying Emulsified Asphalt

1. Apply the AST within 72 hours of the time that surface preparation is completed.
2. The surface should not be completely dry. If dry, you can *dampen* the surface with a fine spray of water. Check that no standing water remains when the AST is applied.
3. Do not allow the length of spread of high float asphalt emulsion to be more than the aggregate spreader can immediately cover.
4. The first pass over the segment of roadway being surfaced will follow a string line, set either on the shoulder or on the centerline, whichever is on the driver's side of the distributor. Do the second pass with the centerline joint on the driver's side of the distributor.
5. Do not allow equipment or vehicles on sprayed asphalt before cover aggregate application.
6. Do not spread the emulsion more than 6 inches (150 mm) wider than the width covered by the cover aggregate from the spreader.
7. Do not allow the emulsion to chill, set up, dry, or otherwise impair retention of the cover aggregate.
8. When the distributor is not spraying, park it so that the spray bar or mechanism will not drip asphalt material on the surface of the roadway.
9. Apply HFMS-2s at temperatures between 150 and 180˚F (65 to 82˚C).
10. Correct skipped areas or deficiencies. At joints, be careful to prevent applying too much asphalt.

Applying Cover Aggregate

1. Use cover aggregate that is at a temperature no lower than 40˚F (5˚C) and that has a moisture content of 2% to 4% (by dry weight)

at the time of application (see discussion in section 4.2.2.1, “Moisture Control for High Float Cover Aggregate”). Cover aggregate must be moistened (almost never required) or dried to achieve the specified moisture content.

2. Apply cover aggregate within 1.5 minutes after application of the emulsified asphalt (existing Alaska DOT&PF Highway Construction Specifications requirement). This time period should be kept as constant as possible, but can be adjusted as needed to meet unusual conditions (see Wave Control discussion below). Whenever it is apparent that the time limit above will be exceeded, make a transverse joint by placing construction paper (roofing felt or similar product) on the prepared surface and ending the paving operations on the paper. Remove the paper and dispose of it properly. Touch up the edges of the applied AST before restarting paving operations.
3. Immediately after cover aggregate is spread, cover deficient areas using additional material. Compact using rubber-tired rollers for the full width of the aggregate immediately after placement of cover aggregate. Continue compacting for at least six complete coverages. The rolling operation should be accomplished within 500 feet (150 meters) of the cover aggregate application. The high float application must be slowed if rolling cannot be completed within this distance.
4. Do not allow the rubber-tired roller to exceed 5 mph (8 km/hr).
5. Do not allow the tires of the trucks or aggregate spreader to contact the uncovered emulsion.
6. Sweep to remove excess cover aggregate. Sweeping should occur after the material is sufficiently cured to prevent damage—usually between one and two weeks following the application of cover aggregate. Redistribute ridges of loose aggregate created by traffic during the period before final sweeping. As the ridges develop, carefully spread the material uniformly over the surface using brooms or graders.

Wave Control During High Float Applications

This discussion covers one of the finer points of high float application technique. Be aware that the “wave” as discussed here may or may not exist on a particular paving project. Its existence depends on the type of aggregate spreader being used, as well as other variables involving materials properties.

Just ahead of aggregate being spread by a chip spreader, the asphalt emulsion can form a wave. If this wave is too high, an emulsion/aggregate mixture will flow laterally past the edge of the spread. Lateral flow causes an excess application of material along the longitudinal joint. Also, if the wave is too large, the wave mass can be overridden by the forward motion of the spreading operation. Overriding the wave leaves behind a transverse line of extra material, i.e., a transverse, linear bump.

DOT&PF Northern Region’s M&O personnel offer the following suggestions to cope with a wave problem, should it occur during aggregate application.

1. Delay the aggregate spreader behind the distributor. This delay will allow the oil to break and partially stiffen. This delay may range between 3 minutes and 10+ minutes. The delay should not be longer than the minimum required to eliminate the problem wave. Factors that affect the length of delay required include wind, sun exposure, air and ground temperature, cross slope, and grade.
2. Limit forward speed of the aggregate spreader. The forward speed of the spreader has a significant affect on the wave. Generally, spreaders should not exceed 120 feet per minute, and it may be necessary to slow below 70 feet per minute.
3. Install a comb on the aggregate spreader hopper. Northern Region M&O (Fairbanks

area) has used a comb on their high float cover aggregate spreaders for several years. Contact them for comb design and installation details.

Applying Blotter Material

Same as for section 7.3.3.2 above, “Applying Blotter Material” for seal coats.

Traffic Control

Do not operate construction equipment at speeds exceeding 15 mph (25 km/hour) on a freshly applied surface treatment for a period of up to 24 hours or until there is no threat of damage to the AST.

Unless otherwise specified, keep the highway open to traffic at all times. Do not allow traffic on freshly sprayed emulsified asphalt or on cover aggregate material that is not fully compacted. As soon as all required rolling has been completed for the high float surface, controlled traffic may be permitted to operate on that surface. Control traffic on the AST through use of pilot cars to a speed not exceeding 15 mph (25 km/hour) for a period of 2 to 24 hours, until legal-speed traffic will not damage the surface. Repair any damage to the surface caused by construction equipment or public traffic as soon as possible.

7.4. Permanent Markings

Until the AST pavement has cured enough to do finish brooming, you are essentially dealing with a gravel road. For information on interim markings, refer to Alaska Highway Construction Specifications, subsection 643-3.09, and section 5.2 of this guide. After final brooming, apply painted markings using a heavy application of marker paint, generally according to the applicable requirements of the Alaska Traffic Manual. Use striping methods described in DOT&PF Highway Construction Specification, subsection 670 and specifically according to 670-3.01, item 1 for painted markings. AST surfaces (especially newer surfaces) are highly textured. To maximize visibility of the painted markings, apply two coats of paint, one coat applied with the striping equipment moving in one direction and the other coat applied with the striping equipment traveling in the opposite direction (for some markings and in some locations it will be impossible to do this). Make sure you check with your regional traffic engineer to verify that the permanent markings meet the most recent requirements.

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Chapter 8. Common Problems

8.1. Avoiding Problems

8.1.1. View of AST Problems Based on Alaskan Experience

Problem Sources in Likely Order of Importance

1. Bad weather and/or paving too early or too late in the season have combined to produce most AST failures. Read Chapter 6, "Weather for Construction and Curing."

   The most repeated problem is bad weather during or after construction. The principle here is that the AST curing process must be allowed to (1) initiate with emulsion and aggregate in good contact, i.e., no rain during construction; and (2) continue to a certain point before the AST can withstand full-speed traffic, i.e., good weather after construction. In Alaska, and *even under fairly ideal conditions,* there is a "super" critical period for curing that begins during paving and continues for at least four days. *Important concept:* A post-construction turn in the weather can turn the hoped for four-day period into the need for additional curing the following spring.

   AST paving near the low temperature limit or during windy or high-humidity weather has often caused a call for a substantial increase in the emulsion application rate. This has been a common response to the observation that "the oil is not holding the chips." **This can be a trap!** Think long and hard (and consult with management) before increasing the emulsion application rate much more than 10% above the rate established for the project (see discussion about the expected ranges of application rates in section 7.3.1, "Application Rates for Emulsified Asphalt and Cover Aggregate."

   Traffic control for an extended period of time might have prevented some DOT&PF failures. After the "chips are down," AST survival can be a matter of additional traffic control costs versus AST repair costs. On smaller AST patching-type jobs, it may be cheaper to redo the patches. On a miles-long contracted construction project, extended traffic control may be a bargain compared to a repave.
2. Poor pavement structure, including poor drainage (see section 7.2, "Road Surface Preparation").
3. Nonspecification materials (see a general discussion in 4.1.1, "Specifications and Test Methods").

   Moisture and/or clay content of high float cover aggregate (see sections 4.2.2.1, "Moisture Control for High Float Cover Aggregate" and 4.2.1.2, "Aggregate for High Float ASTs").

   Dirty aggregate for seal coats and double-layer ASTs (see section 4.2.1.1, "Aggregate for Seal Coats and Double-Layer ASTs")
4. Problems along joints (see section 7.3.3, "The Paving Operation").

Suggestions for Future Jobs

- If in doubt about how to proceed with the construction process—first do a test section.
- Consider minimizing damage to new AST pavements on narrow, heavily truck-trafficked roadways such as the Dalton Highway. Without opposing traffic in sight, trucks tend to travel down the middle part of the roadway. While curing, the new AST takes a beating in the single wheelpath of what essentially becomes a one-lane road. To boost pavement longevity, consider marking the centerline with cones or other devices for a few days to force two-lane road use while the centerline area is allowed extra cure time.
- If AST life is estimated to be long or if the original AST surface is unacceptably rough, consider adding an additional AST layer. Consider applying a final seal coat approximately one year after original AST construction.

- Consider adding warranty language to AST contracts.

Helpful Guidelines for the Field Inspector

One of the best tools for avoiding AST problems is the discerning eye of a good inspector. Successful AST work requires that a diligent inspector be present during the entire construction process. On maintenance work, the foreman can double as the inspector—but a knowledgeable inspector in some form or another is required!

The Inspector's Job

The field inspector must spend a lot of time walking behind and ahead of the operation checking:

- Correct application rates (or adjusted rates). Also documents that calibrations on distributor and aggregate spreader have been properly done.
- Materials are within specification and shipping documentation for the emulsion is supplied.
- The required AST application widths are accomplished.
- Required touch-up of uncovered binder is done before rolling.
- Structures in the road are being protected and promptly cleaned after final rolling.
- The distributor is not applying binder too far ahead of the chip spreader.
- Roller operation is not more than five minutes behind the chip spreader.
- Traffic control devices are keeping up with the project.

Generally, the inspector will observe and inspect the operation from the binder application to the final rolling to ensure the product meets the desired results. At the end of each day, the inspector tours the newly paved areas and looks for bleeding problems, excess aggregate or "float," and how well the curing process is working. Any concerns or problems noticed should be brought to the attention of the field supervisor and corrections made as needed. Depending on the competence of the inspector, the supervisor may want to allow the inspector to make decisions regarding application rate changes.

The field inspector should keep a daily diary of the project's process, quantities of aggregate and binder placed, weather conditions, and any problems that occurred. The diary should include comments concerning performance of the equipment and operators. The inspector and field supervisor should agree on pay item quantities daily to minimize overruns, calculate yields, and avoid disagreements at project closing.

At the end of a contracted project, the DOT&PF field inspector and the contractor's field supervisor should do the following:

- Agree in writing on total pay quantities for the project.
- Remove excess emulsion or aggregate from the site or agree on the schedule to do so.
- Review the daily diary of the project and discuss methods or ways to improve the operation for future projects.
- Clean up the sites used to store the equipment or stockpile materials.

Appearance Checks by Field Inspector

- Determine if your application rates are appropriate to the road surface condition by doing a "wave test." The wave test is fully described in section 7.3.1, "Application Rates for Emulsified Asphalt and Cover Aggregate."
- Bluish smoke from the binder as it is applied means the binder is too hot—check the temperature gauge on distributor and allow cooling to the specified temperature before proceeding.
- Streaking or "binder lines" appearing before initial rolling of the aggregate mean that the height of the distributor bar is too high or too low and operator should adjust accordingly. See section 7.3.2.2, "Distributors" for details.
- The emulsified asphalt will be brown in color at application. The material will turn black as it "breaks" and begins to cure. Cover aggregate must be applied before the binder

breaks to ensure the bond between the aggregate, the binder, and the road surface occurs.

- On a hot, low-humidity day, the emulsion will break in three to five minutes. The cover aggregate should be rolled before this happens.
- The field inspector will get a strong indication of the success of the AST by touring the areas the next spring after a winter of plowing and freeze-thaw cycles.

Additional Hints for the Inspector

The following list (slightly modified) for AST projects is from the "Inspector's Job Guide and Highway Maintenance Tables," published by Michigan's Technical Assistance Program, Transportation Center, Michigan Technological University.

- Be familiar with the specifications and methods applicable to the work—this type of construction proceeds rapidly!
- Check that all necessary testing equipment is available (or that you are prepared to do the required sampling and transport the samples correctly).
- Check asphalt distributor and aggregate spreader for a current inspection sticker and all other equipment to ensure that it meets specifications.
- Check the condition and adjustment of the asphalt pump, spray bar, and spray nozzles. The asphalt pump should provide uniform pressure. The nozzles should be set uniformly at the proper angle from the axis of the spray bar. The height of the spray bar should provide correct overlap of the spray from each nozzle.
- Check the motor graders, rollers, tankers, etc., to ensure that they are in good operating condition.
- Check that the roadway to be treated is smooth, compacted, and has a uniform grade and cross section. For seal coating, the existing surface should be clean and free of loose patches or excessive joint and crack sealing materials. Prelevel or grade uneven surfaces as required.
- Inspect the stockpiled aggregate to determine the grading of the material. Aggregate for seal coats and double-layer ASTs should be damp when loaded onto trucks for hauling to the roadway. (Emulsified asphalt will not readily coat dry or dusty aggregate.)
- Test the spray bar and nozzles immediately before starting the application.
- Keep a record of each distributor load applied showing area treated, gallons spread, and temperature of the asphalt.
- Check that aggregate is applied at the specified rate immediately after the application of the asphalt. Ensure that the spread of asphalt is not extended beyond the area that can be covered within the allowed time.
- Cover any areas where there are skips or omissions.
- Check that rolling is conducted as soon as possible following application of the aggregate in order to properly embed the cover stone in the asphalt.
- Broom the surface after curing to remove loose or excessive cover stone.
- In the daily record, include the square yards placed, spread rates, and other necessary information on an approved form for documentation and payment.

8.2. AST First Aid

Damp? Raining? Threatening rain? Too cold? Too late in the season? Too early in the season? — STOP ! DON'T PAVE!

The following information is taken from the Minnesota Seal Coat Handbook and is slightly modified. The three most common problems that occur in the construction of a seal coat are

- streaked appearance,
- bleeding or flushing, and
- loss of cover aggregate.

Problem: Streaked Appearance

Identify streaking by longitudinal grooves or ridges in the seal coat surface. Although streaking is primarily a cosmetic problem, it is an undesirable one. If the distributor is calibrated properly, streaking can virtually be eliminated. Streaking of high float ASTs is very common and can be severe to the point that it can be easily felt while driving and will channel water during a storm. Figure 8.1 shows an example of streaking.

The three most common causes of streaking, in order of occurrence, are:

- Incorrect spray bar height
- Misalignment of the nozzles
- Clogged nozzles

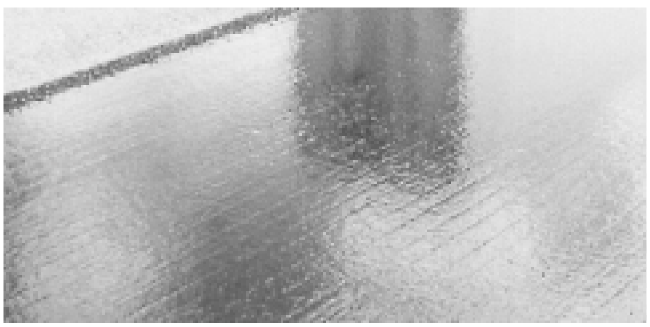

Figure 8.1. Example of streaking caused by incorrect spray bar height

Solution #1: Check the Spray Bar Height

If the distributor's spray bar is the wrong height, the fans of asphalt from the nozzles will not meet the pavement surface at the same point. As a result, there will be gaps if the bar is too low and ridges if the bar is too high. Both result in a non-uniform layer of asphalt binder.

Notice that for a triple lap application, every fourth nozzle should hit the pavement at the same point. For a double lap application, every other nozzle should meet the pavement at the same point. Figure 8.2 shows what happens with an incorrect spray bar height. Refer to section 7.3.2.2, "Distributors," for more detail about calibrating the distributor.

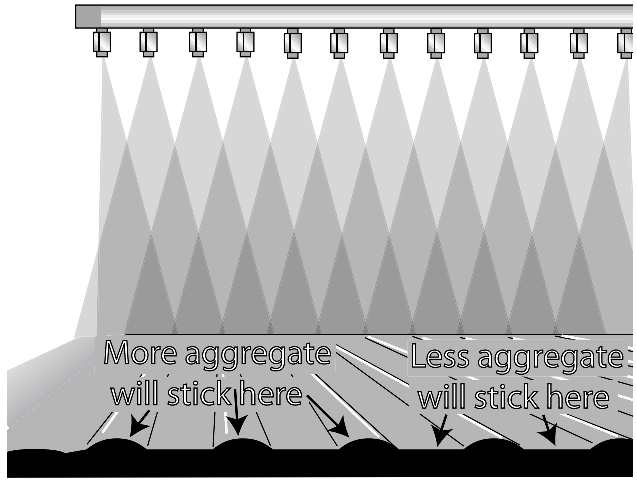

Figure 8.2. Incorrect spray bar height

Solution #2: Align the Nozzles Properly

For the asphalt binder to be a uniform thickness across the pavement surface, the spray bar nozzles must all be set at the same angle. If the nozzles are at different angles, the width of the fans will also be different. This results in a non-uniform application. Normally, the angle of the nozzles can be adjusted with a simple turn of a wrench.

Solution #3: Make Sure the Nozzles are Not Clogged

Because asphalt cement is sticky, and its viscosity increases as it cools, the nozzles of the spray bar are susceptible to clogging from stiffened asphalt as well as grass and weeds that may be picked up during construction. Before beginning an AST project, the nozzles of the spray bar should be inspected and cleared of debris. The emulsion must be heated sufficiently (see spray temperature requirements in section 4.1.1, "Specifications and Test Methods").

During construction, the spray pattern should be checked often and any noticeable blockage should be cleared immediately.

Problem: Flushing (Bleeding)

Flushing, also referred to as bleeding, is defined as excess asphalt in the wheel path, or traffic areas. Too much emulsified asphalt for a given amount of aggregate causes it. If too much emulsion is applied, it may rise above the top of the aggregate and stick to the construction equipment, as well as everything else. Unfortunately (and most often), the problem of excess binder is not apparent during construction but is brought to the surface by traffic action during the first hot summer day.

Solution #1: Use a Cubical Aggregate

Using flat aggregate greatly increases the risk of bleeding. This is because traffic forces flat chips in the wheel path to rotate and the layer of aggregate effectively becomes too thin.

Solution #2: Reduce the Asphalt Binder Application Rate

Bleeding can also occur when using cubical aggregate simply because too much binder is used. Exceed the prescribed application rates of emulsified asphalt only with great care! For more details on seal coat and double-layer AST mix designs, refer to Appendix D. Refer to 7.3.1.3, "For High Float AST" to find required high float application rates.

Problem: Loss of Cover Aggregate

A very common problem is the loss of some or all of the cover aggregate. **The number one reason for this in Alaska is bad construction weather and/or AST paving too late or too early in the year.**

Other possible causes are:

- insufficient asphalt binder,
- poor materials application and/or poor rolling of longitudinal joints,
- allowing the binder to "break" before the aggregate is placed and rolled,
- dusty aggregate (for seal coat and double-layer AST projects),
- poor gradation, and
- also possible: during the first winter after construction, use of excessive snow plow down pressure.

Solution #1: Do not pave in bad weather or during the prohibited time of year (read Chapter 6).

Solution #2: Apply more emulsion (but be careful going more than about 10% above the prescribed amount!)

For seal coat and double-layer ASTs, perform a "wave" test (see section 7.3.1 of this guide) or pull out individual pieces of aggregate to check the aggregate/asphalt bond.

For high float cover aggregate, the goal is to apply enough emulsion so that it barely reaches the surface after the AST is compacted. This is usually judged by the surface appearance immediately after compaction. Emulsion will be visible at many random locations across the compacted surface. These "shows" of emulsion will usually be less than a meter apart and the surface will therefore have a somewhat mottled appearance. Do not use so much emulsion that emulsion becomes visible after compaction over the entire surface.

Solution #3: Use clean aggregate (applies to cover aggregate for seal coats and double-layer ASTs)

Specifications in this guide limit fines minus #200 sieve size (minus 0.075 mm) in seal coat and double-layer cover aggregate to 1%. Dirty aggregate should not be used for seal coating or double-layer ASTs. Dust coats the outside of the aggregate particles and severely reduces the aggregate/asphalt bond.

If the aggregate is dirty, wash it! If washing is not possible, consider switching to a high float AST or using one of the following methods.

Warning!

The following methods are experimental in Alaska:

- Try using a high float emulsion, such as HFMS-2s (Minnesota's recommendation—this has not been tried in Alaska for seal coating or double-layer ASTs.)

- Pre-coat the chips with asphalt cement (Minnesota's recommendation—this has not been tried in Alaska for seal coating or double-layer ASTs).

Problem: Bad Centerline Joint on a Seal Coat Project

If the existing roadway has a deteriorated centerline joint, it should be repaired before seal coating. An open, spalled, or raveled paving joint will absorb much more emulsion than the surrounding pavement. The result is insufficient binder in this area and loss of cover aggregate. Since snow plows tend to ride on this high spot of the pavement, having a good longitudinal seam is important to the longevity of a seal coat project.

Solution: Apply a Strip of Fog Seal Along the Centerline

Placing a fog seal in this area will help to prevent too much of the binder from being absorbed into the pavement. A two-to-three-foot wide application of CRS-2 emulsion applied at about 0.1 to 0.2 gal/yd^2 (0.4 to 0.9 L/m^2) has worked well (in Minnesota) as shown in Figure 8.3. The emulsion fog seal should be allowed to cure before placing the seal coat AST.

Figure 8.3. Fog seal on centerline before seal coat to prevent excess absorption

Problem: Bad Centerline Joint on a Double-Layer or High Float AST

A ridge may be created during construction but does not become visible until sweeping or a line of potholes may appear late in the project (or after the project is completed).

Solution: Verify the correct application of emulsified asphalt and correct alignment of application along the joint

Verify that the application rate of emulsified asphalt is correct at the ends of the spray bar. The inspector must keep careful watch over the quality of the joint and require additional materials or raking if needed. Using a string line can help the distributor operator maintain an accurate line along the joint.

Problem: The AST is completed or nearly completed before raveling and potholing become apparent

Many problems (most likely bad post-construction weather) can cause an apparently good AST job to go sour.

Solution #1: Extend period of traffic control

Limit the speed of traffic and immediately patch potholes that have developed. A few extra days of curing could be enough to stop further damage. Unfilled potholes will enlarge very rapidly, especially in rainy weather—quick action can sometimes save a lot of pavement.

Solution #2: Consider applying an additional AST layer

If extended traffic control and patching doesn't suffice, consider armoring the existing AST by applying an additional layer, i.e., a seal coat AST.

Figure 8.4. Evidence of dusty aggregate

Notes

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Alaska DOT&PF Preconstruction Manual, Chapter 11, Section 1180 (Pavement Design), Alaska Department of Transportation and Public Facilities, Juneau, Alaska, 2001.

Notes

Appendix A: Pavement Distress Summary

(Adapted From The Asphalt Institute, Manual Series No. 16)

1. Pot Hole

Possible Causes

1. Weak pavement, surface, base, subgrade
2. Thin surface
3. Excess or deficient fines
4. Poor drainage

Maintenance Suggestions

Cut wet material out, clean and fill with asphalt mix. Allow an extra 25% of volume for compaction. Use a straight edge to restore patch to existing roadway section.

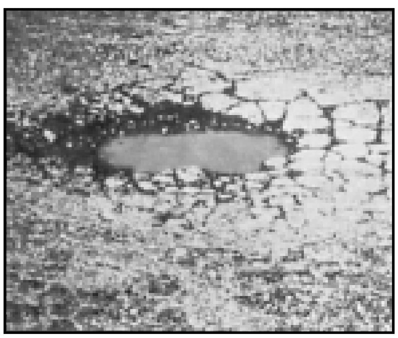

Figure A.1. Pot hole

2. Base Failure

Possible Causes

1. Consolidation of subgrade
2. Overload in area
3. Lack of lateral support
4. Poor drainage

Maintenance Suggestions

Remove all surface and base to a fine material and replace with an asphalt mix to a minimum depth according to required structural design.

3. Raveling

Possible Causes

1. Lack of compaction
2. Constructed in cold or wet weather
3. Dirty aggregate
4. Dry mix
5. Over heating mix

Maintenance Suggestions

Skin patch, spot seal, fog seal, or slurry seal. If required for entire project, a thin overlay may be required.

Figure A.2. Raveling

4. Flushing (Bleeding)

Possible Causes

1. Excess asphalt
2. Low air voids
3. Excess prime or tack

Maintenance Suggestion

Blot with screenings, apply chip surface treatment, or thin overlay. If project is pushing or other signs of plastic movement, then mill and overlay.

Figure A.3. Bleeding

5. Corrugations

Possible Causes

1. Plastic mixture
2. Low air voids
3. Excessive asphalt or fines
4. Unstable base material

Maintenance Suggestion

Mill plastic mixture off and replace with proper mixture. If base material is responsible, remove pavement, scarify and recompact.

6. Depressions

Possible Causes

1. Consolidation of subgrade
2. Poor construction
3. Poor drainage

Maintenance Suggestion

Clean area, tack, and place a hot-mix skin patch. The area should be string lined for limits of patch.

7. Alligator Cracks (Fatigue Cracks)

Possible Causes

1. Weak surface, base, or subgrade
2. Thin surface or base
3. Poor drainage

Maintenance Suggestion

Remove all distressed area to a depth of firm material and replace with the proper asphalt mix, allowing 25% times depth of patch for compaction.

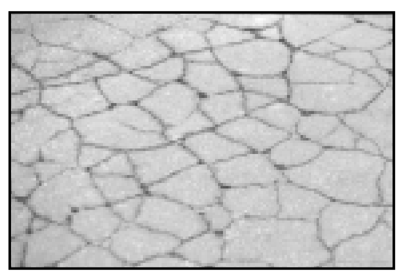

Figure A.4. Alligator cracks

8. Dry Surface/Cracking

Possible Causes

1. Old and dried out mix
2. Mix was placed too dry

Maintenance Suggestion

Fog seal, slurry seal, or overlay.

9. Edge Cracks

Possible Causes

1. Lack of lateral support
2. Settlement of underlying material
3. Shrinkage of drying out soil

Maintenance Suggestion

Improve drainage. Remove trees, shrubs etc, close to edge. Fill cracks with asphalt emulsion slurry or emulsified asphalt.

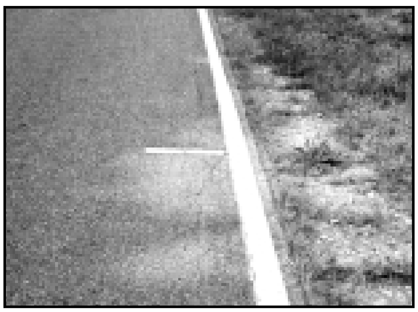

Figure A.5. Edge cracks

10. Edge Joint Cracks

Possible Causes

1. Wetting and drying beneath shoulder surface
2. Poor shoulder drainage due to a shoulder higher than main pavement
3. Depression in pavement edge
4. Shoulder settlement, mix shrinkage and trucks straddling the joint

Maintenance Suggestion

Improve drainage by removing the source that traps the water. Fill with asphalt emulsion slurry or light grade of asphalt mixed with fine sand. Provide side drainage ditches.

11. Slippage Cracks

Possible Causes

1. Lack of a good bond between surface layer and the course beneath
2. Lack of bond due to dust, oil, dirt, rubber, water, and other nonadhesive material
3. Tack coat has not been used
4. Mixture has a high sand content

Maintenance Suggestion

Remove surface layer from around crack until a good bond between layers is found. Patch with plant-mixed asphalt material. Tack with an asphalt emulsion.

12. Rutting

Possible Causes

1. Results from consolidation or lateral movement of material under traffic
2. New asphalt pavements with too little compaction during construction
3. Plastic fines in mix that does not have enough stability to support traffic (high minus #200 material causing low air voids)
4. Too much asphalt cement
5. Studded tire wear
6. Weak aggregate layers below the asphalt concrete layer

Maintenance Suggestion

Level pavements by filling with hot plant-mixed asphalt materials. Follow with thin asphalt plant-mix overlay or roto-mill and overlay. Remove plastic mix by milling and replace with stable mix.

Figure A.6. Rutting

13. Loss of Aggregate on Surface Treatments

Possible Causes

1. Not spread immediately (1.5 minutes)
2. Asphalt may have cooled too much
3. Aggregate too dusty or too wet when spread
4. Not rolled immediately after placing, it may not have become seated
5. Steel-wheeled roller alone was used for compaction
6. Weather too cool when treatment applied
7. Fast traffic too soon after application

Maintenance Suggestion

Spread hot coarse sand over affected areas. After spreading it should be rolled immediately with a pneumatic-tired roller.

14. Longitudinal Streaking

Possible Cause

1. Spray bar not set at correct height
2. Nozzle on spray bar not set at the correct angle
3. Wrong asphalt pump size
4. Asphalt too cold
5. Pump pressure too low

Maintenance Suggestion

Adjust equipment and reseal surface using proper procedure.

15. Moisture Damage (Stripping) Identified by Pavement Shoving, Bleeding or Rutting

Possible Cause

1. Moisture in pavement by high voids/low density, usually trapped in lower or intermediate layer
2. Excessive minus #200 material: high fines to asphalt ratio

Maintenance Suggestion

Remove and replace with good mix.

16. Orthogonal Cracking, Uniform Crack Spacing (Map Cracking)

1. Low temperature thermal cracking, asphalt grade is too hard for climatic conditions.

Maintenance Suggestion

Should use softer grade asphalt.
Pour with ASTM 3405 joint material.

Figure A.7. Map cracking

Notes

Notes

ADT—Average Daily Traffic.

Aggregate Spreaders—Machines used for spreading aggregate evenly at a uniform rate on a surface.

Mechanical Spreaders—Spreader boxes that are mounted on wheels. The spreaders are attached to and pushed by dump trucks.

Self-Propelled Spreaders—Spreaders having their own power units and two hoppers. The spreader pulls the truck as it dumps its load into the receiving hopper. Conveyor belts move the aggregate forward to the spreading hopper.

Tail Gate Spreaders—Boxes with adjustable openings that are attached to and suspended from the tailgates of dump trucks.

Whirl Spreaders—Spreaders that are attached to or are built onto dump trucks. Aggregate is fed onto the spreader disc through an adjustable opening and the speed of the disc controls the width of spread.

Aggregate Trucks—Trucks equipped with hydraulic lifts to dump the aggregate into the spreader.

Alligator Cracking—Also known as fatigue cracking. Cracks in an asphalt layer caused by repeated traffic loadings. The cracking pattern resembles an alligator's skin of chicken wire. The cracks indicate that the pavement has failed by fatigue.

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 left after the lubricating and fuel oils have been extracted from the crude oil. Common term for both asphalt cement and emulsified asphalt (also see oil).

Asphalt Cement—Asphalt that is refined to meet specifications for paving, roofing, industrial, and special purposes. Heat is required to made it fluid.

Asphalt Concrete—A high-quality mixture of aggregate particles embedded in a matrix of asphalt cement that fills most of the voids between the aggregate particles and binds them together. The mixture is compacted to a uniform, dense state. An asphalt surface treatment consists of a thin layer of asphalt concrete where the asphalt concrete mixture is created by spreading alternate layers of emulsified asphalt and aggregate directly onto the roadway surface (instead of plant-mixing the components).

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

Asphalt Emulsion—See Emulsified Asphalt.

Asphalt Prime Coat—Spray application of asphalt primer, that is, cutback or emulsified asphalt applied to a base course surface before application of an asphalt surfacing material. The asphalt prime penetrates or is mixed into the surface of the base and plugs the voids, hardens the top, and helps bind it to the overlying asphalt course. Under ideal conditions the prime coat may effectively increase the total thickness of the AST by about 12 mm. An MC-30 cutback asphalt is often used by DOT&PF as the prime coat for double-layer ASTs.

Asphalt Surface Course—The asphalt concrete, i.e., AST driving surface. The top layer of an asphalt pavement structure. Also known as the wearing course or simply as the pavement. See pavement.

Asphalt Surface Treatment (AST)—A thin layer of asphalt concrete formed by the application of emulsified asphalt or emulsified asphalt plus aggregate to protect or restore an existing roadway surface. Surface treatments are typically less than 1 inch (25 mm) thick.

Seal Coat AST—A thin surface treatment used to improve the surface texture and protect an asphalt surface. Constructed using a single application of rapid-setting emulsified asphalt and crushed, uniformly sized aggregate. The seal coat AST is placed on an existing paved surface and is typically about 12 mm thick, about the same as the nominal maximum size of the aggregate particles.

Double-Layer AST—An AST surface applied as a permanent dust-palliative driving surface—normally considered as an upgrade from a gravel surface but lower in quality than a hot mix asphalt concrete pavement. Often selected for areas where a paved surface is desired but pavement design life is expected to be short for some reason. Constructed using two applications of rapid-setting emulsified asphalt and crushed, uniformly sized aggregate. Aggregate used for the first layer is nominally twice as large as aggregate used for the second layer. The double-layer AST is placed on a prepared base course surface and is typically about 19 mm thick, about the same as the nominal maximum size of the aggregate particles used for the first layer.

High Float AST—An AST surface applied as a permanent dust-palliative driving surface—normally considered as an upgrade from a gravel surface but lower in quality than a hot mix asphalt concrete pavement. Often selected for areas where a paved surface is desired but pavement design life is expected to be short for some reason. Constructed using a single application of high float emulsified asphalt and a crushed, well-graded aggregate. The high float AST is placed on a prepared base course surface and is typically about 19 mm thick.

Base Course—The layer of the pavement structure located directly beneath the surface layer. The base course can consist of an asphalt-aggregate mixture or untreated aggregate (gravel) material.

Binder—Commonly used term for residual asphalt cement.

Bleeding—Commonly used term for flushing (see flushing).

Block Cracking—A rectangular pattern of cracking in asphalt pavements that is caused by hardening and shrinkage of the material during low temperatures. Often referred to as map cracking.

Bound Layer—Layer of pavement structure where aggregate materials are cemented together with asphalt cement or other bonding agent.

Breaking—This is the first stage of the curing process when the emulsified asphalt is said to "break down" as the asphalt cement separates from its water matrix. The emulsifying agent primarily controls the rate of breaking.

Chip Job—Common term for a seal coat or a double-layer AST. The seal coat AST is often referred to as a single-shot chop job and the double-layer AST as a double-shot chip job.

Chips—Refers to the uniformly sized crushed aggregate used for seal coat and double-layer ASTs.

Compaction—Increases density, increases strength, decreases voids of AST pavement by rolling with rubber-tired or steel wheel rollers.

Curing—The development of the mechanical properties of the asphalt binder. The process eventually transforms the combination of emulsified asphalt and aggregate into a tough asphalt concrete material. Curing begins as asphalt cement separates from the emulsion state. The asphalt particles then begin to coalesce and bond with the aggregate. Curing continues until all nonasphalt liquid components of the original emulsion are evaporated to the atmosphere, and the maximum asphalt cement/aggregate bond (and strength) has developed.

Cutback Asphalt—Asphalt cement that has been diluted through the addition of a petroleum solvent. The solvent softens the asphalt cement and allows it to be easily mixed with aggregates or sprayed on the pavement surface. The solvent eventually evaporates, leaving the residual asphalt cement.

MC-30—Medium-curing cutback often used by DOT&PF for prime coat.

Embankment Material—Roadway fill material placed between the original ground surface and the bottom of the pavement structure.

Emulsified Asphalt—A mixture of asphalt cement, water, and an emulsifying agent. The emulsifying agent acts like a soap and allows the asphalt to be dispersed in the water. Emulsified asphalt droplets are usually either anionic (negatively charged) or cationic (positively charged). The emulsified asphalt can be easily mixed with aggregate or sprayed on a pavement surface. The water and asphalt eventually separate (break) leaving the residual asphalt cement. See *Asphalt Emulsion Manual,* The Asphalt Institute, Manual Series No.19, Chapter 2 for additional information on emulsified asphalt types.

CRS-2—Cationic, rapid-setting emulsified asphalt typically used by DOT&PF for seal coat and double-layer ASTs.

HFMS-2s—High float, anionic, medium-setting emulsion used by DOT&PF for high float ASTs.

Emulsifying Agent or Emulsifier—The chemical added to the water and asphalt that keeps the asphalt in stable suspension in the water. The emulsifier determines the charge of the emulsion and controls the breaking rate.

ESAL—Equivalent single axle loads.

Fatigue Cracking—See alligator cracking.

Flushing—Also known as bleeding. Excess asphalt binder occurring on the pavement surface. The flushing may create a shiny, glass-like surface that may be tacky to the touch. Flushing is usually found in the wheelpaths.

Foundation Material—Natural material located beneath the original ground surface.

Gravel—Aggregate material larger than sand and smaller than cobbles (2 to 75 mm). Gravel size materials are the predominant component of AST aggregate and are a highly desirable component of all layers in the pavement structure.

IRI—International Roughness Index.

Map Cracking—See block cracking.

Oil—Common term for both asphalt cement and emulsified asphalt (also see asphalt).

Patch—A portion of the pavement surface that has been removed and replaced or additional material applied to the pavement after original construction.

Pavement—The surfacing layer of the roadway. The AST is a form of asphalt concrete pavement.

Pavement Design—Design of the layers of the pavement structure with regard to required pavement design life, design traffic loadings, materials quality, and expected seasonal changes in materials properties.

Pavement Design Life—Number of years of service expected from a pavement before it needs to be replaced. Design life is dependent on variables such as intensity of traffic loadings, material layer quality, material layer thickness, weather, and quality of drainage and maintenance practices.

Pavement Structure—The pavement layer or surface layer plus an additional meter of selected material that is designed as a layered elastic system intended to support the live loadings of traffic for a specified design life. Alaska DOT&PF pavement design procedures address only those materials within the pavement structure. Layers of materials within the pavement structure must withstand significant stresses imposed by truck traffic loadings. The pavement structure is composed of a base course and subbase materials. The pavement structure is underlain by material comprising the subgrade (embankment plus foundation material).

Potholes—Bowl-shaped holes of various sizes in the pavement surface. Usually occurs after fatigue cracking and is often associated with base course drainage problems.

Power Sweeper—A power-operated rotary broom used to clean loose material from the pavement surface.

Pumping—Ejection of loose material and water from under the pavement through joints and cracks, caused by vertical movement of the pavement under traffic loadings. Also refers to the detrimental migration of fine particles within saturated base and subbase layers under traffic loadings.

Raveling—Wearing away of the pavement surface caused by the dislodging of aggregate particles and loss of asphalt binder.

Reclaiming—Through mechanical grinding and other size reduction methods, an existing pavement layer is broken down to particles of about minus 2 inches (50 mm) size for reuse (recycled) as selected material in the pavement structure. Equipment uses drum-mounted carbide cutting bits to accomplish the milling and pulverizing action.

Reclaiming Machine—A self-propelled unit having a transverse-mounted, carbide bit equipped cutting and mixing head inside of a closed chamber for pulverizing and mixing existing pavement materials (sometimes) with asphalt emulsion. Emulsified asphalt and/or water may be added directly through the machine by a liquid additive system and spray bar.

Reconstruction—Complete removal and replacement of a pavement section with a new pavement design.

Recycling—General term commonly applied to processing and reusing old asphalt concrete (from an existing pavement surface) in a new pavement structure.

Reflection Cracking—Cracking that appears on the surface of a seal coat AST above joints and cracks in the underlying pavement layer due to continued horizontal and vertical movement of these joints and cracks. Cracking in double-layer and seal coat ASTs above active major thermal cracks that formed in the underlying roadway materials before AST placement.

Rehabilitation—Work undertaken to extend the service life of an existing pavement.

Residual Asphalt Cement—Asphalt cement residue material that remains after an emulsified asphalt's water component has evaporated and the material has cured. The residual asphalt cement and aggregate comprise the asphalt concrete, which is the AST pavement. Commonly referred to as binder.

Rideability—Sometimes referred to as ride quality, it is a measure of ride quality as perceived by its users.

Restoration—Work required to return the existing pavement structure to a suitable condition to perform satisfactorily.

Roller Coverage—One passage of a roller over a particular location. Also known as a roller pass.

Roller Pass—See roller coverage.

Roller Trip—Two roller coverages, i.e., two passages of a roller over a particular location.

Rubber-Tired Roller—Rollers with a number of tires spaced so their tracks overlap while giving kneading compaction. Also known as a pneumatic-tired roller.

Rutting—Longitudinal surface depressions in the wheelpath caused by plastic movement of the mix, inadequate compaction, or abrasion from studded tires.

Sand—Fine aggregate material larger than silt and smaller than gravel #200 sieve to #10 sieve (0.075 mm to 2 mm). Sand is usually produced from natural disintegration and abrasion of rock or processing of completely friable sandstone.

Shoving—Longitudinal displacement of a localized area of the pavement surface caused by breaking or accelerating vehicles.

Slippage Cracks—Crescent-shaped cracks occurring in the direction of traffic, generally caused by shoving of the asphalt concrete pavement.

Steel Wheel Static Rollers—Tandem or three-wheel rollers with cylindrical steel rolls that apply their weight directly to the pavement.

Steel Wheel Vibratory Rollers—Rollers having single or double cylindrical steel rolls that apply compactive effort with weight and vibration. The amount of compactive force is adjusted by changing the frequency and amplitude of vibration.

Structural Condition—The condition of a pavement structure as it pertains to its ability to support repeated traffic loadings.

Subbase Material—High-quality material located within the pavement structure beneath the base course.

Subgrade Material—All materials beneath the pavement structure (includes embankment and foundation materials).

Tight Blading—Very lightly scarifying or roughening the compacted base course surface with a grader blade, to a depth not exceeding about 6 mm (0.25 inch).

Trade Organizations—Private organizational resources providing technical information and other support to specific trades. Some of the important trade organizations specializing in AST materials and technology are:

Asphalt Emulsion Manufacturers Association (AEMA)
#3 Church Circle, Suite 250
Annapolis, MD 21401
Tel: 410-267-0023
Fax: 410-267-7546
http://rampages.onramp.net/~prime/AEMApage.htm

Asphalt Recycling and Reclaiming Association (ARRA)
#3 Church Circle, Suite 250
Annapolis, MD 21401
Tel: 410-267-0023
Fax: 410-267-7546
http://rampages.onramp.net/~prime/arra.htm

National Asphalt Paving Association (NAPA)
NAPA Building, 5100 Forbes Boulevard
Lanham, MD 20706-4413
Tel: 301-731-4748
Fax: 301-731-4621
http://www.hotmix.org

The Asphalt Institute (TAI)
Research Park Drive
P.O. Box 14052
Lexington, Kentucky 40512-4052
Tel: 606-288-4960
Fax: 606-288-4999
http://www.asphaltinstitute.org

National Stone Association (NSA)
2101 Wilson Blvd.
Arlington, VA 22201
Tel: 703-525-8788
Fax: 703-525-7782
http://www.aggregates.org/home.htm

International Slurry Surfacing Association (ISSA)
1200 19th Street N.W., Suite 300
Washington, DC 20036-2401
Tel: 202-857-1160
Fax: 202-857-1111
http://www.history.rochester.edu/issa/

Unbound Layer—Layer of pavement structure where aggregate materials are not cemented together.

Viscosity—Resistance to flow for a fluid material. The internal friction within a fluid.

Wheelpaths—Areas of the roadway surface most heavily trafficked by vehicle tires. Since these areas receive most of the directly applied wheel loads, they are the areas of the pavement surface likely to be most heavily alligator cracked, rutted, or otherwise damaged by load applications.

Notes

Appendix C: AST Specification Examples

Note: Specifications contained in this appendix come from Alaska DOT&PF and are intended to represent an example of the latest available. They provide examples useful on most kinds of AST projects. However, they may still contain criteria intended to handle specific problems on the project of origin.

Appendix C1, Seal Coat AST

Section 404 Seal Coat

404-1.01 Description

This work consists of an application of asphalt material with cover coat aggregate in accordance with these specifications and in reasonable conformance with the plans.

404-2.01 Asphalt Materials

Add polymer solids, in the amount of 2% by weight of the asphalt residue, to CRS-2 through a high speed colloid mill to produce CRS-2P. On-the-job mixing will not be permitted. The CRS-2P shall comply with the requirement of AASHTO M-208 except that the maximum viscosity shall be increased to 1,000 Saybolt Furol seconds. Store CRS-2P at a temperature between 100˚F and 176˚F (38˚C and 80˚C). Keep the spray temperature between 160˚F and 190˚F (71˚C and 88˚C).

404-2.02 Cover Coat Aggregate

Use cover coat aggregate that conforms to the requirements of 703-2.05 and with Table 703-4 for Type 3 Cover Aggregate, Grading C.

404-2.03 Blotter Material

Use a suitable clean sand as blotter material. Unless otherwise required by the engineer, the sand used shall pass the #10 (2.0 mm) sieve and have no more than 0.5% material passing the #200 (0.075 mm) sieve. The sand may be accepted in stockpile at the source. Use ATM T-7 to determine the gradation.

404-2.04 Submitting AST Components for Evaluation

Within two days after the start of cover aggregate crushing, submit a representative 65 lb (30 kg) sample of the cover aggregate proposed for use on the project and a 1 gallon (4 liter) sample of the asphalt emulsion proposed for use. The engineer will determine composition of the seal coat, i.e., the application rates for the asphalt emulsion and cover aggregate to be used on this project. Submit changes in application rates warranted by changes in cover aggregate gradation, source of cover aggregate, or asphalt emulsion supplier in the same manner as the original submittal.

404-2.05 Composition of Seal Coat

The quantities of asphalt and cover aggregate per square yard shall be determined, for the seal coat, based on samples submitted in accordance with Subsection 405-2.04. The engineer may adjust these application rates one or more times as required by field conditions during placement of the seal coat.

Construction Requirements

404-3.01 General

1. Construct longitudinal joints only along the centerline and the lane lines.
2. Complete asphalt and cover aggregate seal coat applications full width by the end of each shift.

404-3.02 Weather Limitations

1. Do not apply seal coat unless the ambient air temperature is 60˚F (15˚C) or above. Measure temperatures in the shade, away from any heat source.
2. Do not apply the seal coat when weather conditions prevent the proper penetration of the asphalt material and/or adhesion of the cover aggregate. Do not apply seal coat

during periods of rain, fog, mist, or imminent rain.

3. Apply seal coat only when weather conditions allow adequate curing time before inclement weather or freeze-up. Do not apply seal coat after August 15 or before May 15.

404-3.03 Equipment

1. Distributor

Use a distributor that is designed, equipped, maintained, and operated so that asphalt material at even heat may be applied uniformly on variable widths of surface, up to 15 feet (4.5 meters) wide, at the specified rate from 0.1 to 0.8 gallons per square yard (0.45 to 3.60 liters per square meter), with uniform pressure and within a tolerance of 0.04 gallons per square yard (0.18 liters per square meter).

Equip the distributor as follows:

- Computerized control of liquid asphalt application so that the specified application rate is automatically delivered, and with controls to allow quickly changing application rates as directed by the engineer.
- Computer monitoring of spread rate, truck speed, and distance traveled.
- A thermometer for measuring temperatures of the tank's contents, readily visible from outside the truck cab.
- All spray bar nozzles of the same manufacture, type, and size.
- A spray bar with a positive shutoff to prevent dribbling.
- Controls such that the spray bar can be maintained at a constant height throughout the entire seal coat operation.
- Controls such that the distributor shall be capable of maintaining a uniform speed.

The distributor will be inspected by the engineer before beginning the operation. Completely assemble, adjust, calibrate, and perform all other preparation work on the distributor before producing seal coat. Use a distributor that is assembled, calibrated, adjusted, operated, and maintained according to standard construction practice and that includes the following requirements:

- Turn each nozzle in the spray bar to make the constant angle with the longitudinal axis of the spray bar that is recommended by the manufacturer of the distributor. Adjust the spray bar height to provide triple overlap of the asphalt emulsion applied by the spray nozzles.
- Calibrate the distributor before beginning the asphalt application and any time thereafter if deemed necessary. Calibrate the distributor in accordance with the manufacturer's recommendations. The engineer may require the contractor to prove the accuracy of the distributor. Recalibrate the distributor if the initial settings are changed.
- Keep spray bar nozzles clean and in good working condition throughout the seal coat operation. Cease application of the asphalt material if any of the nozzles on the spray bar fail to provide a constant, uniform flow during the asphalt application process. Do not allow the distributor to resume applying asphalt material until all of the nozzles are in good working order. Nozzle adjustments and/or repairs will be approved by the engineer.

2. Aggregate Spreader

Use an aggregate spreader that is computer controlled to automatically maintain the specified delivery rate of cover aggregate regardless of variations in machine speed. The spreader shall have a sufficient size feed system to maintain cover aggregate in the spread hopper at all times. Equip the spreader hopper with augers or other approved equipment to prevent segregation of the cover aggregate.

Stopping the aggregate spreader to refill the receiving hopper will be permitted provided that the spreader is backed up at least 20 feet (6 meters) from the last cover aggregate application. The aggregate spreader will be permitted to slow down to allow trucks to back up and discharge loads into the receiving hopper.

Immediately before using the aggregate spreader on the project, calibrate the aggregate spreader for the cover aggregate to be applied. Set the forward speed of the aggregate spreader during calibration so that it approximates the speed required to apply the cover aggregate over the asphalt material and maintain a continuous operation with the distributor. Calibrate the aggregate spreader in accordance with the manufacturer's recommendations. The engineer may require the contractor to prove the accuracy of the aggregate spreader.

Recalibrate the aggregate spreader whenever directed. The calibration procedure will be observed by the engineer each time it is done.

3. Rollers

Use a minimum of three self-propelled pneumatic rollers weighing not less than 10 tons (9 megagrams) each, equipped with not less than nine tires staggered back and front, inflated to 60 psi (414 kPa). Adjust pressure in all tires so they have equal pressure. Equip each roller with a suitable tire pressure gauge for checking tire inflation pressures.

4. Rotary Power Broom or Power Vacuum Sweeper

404-3.04 Preparation of Surface

The existing roadway surface will be prepared and broomed by others. The engineer may direct the contractor to perform brooming immediately before applying the seal coat.

Obtain the engineer's approval of the surface before applying CRS-2P and cover coat aggregate (together referred to as chip seal.) Apply the chip seal within 24 hours of the engineer's approval. Areas of roadway not chip sealed within the 24 hour period are subject to reapproval by the engineer.

Apply chip seal only when the prepared surface is dry or damp and when rain or fog is not present or imminent.

404-3.05 Test Strips

Construct a 500-foot (150-meter) test strip on the roadway using the application rates for asphalt material and cover aggregate determined by the engineer. The engineer will adjust the application rates of the asphalt material and/or cover aggregate as required to produce the desired seal coat product.

404-3.06 Applying Asphalt Material

1. Do not extend the length of the spread of asphalt material beyond what trucks loaded with cover aggregate can immediately cover.
2. Do not allow equipment or other vehicles on sprayed asphalt before cover aggregate is applied.
3. Do not spread asphalt material more than 6 inches (150 mm) wider than the width covered by the cover aggregate from the spreader.

At the beginning of each spread, use a strip of building paper at least 1 yard wide and with a length equal to that of the spray bar of the distributor plus 1 foot. Remove and dispose of the used paper in a satisfactory manner. The distributor shall be moving forward at proper application speed at the time the spray bar is opened.

Apply asphalt material at a temperature between 160˚ and 190˚F (71˚ and 88˚C).

Do not allow asphalt material to chill, set up, dry, or otherwise impair retention of the cover aggregate.

Do not allow asphalt material to drip from the distributor onto the surface of the roadway nor drip at any other unapproved location when the asphalt distributor is not spreading.

Correct skipped areas or other deficiencies. Make junctions of spreads carefully to prevent applying too much asphalt material along the junctions.

404-3.07 Application of Cover Aggregate

Moisten the cover aggregate with water as directed, the day before the aggregate is to be used.

Do not apply cover aggregate at a rate greater than 100 yards per minute or 3.4 mph (90 meters per minute or 5.5 km/hr.)

Apply the cover aggregate within 1.5 minutes after application of the asphalt material or, depending on weather conditions, as directed. Keep this time increment as constant as possible, but adjust as needed to meet changing conditions. Whenever it is apparent that the time limit above will be exceeded, make a transverse joint by placing construction paper (roofing felt or similar product) on the prepared surface and ending the chip seal operations on the paper. Remove the paper and dispose of the paper properly. Touch up the edges of the applied chip seal before restarting operations.

Spread cover aggregate so that the tires of the trucks and aggregate spreader at no time contact the uncovered and newly applied asphalt material.

Immediately after the cover aggregate is spread, repair deficient areas using additional cover coat aggregate. Then immediately compact the aggregate with at least three complete coverages using the pneumatic tire rollers or as directed by the engineer. Operate pneumatic tire rollers at a speed less than 5 mph (8 km/hr).

After the application of cover aggregate, sweep excess cover aggregate from the entire surface at the time determined by the engineer. In addition, where specified, broom or otherwise maintain the finished chip seal surface for a period of four days after cover aggregate application or as directed by the engineer. Temporary maintenance shall include the distribution of cover aggregate over the surface to absorb any free asphalt material and cover any area deficient in cover aggregate. Conduct this maintenance so as not to displace embedded aggregate. Repair any failures detected by the engineer at contractor expense, before striping.

404-3.08 Application of Blotter Material

Due to weather, construction, and/or materials problems, it is possible that the finished surface treatment may become unstable. To minimize damage to the surface, blotter material may be required. If blotter material is required, apply the blotter material as directed by the engineer and roll immediately with a pneumatic-tired roller (as described above) with tire pressures adjusted to 90 to 100 psi (620 to 690 kPa).

404-3.09 Traffic Control

Do not operate construction equipment at speeds exceeding 15 mph (25 km/hr) on a freshly applied surface treatment for up to 24 hours or until there is no threat of damage to the chip seal.

Unless otherwise specified, keep the roadway open to traffic at all times. Do not allow traffic on freshly sprayed asphalt or on cover aggregate that is not fully compacted. As soon as all required rolling has been completed for a chip sealed area, controlled traffic may be permitted to operate on that surface. Control traffic on the chip seal using flaggers and pilot cars. Do not permit traffic speed to exceed 15 mph (25 km/hr) for a period of 2 to 24 hours until legal speed traffic will not damage the surface. Repair any damage to the surface caused by construction equipment or public traffic at no cost to the state.

404-4.01 Method of Measurement

Measure asphalt material and cover aggregate by the ton in accordance with Section 109.
Polymer solids are subsidiary to Item 404(1P).
Blotter material, water used for aggregate and surface preparation, and sweeping will not be measured for payment, but is subsidiary to Item 404(2).

404-5.01 Basis of Payment

Payment will be made at the contract unit price, per ton of asphalt material and per ton of cover coat aggregate, complete in place including that used for the test strip.

Payment will be made under:

Pay Item No.	Pay Item	Pay Unit
404(1P)	CRS-2P Asphalt for Seal Coat	Ton
404(2)	Cover Coat Aggregate,Type 3, Grading C	Ton

Appendix C2, Double-Layer AST

Section 405 Asphalt Surface Treatment

405-1.01 Description

This work consists of constructing a single or multiple course asphalt surface treatment (AST) in accordance with these specifications and in reasonable conformance with lines and other information contained in the plans.

405-2.01 Asphalt Materials

Use the types and grades of asphalt material shown in the bid schedule.

The asphalt material shall conform to the applicable requirements of Section 702. Asphalt material will be conditionally accepted at the source.

405-2.02 Aggregates

Use aggregates for asphalt surface treatment cover coat material (cover aggregate) conforming to the general requirements of Subsection 703-2.05 and the gradation or gradations specified from Table 703-5. The cover aggregate material may be accepted in stockpile at the source. Determine the gradation using ATM T-7.

405-2.03 Surface Treatment Blotter Material

Use blotter material composed of suitable clean sand. Unless otherwise required by the engineer, use sand that passes the 2.0 mm sieve, and contains no more than 0.5% material passing the #10 (0.075 mm) sieve. The material may be accepted in stockpile at the source. Determine gradation by ATM T-7.

405-2.04 Submitting AST Components for Evaluation

Within two days after the start of cover aggregate crushing, the contractor shall submit a representative 65 lb (30 kg) sample of each gradation of cover aggregate proposed for use on the project and a 1 gal. (4 L) sample of the asphalt emulsion proposed for use. The engineer will determine composition of the asphalt surface treatment, i.e., the application rates for the asphalt emulsion and cover aggregates to be used on this project. Changes in application rates warranted by changes in aggregate gradations, source of cover aggregates, or asphalt emulsion supplier shall be submitted by the contractor in the same manner as the original submittal.

405-2.05 Composition of Surface Treatment

The quantities of asphalt and cover aggregate materials per square meter shall be determined by the engineer for the AST, based on samples submitted in accordance with Subsection 405-2.04. The engineer may adjust these application rates one or more times as required by field conditions during placement of the AST.

The sequence of application and spreading is given below. The following table also specifies tolerances allowed the contractor for applying surface treatment material above or below the application rates determined by the engineer.

Construction Requirements

405-3.01 General

1. Construct longitudinal joints only along the centerline and the lane lines.
2. Complete asphalt and cover aggregate applications full width by the end of each shift.

405-3.02 Weather Limitations

1. Do not apply AST unless the ambient air temperature is 60˚F (15˚C) or above. Measure temperatures in the shade, away from any heat source.
2. Do not apply the AST when weather conditions prevent the proper penetration of the asphalt material and/or adhesion of the cover aggregate. Do not apply AST during periods of rain, fog, mist, or imminent rain.
3. Apply AST only when weather conditions allow adequate curing time before inclement weather or freeze-up. Do not apply AST after August 15 or before May 15.

405-3.03 Equipment

1. Distributor

The contractor shall use a distributor that is designed, equipped, maintained, and operated so that asphalt material at even heat may be applied uniformly on variable widths of surface up to 15 feet (4.5 m) wide, at the specified rate from 1.10 to 0.80 gallons per square yard (0.45 to 3.60 L/m^2), with uniform pressure and within specified tolerances.

Use a distributor equipped with the following:

- Computerized control of liquid asphalt application so that the specified application rate is automatically delivered, and with controls to allow quickly changing application rates as directed by the engineer.
- Computer monitoring of spread rate, truck speed, and distance traveled.
- A thermometer for measuring temperatures of the tank's contents, readily visible from outside the truck cab.
- All spray bar nozzles of the same manufacture, type, and size.
- A spray bar with a positive shutoff to prevent dribbling.
- Controls such that the spray bar can be maintained at a constant height throughout the entire AST operation.
- Controls such that the distributor shall be capable of maintaining a uniform speed.

The distributor will be inspected by the engineer before beginning the operation. The contractor shall completely assemble, adjust, calibrate, and perform all other preparation work on the distributor before producing AST. Use a distributor that is assembled, calibrated, adjusted, operated, and maintained according to standard construction practice and that includes the following requirements:

- Turn each nozzle in the spray bar to make the constant angle with the longitudinal axis of the spray bar that is recommended by the manufacturer of the distributor. Adjust the spray bar height to provide triple overlap of the asphalt emulsion applied by the spray nozzles.
- Calibrate the distributor before beginning the asphalt application and any time thereafter if deemed necessary by the engineer. Calibrate the distributor in accordance with the manufacturer's recommendations. The engineer may require the contractor to prove the accuracy of the distributor. Recalibrate the distributor if the initial settings are changed.
- Keep spray bar nozzles clean and in good working condition throughout the AST operation. Cease application of the asphalt material if any of the nozzles on the spray bar fail to provide a constant, uniform flow during the asphalt application process. Do not allow the distributor to resume applying asphalt material until all of the nozzles are in good working order. Nozzle adjustments and/or repairs will be approved by the engineer.

Aggregate Gradings and Sequence of Operations	Asphalt and Cover Aggregate Materials	Tolerance Above and Below AST Composition Designated by the Engineer
First Layer:	Asphalt Type ____	0.04 gal./yd^2 (±0.20 L/m^2)
	Cover Aggregate Gradation ____	2.3 lb/yd^2 (±1.3 kg/m^2)
Second Layer:	Asphalt Type ____	0.04 gal./yd^2 (±0.20 L/m^2)
	Cover Aggregate Gradation ____	1.3 lb/yd^2 (±0.7 kg/m^2)
Third Layer:	Asphalt Type ____	0.03 gal./yd^2 (±0.15 L/m^2)
	Cover Aggregate Gradation ____	0.8 lb/yd^2 (±0.4 kg/m^2)

2. Aggregate Spreader

Use an aggregate spreader that is capable of evenly applying cover aggregate material to the specified roadway width in a maximum of two passes. Use an aggregate spreader that is computer controlled to automatically maintain the specified delivery rate of cover aggregate, regardless of variations in machine speed. The spreader shall have a sufficient size feed system to maintain cover aggregate in the spread hopper at all times. Equip the spreader hopper with augers or other approved equipment to prevent segregation of the cover aggregate materials.

Stopping the aggregate spreader to refill the receiving hopper will be permitted, provided that the spreader is backed up at least 20 feet (6 m) from the last cover aggregate application. The aggregate spreader will be permitted to slow down to allow trucks to back up and discharge loads into the receiving hopper. Use an aggregate spreader that is constructed to eliminate material segregation in its hoppers.

Immediately before using the aggregate spreader on the project, calibrate the aggregate spreader for the cover aggregate to be applied. Set the forward speed of the aggregate spreader during calibration so that it approximates the speed required to apply the cover aggregate over the asphalt material and maintain a continuous operation with the distributor. Calibrate the aggregate spreader in accordance with the manufacturer's recommendations. The engineer may require the contractor to prove the accuracy of the aggregate spreader.

Recalibrate the aggregate spreader whenever directed by the engineer. The calibration procedure will be observed by the engineer each time it is done.

3. Rollers

Use a minimum of three self-propelled pneumatic rollers weighing not less than 10 tons (9 megagrams) each, equipped with not less than nine tires staggered back and front, inflated to 60 psi (414 kPa). Adjust pressure in all tires so they have equal pressure. Equip each roller with a suitable tire pressure gauge for checking tire inflation pressures.

Use a minimum of one self-propelled steel wheel roller, in good condition, weighing between 10 and 12 tons (9 and 11 megagrams) static weight and capable of reversing without backlash. Use steel wheel rollers that are specifically designed to compact asphalt concrete pavements.

4. Rotary Power Broom or Power Vacuum Sweeper

405-3.04 Preparation of Surface

1. Apply AST on sections of fully shaped and compacted grade. Obtain the engineer's approval of the grade applying AST. Apply AST within 72 hours of the engineer's approval of the grade. Areas of grade not surfaced within the 72-hour period are subject to reapproval by the engineer. Roll the surface of the grade with a steel wheeled soil compactor immediately before applying asphalt materials. Do not leave windrows of materials that may impede drainage on or adjacent to the surface treatment area.
2. Apply AST only when the prepared surface is dry or damp and when rain or fog is not present or imminent.
3. The engineer may require surface dampening before applying asphalt. Apply a light spray of water to the prepared surface if required.

405-3.05 Prime Coat

Apply prime coat in accordance with the requirements of Section 403, Prime Coat.

Do not prime an area larger than can be covered by the following day's paving operations.

Keep the primed surface in good repair during the period between application of the prime coat and application of the AST. Patch or otherwise repair all holes, ravels, and areas deficient in prime with asphalt treated materials, by penetration methods, or other approved procedures.

405-3.06 Applying Asphalt Material

1. Do not extend the length of the spread of asphalt material beyond what trucks loaded with cover aggregate can immediately cover.
2. Do not allow equipment or other vehicles on sprayed asphalt before applying cover aggregate.
3. Do not spread asphalt material more than 6 inches (150 mm) wider than the width covered by the cover aggregate from the spreader.
4. At the beginning of each spread, use a strip of building paper at least 3 feet (1 m) wide and with a length equal to that of the spray bar of the distributor plus 1 foot (0.3 m). Remove and dispose of the used paper in a satisfactory manner. The distributor shall be moving forward at proper application speed at the time the spray bar is opened.
5. Apply asphalt material at a temperature between 125˚ and 175˚F (52 and 80˚C).
6. Do not allow asphalt material to chill, set up, dry, or otherwise impair retention of the cover aggregate.
7. Do not allow asphalt material to drip from the distributor onto the surface of the roadway nor drip at any other unapproved location when the asphalt distributor is not spreading.

If the texture of the surface is such that the initial application of asphalt material penetrates the surface, a preliminary application of 0.05 to 0.10 gallons per square yard (0.23 to 0.45 L/m^2) of surface may be required. The need for this additional application of asphalt material will be determined by the engineer.

Correct skipped areas or other deficiencies. Make junctions of spreads carefully to prevent applying too much asphalt material along the junctions.

405-3.07 Application of Cover Aggregate Material

1. Moisten the cover aggregate with water as directed by the engineer. Moistening shall be done the day before the aggregate is to be used.
2. Apply the cover aggregate within 1.5 minutes after application of the asphalt material or, depending on weather conditions, as directed by the engineer. This time increment shall be kept as constant as possible but shall be adjusted as needed to meet changing conditions. Whenever it is apparent that the time limit above will be exceeded, make a transverse joint by placing construction paper (roofing felt or similar product) on the prepared surface and ending the AST operations on the paper. Remove the paper and dispose of it properly. Touch up the edges of the applied AST before restarting AST operations.
3. Spread cover aggregate so that the tires of the trucks and aggregate spreader at no time contact the uncovered and newly applied asphalt material.
4. When more than one cover aggregate gradation is required, each subsequent cover aggregate application shall follow the previous one by no more than two working days without prior approval by the engineer.

When a Single Gradation of Cover Aggregate is Required

Immediately after the cover aggregate is spread, cover deficient areas using additional material. Then, immediately compact the cover aggregate with at least two complete coverages using pneumatic tire rollers, followed by a third and final coverage by steel wheel rollers, or as directed by the engineer. Operate pneumatic tire rollers at a maximum speed not exceeding 5 mph (8 km/hour). Operate steel wheel rollers in static (nonvibratory) mode only and at a maximum speed not exceeding 5 mph (8 km/hour). Stop using steel wheel rollers if crushing or fracturing of the cover aggregate is evident.

When Two Gradations of Cover Aggregate are Required

Immediately after the first cover aggregate is spread, cover deficient areas using additional material. Then, immediately compact the first application of cover aggregate by at least three complete coverages using pneumatic tire rollers. Following compaction of the first cover aggregate application, sweep excess cover aggregate from the entire surface by means of rotary brooms at a time determined by the engineer. Apply the second course of cover aggregate using the same equipment and methodology as for the first course of cover aggregate. After deficient areas have been covered by additional material, compact the second cover aggregate application by at least two coverages using pneumatic tire rollers, followed by a third and final coverage by steel wheel rollers, or as directed by the engineer. Operate pneumatic tire rollers at a maximum speed not exceeding 5 mph (8 km/hour). Operate steel wheel rollers in static (nonvibratory) mode only, and at a maximum speed not exceeding 5 mph (8 km/hour). Stop using steel wheel rollers if crushing or fracturing of the cover aggregate is evident. Complete all rolling required for each cover aggregate application the same day as that application.

When Three Gradations of Cover Aggregate are Required

Apply the first and second courses of cover aggregate using the same equipment and methodology as for the first cover aggregate application, described in the preceding paragraph. After compacting the second cover aggregate application, sweep excess cover aggregate material from the entire surface by means of rotary brooms at a time determined by the engineer. Apply the third course of cover aggregate using the same equipment and methodology as for the second cover aggregate application described in the preceding paragraph. Operate pneumatic tire rollers at a maximum speed not exceeding 5 mph (8 km/hour). Operate steel wheel rollers in static (nonvibratory) mode only, and at a maximum speed not exceeding 5 mph (8 km/hour). Discontinue using steel wheel rollers if crushing or fracturing of the cover aggregate is evident. Complete all rolling required for each cover aggregate the same day as that application.

Temporary Maintenance After Final Cover Aggregate Application

After applying all required courses of cover aggregate, sweep excess cover aggregate from the entire surface by means of rotary brooms at the time determined by the engineer. In addition, where specified, broom or otherwise maintain the finished AST surface for a period of four days (after final cover aggregate application) or as directed by the engineer. Temporary maintenance shall include distributing cover aggregate over the surface to absorb any free asphalt material and to cover any area deficient in cover aggregate. Conduct this maintenance so as not to displace embedded material.

405-3.08 Application of Blotter Material

Due to weather, construction and/or materials problems, it is possible that the finished surface treatment may become unstable. To minimize damage to the surface, blotter material may be required. If blotter material is required, apply the blotter material as directed by the engineer and roll immediately with a pneumatic-tired roller (as described above) with tire pressures adjusted to 90 to 100 psi (620 to 690 kPa).

405-3.09 Traffic Control

Do not operate construction equipment at speeds exceeding 15 mph (25 km/hour) on a freshly applied surface treatment for a period of up to 24 hours as directed by the engineer.

Unless otherwise specified, keep the highway open to traffic at all times. Do not allow traffic on freshly sprayed asphalt or on cover aggregate material that is not fully compacted. As soon as all required rolling has been completed for each AST layer, controlled traffic may be permitted to operate on that surface (this includes allowing traffic operation on intermediate layers of cover aggregate if all required rolling has been completed for that layer). Control traffic on the AST through use of pilot cars to a speed not exceeding 15 mph (25 km/hour) for a period of 2 to 24 hours, as directed by the engineer.

405-4.01 Method of Measurement

Measure asphalt material and cover aggregate material by the ton in accordance with Section 109.

Surface treatment blotter material, water used for aggregate and surface preparation, and sweeping will not be measured for payment; these items are considered subsidiary obligations.

405-5.01 Basis of Payment

The accepted quantities of surface treatment will be paid for at the contract price per ton of asphalt material and per ton of cover aggregate material, complete in place.

Payment will be made under:

Pay Item No.	Pay Item	Pay Unit
405(1)	________ Asphalt for Asphalt Surface Treatment	Ton
405(2)	Grading______, Cover Aggregate Material for Asphalt Surface Treatment	Ton

Note to the Designer (remove this note from final version of project specifications)

When more than one gradation of cover aggregate is specified, include letter suffixes within the parentheses of the pay item number in order to differentiate between the gradations.

Appendix C3, High Float AST

> Note to Designers: Use of this spec requires use of the companion Section 703-2.05 special provision for cover aggregate for high float surface treatment. Select Grading B, C, or D from table 703-5HF and enter it in the shaded locations in this spec. Also select calendar limits in Section 405-3.02, ¶ 3, appropriate for the location of the project. Delete this note and the shading before using.

Section 405: High Float Surface Treatment

405-1.01 Description

This work consists of the construction of a single-course high float asphalt emulsion surface treatment (HFST) in accordance with these specifications and in reasonable conformance with the lines shown on the plans.

405-2.01 Asphalt Materials

The HFMS-2s high float asphalt emulsion material shall conform to the applicable requirements of Section 702-2.03. The asphalt material will be conditionally accepted at the source.

405-2.02 Aggregates

Aggregates for cover coat material (cover aggregate) shall meet the requirements of Subsection 703-2.05 and Table 703-5HF, Cover Aggregate for High Float Surface Treatment, Grading C, except that the following quality requirements shall apply:

Percent of Wear	AASHTO T-96	50 max.
Degradation Value	ATM T-13	30 min.
Percent Fracture	WAQTC TM-1	70 min.
Sodium Sulfate Soundness	AASHTO T-104	9% max (5 cycles)
Thin - Elongated Pieces	ATM T-9	8% max.
Plasticity Index *	AASHTO T-90	3 max.

* Prepare material for AASHTO T-90 according to the wet preparation method, AASHTO T-146.

The test sampling location(s) will be determined by the engineer before crushing operations begin.

Cover coat material stockpiles shall be covered to exclude precipitation.

Gradation Testing

Acceptance Testing: Determine the gradation by AASHTO T-27. Testing will be done upon notification by the contractor that the crusher is ready for production.

Assurance Testing: Determine the gradation by AASHTO T-27 and AASHTO T-88 except dry the material for the T-88 test within a temperature range of 90˚ to 100˚F (32˚ to 38˚C).

405-2.03 Surface Treatment Blotter Material

Blotter material shall be suitable clean sand. Unless otherwise required by the engineer, all sand used as blotter material shall pass the #10 (2 mm) sieve and have no more than 0.5% material passing the #200 (0.075 mm) sieve. The material may be accepted in stockpile at the source. Gradation shall be determined by AASHTO T-27.

405-2.04 Determine HFST Design Composition

Within two days after the start of cover aggregate crushing, the contractor shall submit a representative 65 lb (30 kg) sample of the cover aggregate and a 1 gallon (3.8 liter) sample of the high float asphalt emulsion proposed for use on the project. Fill the asphalt container to the brim so that it contains no air.

Based on the samples submitted, the engineer will determine the asphalt and cover aggregate application rates to be used on this project. Changes in application rates warranted by changes in aggregate gradation, source of cover aggregate, or high float emulsion supplier shall be submitted by the contractor in the same manner as the original submittal.

405-2.05 Composition of Surface Treatment

The initial application rates of asphalt and cover aggregate materials shall be as determined by the engineer per Subsection 405-2.04. The engineer may adjust application rates as required by field conditions.

The following table provides the pre-HFST design estimating factors and specifies the tolerance allowed the contractor for applying surface treatment material above or below the application rates determined by the engineer.

Material	Pre-HFST Design Estimating Factor	Specified Tolerance
HFMS-2s Asphalt	0.75 gal./yd^2 (3.4 L per sq. meter)	0.04 gal/yd^2 (±0.18 L per sq. meter)
Cover Aggregate	75 lb/yd^2 (40.7 kg per sq. meter)	2.5 lb/yd^2 (±1.4 kg per sq. meter)

Construction Requirements

405-3.01 General

1. The longitudinal joints shall be allowed only at the centerline.
2. The work shall be done so that asphalt and cover aggregate applications are completed full width by the end of each shift.

405-3.02 Weather Limitations

1. The ambient air temperature shall be 50˚F (10˚C) or above. Temperatures shall be measured in the shade, away from any heat source.
2. The HFST shall not be applied during periods of rain, fog, mist, or imminent rain. Do not apply the HFST when weather conditions prevent the proper penetration of the asphalt material and/or adhesion of the cover aggregate.
3. Weather conditions shall be such that proper construction of the HFST and adequate curing time is available before inclement weather or freeze-up. No HFST shall be applied before June 15 or after July 15.

405-3.03 Equipment

1. Distributor

The distributor shall be so designed, equipped, maintained, and operated that asphalt material at even heat may be applied uniformly on variable widths of surface up to half the roadway width plus 6 inches (150 mm), at the specified rate from 0.4 to 0.9 gal/yd^2 (1.9 to 3.8 liters per square meter), with uniform pressure and within specified tolerances.

The distributor equipment shall include the following:

- Computerized control of liquid asphalt spread rates to automatically deliver specified delivery rates and capable of changing rates when so directed.
- Computer monitoring of spread rate, truck speed, and distance traveled.
- A thermometer for measuring temperatures of the tank's contents, readily visible from outside the truck cab.
- Each nozzle in the spray bar shall be turned to make the constant angle with the longitudinal axis of the spray bar that is recommended by the manufacturer of the distributor. All nozzles in the spray bar shall be of the same manufacture, type, and size. The spray bar height shall provide triple overlap of the asphalt emulsion being applied by the spray nozzles.

Before applying asphalt, the contractor shall ensure that the distributor meets the following requirements:

- The spray bar can be maintained at a constant height throughout the entire operation.
- Spray bar nozzles are clean and in good working condition.
- The spray bar has been provided with a positive shutoff to prevent dribbling.
- The distributor is capable of maintaining a uniform speed.

Calibration and adjustment requirements will include:

- The distributor will be inspected by the engineer before beginning the operation. Any adjustments, maintenance, and other requirements shall be performed before being used.

- The distributor shall be calibrated in accordance with the manufacturer's recommendations. The engineer may require the contractor to prove the accuracy of the distributor before commencing the asphalt application and any time thereafter if deemed necessary by the engineer. Any change in settings on the distributor after calibrating will require that the distributor be recalibrated.
- Should any of the nozzles on the spray bar fail to provide a constant, uniform flow during the application of asphalt material, the distributor shall immediately cease application of the asphalt material. The distributor shall not be allowed to resume applying asphalt material until all of the nozzles are in good working order. Nozzle adjustments and/or repairs must be approved by the engineer.

2. Aggregate Spreader

The aggregate spreader shall be capable of evenly applying cover aggregate material to the specified roadway width in a maximum of two passes. The aggregate spreader shall be computer controlled to automatically maintain the specified delivery rate of cover aggregate, regardless of variations in machine speed. The spreader shall have a sufficient size feed system to maintain cover aggregate in the spread hopper at all times. The spread hopper shall be equipped with augers or other approved equipment to prevent segregation of the cover aggregate materials.

Stopping the aggregate spreader to refill the receiving hopper will be permitted, provided that the spreader is backed up at least 20 feet (6 m) from the last cover aggregate application. The aggregate spreader will be permitted to slow down to allow trucks to back up and discharge loads into the receiving hopper. The aggregate spreader shall be constructed to eliminate material segregation in the various hoppers.

Immediately before using the aggregate spreader on the project, the aggregate spreader shall be calibrated for the cover aggregate to be applied. The forward speed of the aggregate spreader during calibration shall approximate the speed required to apply the cover aggregate over the asphalt material and maintain a continuous operation with the distributor. The aggregate spreader shall be calibrated in accordance with the manufacturer's recommendations. The engineer may require the contractor to prove the accuracy of the aggregate spreader.

The aggregate spreader shall be recalibrated whenever directed by the engineer. The calibration procedure will be observed by the engineer each time it is done.

3. Rollers

A minimum of three self-propelled pneumatic rollers weighing not less than 10 tons (9 megagrams), equipped with not less than nine tires staggered back and front, inflated to 60 psi (414 kPa) shall be used. All tires shall have equal pressure, and each roller shall be equipped with a suitable tire pressure gauge for checking tire inflation pressure.

4. Rotary Power Broom or Power Vacuum Sweeper

405-3.04 Preparation of Surface

1. HFST shall be applied on sections of fully shaped and compacted grade. Grade shall be approved by the engineer before applying HFST. HFST shall be applied within 72 hours of approval of the grade. Areas of grade not surfaced within the 72-hour period are subject to reapproval by the engineer. The surface shall be rolled with a steel wheeled soil compactor immediately before application of asphalt materials. The contractor shall not leave windrows of materials that may impede drainage on or adjacent to the surface treatment area.
2. HFST shall be applied when the prepared surface is damp. Before the asphalt application, the engineer may require dampening the surface by applying a fine spray of water to the prepared surface. HFST

shall not be applied to a wet surface or when rain or fog is present or imminent.

405-3.05 Applying High Float Asphalt Emulsion Material

1. The length of spread of high float asphalt emulsion (hereafter referred to as asphalt) material shall not be beyond what trucks loaded with cover aggregate can immediately cover.
2. The first pass over the segment of roadway being surfaced will follow a string line set either on the shoulder or on the centerline, whichever is on the driver's side of the distributor. The second pass will be done with the centerline joint on the driver's side of the distributor.
3. At no time shall any equipment or vehicles be allowed on sprayed asphalt before applying cover aggregate.
4. The spread of asphalt material shall not be more than 6 inches (150 mm) wider than the width covered by the cover aggregate from the spreader. Under no circumstances shall asphalt material be allowed to chill, set up, dry, or otherwise impair retention of the cover aggregate.
5. The distributor, when not spreading, shall be parked so that the spray bar or mechanism will not drip asphalt material on the surface of the roadway.
6. Application temperature of asphalt material shall be 150˚ to 180˚F (65 to 82˚C).

Any skipped areas or deficiencies shall be corrected. Junctions of spreads shall be carefully made to prevent too much asphalt material.

405-3.06 Application of Cover Aggregate Material

1. The cover aggregate shall have a temperature of no less than 40˚F (5˚C) and shall have a 2% to 4% moisture content (by dry weight) at the time of application. If necessary, the cover aggregate shall be moistened or dried to achieve the specified moisture content.
2. Cover aggregate shall be applied within 1.5 minutes after application of the asphalt material or as directed by the engineer. This increment shall be kept as constant as possible but shall be adjusted as needed to meet changing conditions. Whenever it is apparent that the time limit above will be exceeded, a transverse joint shall be made by placing construction paper (roofing felt or similar product) on the prepared surface and ending the HFST operations on the paper. The paper shall be removed and disposed of properly. The edges of the applied HFST shall be touched up before restarting HFST operations.
3. Immediately after cover aggregate is spread, deficient areas shall be covered by additional material. Pneumatic tire rolling for the full width of the aggregate shall begin immediately after placement of cover aggregate and shall be continued until at least six complete coverages are obtained or until cover aggregate is bound tightly, to the satisfaction of the engineer. The rolling operation shall be accomplished within 500 feet (150 meters) of the cover aggregate application. The high float application operation shall be slowed if the rolling cannot be completed within this distance. Pneumatic tire roller speed shall not exceed 5 mph (8 km per hour). The contractor shall maintain a spare pneumatic tired roller on the project during high float application, in addition to those rollers necessary to accomplish this specification.
4. Spreading shall be accomplished so that the tires of the trucks or aggregate spreader at no time contact the uncovered and newly applied asphalt material.
5. Sweeping to remove excess cover aggregate is required. Sweeping is to occur between one and two weeks following the application of cover coat material as directed by the engineer. Ridges of loose aggregate created by traffic before sweeping shall be removed or uniformly spread over the surface as they develop as directed by the engineer.

405-3.07 Application of Blotter Material

Due to weather, construction, and/or materials problems, it is possible that the finished surface treatment may become unstable. To minimize development of damage to the surface, blotter material may be required. Blotter material shall be applied as directed by the engineer and immediately rolled with a pneumatic-tired roller (as described above) with tire pressures adjusted to 90 to 100 psi (620-690 kPa).

405-3.08 Traffic Control

Construction equipment shall not operate at speeds exceeding 15 mph (25 km per hour) on a freshly applied surface treatment for a period of up to 24 hours as directed by the engineer.

Unless otherwise specified, the highway shall be kept open to traffic at all times. No traffic shall be allowed on freshly sprayed asphalt or cover aggregate material that is not fully compacted. As soon as final rolling of the HFST layer is accomplished, controlled traffic may be permitted to operate on the HFST surface. Traffic on the HFST shall be controlled by pilot cars to a speed not exceeding 15 mph (25 km per hour) for a period of 2 to 24 hours, as directed by the engineer.

405-4.01 Method of Measurement

Asphalt material and cover aggregate material will be measured by the ton or by the square yard in accordance with Section 109.

Surface treatment blotter material and water used for aggregate and surface preparation will not be measured for payment; these items are considered subsidiary obligations.

If sweeping and/or blading of excess cover aggregate is required, this work shall not be measured or paid for directly but is considered a subsidiary obligation.

405-5.01 Basis of Payment

The accepted quantities of surface treatment will be paid for at the contract price per ton for asphalt material and per square meter for cover aggregate material, complete in place.

Payment will be made under:

Pay Item No.	Pay Item	Pay Unit
405(3)	HFMS-2s Asphalt for Surface Treatment	Ton
405(5-C)	Cover Aggregate for High Float Surface Treatment, Grading C	Square Yard

Section 703

Aggregates

703-2.05 Aggregate for Cover Coat and Surface Treatment

Add the following table:

703-5hf: Requirements for Cover Aggregate For High Float Surface Treatment

* Special note on gradation testing: For acceptance testing, verify compliance with the minus 0.005 mm size fraction at least once for each source used. For assurance testing, use the entire gradation with each test.

	Percent Passing by Weight		
Sieve, in (mm)	Grading B	Grading C	Grading D
1 (25)	100	—	
3/4 (19)	75–95	100	—
5/8 (16)	—	—	100
1/2 (12.5)	—	63–89	—
3/8 (9.5)	50–80	54–76	60–90
#4 (4.75)	35–65	36–56	40–70
#8 (2.36)	20–50	18–38	25–55
#16 (1.18)	—	12–30	—
#40 (0.425)	8–30	—	8–30
#50 (0.30)	—	4–18	—
#200 (0.075)	0–5	0–5	0–5
0.005 mm	0–3*	0–3*	0–3*

Appendix C4, Prime Coat

Section 403: Prime Coat

403-1.01 Description

This work consists of treating a previously prepared roadbed with asphalt material and blotter material if required.

403-2.01 Materials

Use materials that conform to the following:

1. Asphalt: MC-30 liquid asphalt or CSS-1 emulsified asphalt, conforming to Section 702.
2. Blotter material: Suitable clean sand.

Construction Requirements

403-3.01 Weather Limitations

Do not apply asphalt material to a wet surface or when the surface temperature is below 45˚F (7˚C) or when weather conditions would prevent the proper penetration of the prime coat.

403-3.02 Equipment

A distributor conforming to Subsection 402-3.02. An approved self-propelled aggregate spreader and rotary paver broom.

403-3.03 Preparation of Surface

Ensure that surface to be primed is shaped to the required grade and section, free of ruts, corrugations, segregated material, or other irregularities, and uniformly compacted.

403-3.04 Application of Asphalt Material

Before applying the prime coat, obtain approval of rate of application, temperature, and areas to be treated from the engineer.

When CSS-1 emulsified asphalt is specified, dilute with an equal amount of potable water at a temperature between 50 and 120˚F (10 and 50˚C) and mix for a minimum of 15 minutes before using.

Apply asphalt material to the width of the section to be primed by means of a pressure distributor in a uniform, continuous spread. Do not exceed maximum application rate at overlaps. Squeegee excess asphalt material from the surface. Correct any skipped areas or deficiencies. Place building paper over the end of the previous applications and start the joining application on the building paper. Remove and dispose of used building paper.

When road is open to traffic, treat not more than half of the width of the section in one application. Maintain traffic on the untreated portion of the roadbed. As soon as the asphalt material has been absorbed by the surface and will not pick up, traffic may be transferred to the treated portion and the remaining width of the section primed.

Maintain the surface until the next course has been placed. Protect the surface against damage.

403-3.05 Application of Blotter Material

If, after the application of the prime coat, the asphalt material fails to penetrate and dry and traffic must be routed over the primed surface or rain is imminent, apply blotter material as directed.

Do not apply blotter material sooner than four hours after application of the asphalt material.

403-4.01 Method of Measurement

By the ton per Section 109. Emulsified asphalt will be measured for payment before the addition of water.

Blotter material is subsidiary.

403-5.01 Basis of Payment

At the contract price, per unit of measurement, complete in place.

Payment will be made under:

Pay Item	Pay Unit
403(1) MC-30 Liquid Asphalt for Prime Coat	Ton
403(2) CSS-1 Emulsified Asphalt for Prime Coat	Ton

Notes

Notes

Appendix D: N. W. McLeod Mix Design Method for Seal Coats and Double-Layer ASTs

(Minnesota Seal Coat Handbook, Chapter 4, Minnesota DOT.)

Note: Minnesota's Seal Coat Handbook, Chapter 4, is presented here in its entirety, including references. Chapter 4 only covers the case of a seal coat, i.e., single-layer AST. Additional text (page D-113) explains how to adapt the method to mix designing for double-layer ASTs.

Seal Coat Design

Seal coats should be designed to ensure that the proposed materials are of sufficient quality and have the desired properties required for a successful seal coat project. In addition, the design will determine the proper amount of cover aggregate and bituminous binder to apply. The design procedure recommended by the author is based on the one first presented in the late 1960s by Norman McLeod (1). This procedure was later adapted by The Asphalt Institute (2) and the Asphalt Emulsion Manufacturers Association (3). It was also the design procedure used by the Strategic Highway Research Program (SHRP) for designing the Special Pavement Study chip seal sections constructed across the United States (4).

Asphalt Binder Considerations

In both cutback asphalts and asphalt emulsions, a portion of the binder is comprised of either cutter (cutbacks) or water (emulsions) which will evaporate as the binder cures. This will result in a collapse of the asphalt film, effectively reducing the height of the binder. In designing a seal coat, it is important to know the *residual asphalt content* of the binder. The residual asphalt is the "glue" that remains on the roadway after the cutter or water has evaporated out of the binder.

As shown in Figure D.1, cutback asphalts generally consist of about 85% asphalt cement and 15% cutter, by weight. Since the specific gravity of asphalt is very close to 1.0, this works out to about 85% asphalt cement and 15% cutter by volume. Asphalt emulsions generally consist of about two-thirds asphalt cement, with the remainder being water and emulsifier.

In Minnesota, many agencies reported problems when first switching from cutbacks to emulsions. Most of the problems occurred because they were applying the same amount of emulsion as they had been with cutbacks. This results in approximately 20% less asphalt cement on the pavement after curing. This lack of binder led to excessive chip loss and lack of confidence in asphalt emulsions. This problem can be avoided if the concept of residual asphalt is understood.

In order for aggregate particles to remain on the roadway, they need to have approximately 70% of their height embedded into the *residual asphalt.* For this to occur with an asphalt emulsion, the binder must rise near the top of the aggregate particles. This is demonstrated in Figure D.2. If the emulsion rises just below the top of the aggregate (voids ~100% filled), the voids will be roughly two-thirds filled after curing, since about one-third of the binder will evaporate. Failure to allow emulsions to rise this high will result in insufficient embedment and loss of the cover aggregate as soon as the seal coat is exposed to snow plows and traffic.

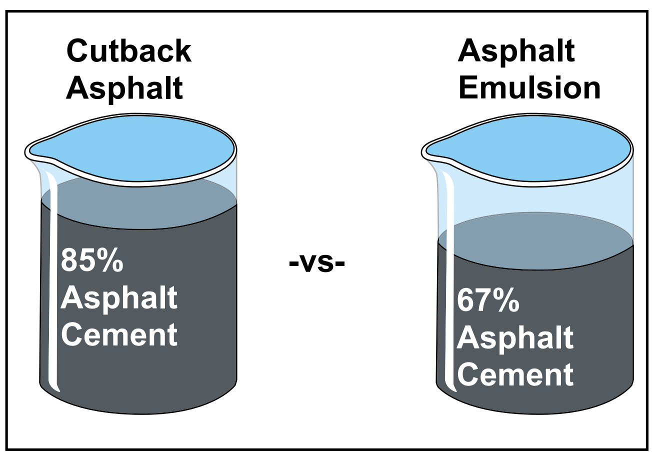

Figure D.1. Comparison of residual asphalt content of different binders

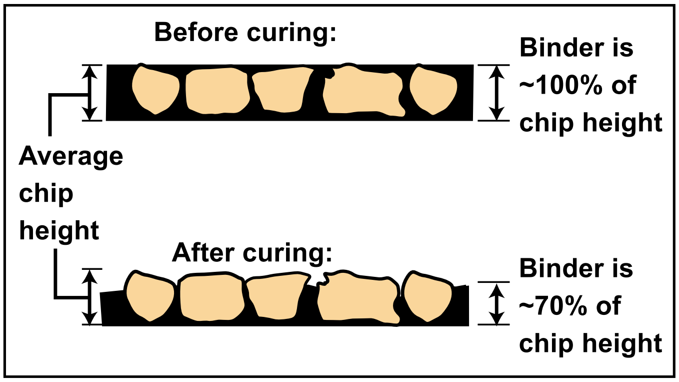

Figure D.2. Change in volume after emulsion has cured

Refer to Chapter 4 of this handbook for more details on asphalt binders used in seal coat construction.

Cover Aggregate Considerations

When designing a seal coat, there are several factors concerning the aggregate that must be considered. They all play a role in determining how much aggregate and binder should be applied to the roadway.

Gradation

The gradation of the cover aggregate is important not only for determining the aggregate application rate but also the binder application rate. The more graded the aggregate is, the closer the particles will be to each other on the roadway. This leaves very little room for the asphalt binder, which can cause bleeding. The best gradation for a seal coat aggregate is one-size. This means that almost every chip is the same size. A one-size aggregate has lots of room between the particles for filling with the binder. In addition, inspection is much easier because each chip is embedded approximately the same amount.

Particle Shape

The shape of the aggregate particles can be round or angular, flat or cubical. Their shape will determine how they lock together on the roadway. The more they lock together, the better the seal coat is able to withstand turning and stopping of vehicles as well as damage from snow plows.

Bulk Specific Gravity

The specific gravity, or unit weight, of the aggregate also plays a role in determining how much aggregate to apply to the roadway. Specific gravities of seal coat aggregate in Minnesota can differ by as much as 20%. The lower the specific gravity, the lighter the aggregate. It will take more pounds of a heavy aggregate, such as trap rock, to cover a square yard or meter of pavement than it will of a light aggregate, such as limestone.

Aggregate Absorption

The amount of binder applied to the roadway not only needs to compensate for absorption into the existing pavement but also into the cover aggregate itself. Sedimentary aggregates such as limestone can have ten times the absorption of igneous aggregate such as granite or trap rock. Failure to recognize this fact and correct for it can lead to excessive chip loss due to lack of embedment.

The McLeod Design Procedure

In the McLeod procedure, the aggregate application rate depends on the aggregate gradation, shape, and specific gravity. The binder application rate depends on the aggregate gradation, absorption and shape, traffic volume, existing pavement condition, and the residual asphalt content of the binder.

In Minnesota, the McLeod design procedure has been modified to apply slightly more binder in order to minimize snow plow damage in the non-wheelpath areas. This will be discussed later in this chapter.

The McLeod procedure is based on two basic principles:

1. The application rate of a given cover aggregate should be determined so that the resulting seal coat will only be **one-stone thick.** This amount of aggregate will remain constant, regardless of the binder type or pavement condition (see Figure D.3).
2. The voids in this aggregate layer need to be **70% filled with asphalt cement** for good

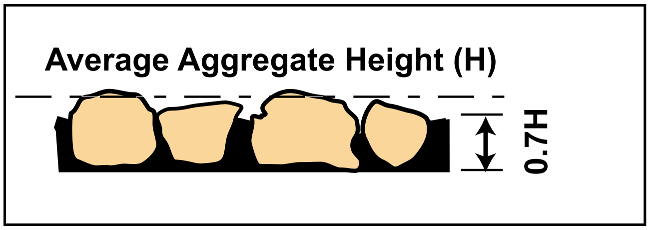

Figure D.3. McLeod design: one stone thick and proper embedment.

performance on pavements with moderate levels of traffic.

Figure D.4 shows an inspector checking for proper chip embedment. Notice that the chip is embedded about 70% into the residual asphalt. This will help to ensure good chip retention.

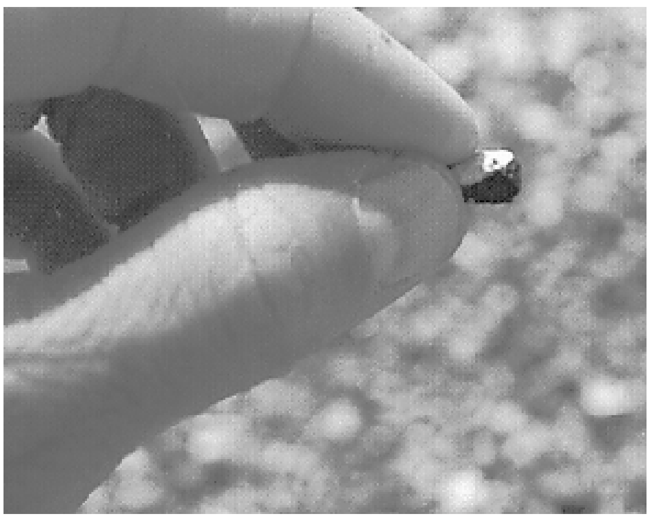

Figure D.4. Proper embedment (~70%) into the residual asphalt

The key components of the McLeod design procedure are as follows:

Median Particle Size

The median particle size (M) is determined from the gradation chart. It is the theoretical sieve size through which 50% of the material passes (50% passing size). The gradation is determined using the sieves shown in Table D.1.

Table D.1. Sieve nest for seal coat gradations

Sieve Name	Opening U.S. Customary Units	Opening S.I. Metric Units
1 inch	1.000 in.	25.0 mm
3/4 inch	0.750 in.	19.0 mm
1/2 inch	0.500 in.	12.5 mm
3/8 inch	0.375 in.	9.5 mm
1/4 inch	0.250 in.	6.3 mm
No. 4	0.187 in.	4.75 mm
No. 8	0.0937 in.	2.36 mm
No. 16	0.0469 in.	1.18 mm
No. 50	0.0117 in.	300 µm
No. 200	0.0029 in.	075 µm

Figure D.5. Seal coat sieve nest

Flakiness Index

The flakiness index (FI) is a measure of the percent, by weight, of flat particles. It is determined by testing a small sample of aggregate particles for their ability to fit through a slotted plate (Figure D.6).

There are five slots in the plate for five different size fractions of the aggregate. If the chips can fit through the slotted plate, they are considered to be flat. If not, they are considered to be cubical. The lower the flakiness index, the more cubical the material is. The test is run according to Central Federal Lands Highway Division (CFLHD) DFT-508 (5).

The five slots in the plate are for the following:

- Slot 1: Material passing the 1 in. sieve (25 mm) but retained on the 3/4 in. sieve (19 mm).

- Slot 2: Material passing the 3/4 in. sieve (19 mm) but retained on the 1/2 in. sieve (9.5 mm).
- Slot 3: Material passing the 1/2 in. sieve (9.5 mm) but retained on the 3/8 in. sieve (6.3 mm).
- Slot 4: Material passing the 3/8 in. sieve (9.5 mm) but retained on the 1/4 in. sieve (6.3 mm).
- Slot 5: Material passing the 1/4 in. sieve (6.3 mm) but retained on the No. 4 sieve (4.75 mm).

For most seal coat aggregate in Minnesota, only the smallest three slots are used. This is because most seal coat projects do not use 1, 3/4, or 1/2 inch (25, 19, or 12.5 mm) stone. The weight of material passing all of the slots is then divided by the total weight of the sample to give the percent flat particles, by weight, or flakiness index.

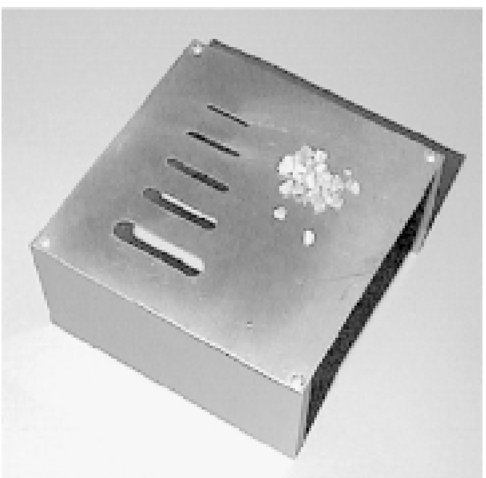

Figure D.6. Flakiness index testing plate

Average Least Dimension

The average least dimension, or ALD (H), is determined from the median particle size (M) and the flakiness index (FI). It is a reduction of the median particle size after accounting for flat particles. It represents the expected seal coat thickness in the wheel paths where traffic forces the flat chips to lie on their flattest side.

The average least dimension is calculated as follows:

$$H = \frac{M}{1.139285 + (0.011506)(FI)} \qquad (1)$$

Where:

H = Average least dimension, inches or mm
M = Median particle size, inches or mm
FI = Flakiness index, in percent

Loose Unit Weight of the Cover Aggregate

The loose unit weight (W) is determined according to ASTM C-29 and is needed to calculate the voids in the aggregate in a loose condition. The loose unit weight is used to calculate the air voids expected between the chips after initial rolling takes. It depends on the gradation, shape, and specific gravity of the aggregate. Well-graded aggregate and aggregate with a high dust content will have the highest loose unit weight because the particles pack together tightly, leaving little room for air. This air space between the aggregate particles is the only space available to place the binder.

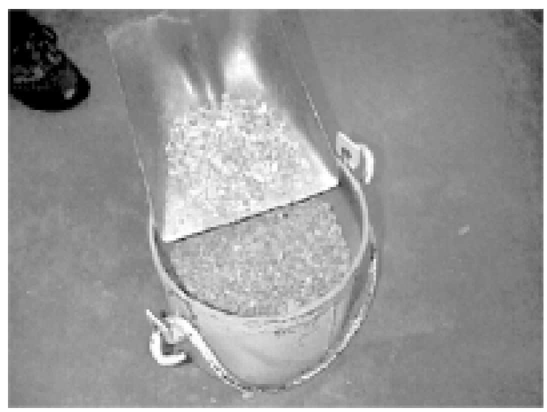

Figure D.7. The loose unit weight test

Voids in the Loose Aggregate

The voids in the loose aggregate (V) approximate the voids present when the chips are dropped from the spreader onto the pavement. Generally, this value will be near 50% for one-size aggregate, less for graded aggregate. After initial rolling, the voids are assumed to be reduced to 30% and will reach a low of about 20% after sufficient traffic has oriented the stones on their flattest side. However, if there is very little traffic, the voids will remain near 30% and the seal coat will require more binder to ensure good chip retention. One of the following equations is used to calculate the voids in the loose aggregate:

U.S. Customary Units:

$$V = 1 - \frac{W}{62.4G} \quad \textbf{(2)}$$

Where:

V = Voids in the loose aggregate, in percent expressed as a decimal
W = Loose unit weight of the cover aggregate, ASTM method C-29, lbs/ft^3
G = Bulk specific gravity of the aggregate

S.I. Metric Units:

$$V = 1 - \frac{W}{1000G} \quad \textbf{(3)}$$

Where:

V = Voids in the loose aggregate, in percent expressed as a decimal
W = Loose unit weight of the cover aggregate, ASTM method C-29, kg/m^3
G = Bulk specific gravity of the aggregate

Bulk Specific Gravity

Different aggregates have different specific gravities or unit weights. This value must be taken into account in the design procedure, because it will take more pounds of a heavy aggregate to cover a square yard of pavement than it will for a light aggregate. Table D.2 can be used as a guideline for determining the specific gravity of typical seal coat aggregates in Minnesota.

Aggregate Absorption

Most aggregates absorb some of the binder applied to the roadway. The design procedure must be able to correct for this condition to ensure enough binder will remain on the pavement surface. Table D.3 can be used as a guideline. A good rule of thumb is that Class A aggregates generally do not require a correction for absorption, whereas Class B and C aggregates generally do. McLeod suggests an absorption correction factor, A, of 0.02 gal/yd^2 (0.09 L/m^2) if the aggregate absorption is around 2%. The author recommends using this correction if the absorption is 1.5% or higher.

Traffic Volume

The traffic volume on the pavement surface, in terms of the number of vehicles per day, plays a role in determining the amount of asphalt binder needed to sufficiently embed the chips. Generally speaking, the higher the traffic volume, the lower the binder application rate. At first glance this may not seem correct. However, remember that traffic forces the chips to lay on their flattest side. Consequently, the greater the traffic volume the greater the chance the chips will be lying on their flat side. If a roadway had no traffic, the chips would lie in the same orientation as when they were first rolled during construction. As a result, they would stand taller and need more asphalt binder to achieve the desired 70% embedment. With enough traffic, the chips will lie as flat as possible, causing the seal coat to be as thin as possible. If this is not taken into account, the wheelpaths will likely bleed. The McLeod design procedure uses Table D.4 to estimate the required

Table D.2. Typical Bulk Specific Gravity of Common Seal Coat Aggregates in Minnesota

		Class A			Class B		Class C
Aggregate type		Granite	Quartzite	Trap Rock	Limestone	Red Rock	Pea Rock
Bulk	Min.	2.60	2.59	2.95	2.40	2.50	2.55
Specific	Max.	2.75	2.63	2.98	2.67	2.52	2.66
Gravity	**Avg.**	**2.68**	**2.62**	**2.97**	**2.61**	**2.51**	**2.62**

embedment, based on the number of vehicles per day on the roadway.

Traffic Whip-Off

The McLeod procedure also recognizes that some of the cover aggregate will get thrown to the side of the roadway by passing vehicles as the fresh seal coat is curing. The amount of aggregate that will do this is related to the speed and number of vehicles on the new seal coat. To account for this, a traffic whip-off factor (E) is included in the aggregate design equation. A reasonable value to assume is 5% for low volume, residential type traffic and 10% for higher speed roadways such as county roads. The traffic whip-off factor is shown in Table D.5.

Existing Pavement Condition

The condition of the existing pavement plays a major role in the amount of binder required to obtain proper embedment. A new smooth pavement with low air voids will not absorb much of the binder applied to it. Conversely, a dry, porous, and pocked pavement surface can absorb a tremendous amount of the binder. Failure to recognize when to increase or decrease the binder application rate to account for the pavement condition can lead to excessive chip loss or bleeding. The McLeod procedure uses the descriptions and factors in Table D.6 to add or reduce the amount of binder to apply in the field.

The inspector needs to be aware of these conditions should they change at some point throughout the project.

Most agencies seal roadways built during different years by different contractors with different materials as part of a single contract. Included may be new pavements, old pavements, porous pavements, flushed pavements, etc. For this reason, **it is not practical to assume that all roadways to be sealed in a given project will need the same amount of asphalt binder.**

Examples of some of these pavement conditions are shown in Figures D.8 to D.11.

Table D.3. Typical Absorption of Common Seal Coat Aggregates in Minnesota

		Class A			Class B		Class C
Aggregate type		Granite	Quartzite	Trap Rock	Limestone	Red Rock	Pea Rock
Percent	Min.	0.40	0.61	0.31	1.75	no data	1.14
Absorption	Max.	0.92	0.72	0.59	5.44	no data	2.32
	Avg.	**0.59**	**0.67**	**0.43**	**2.80**	—	**1.69**

Table D.4. Traffic Correction Factor, T

Traffic factor: The percentage, expressed as a decimal, of the ultimate 20% void space in the cover aggregate to be filled with asphalt.

Traffic—Vehicles per day				
Under 100	100 to 500	500 to 1000	1000 to 2000	Over 2000
0.85	0.75	0.70	0.65	0.60

Note: The factors above do not make allowance for absorption by the road surface or by absorptive cover aggregate.

Table D.5. Aggregate Wastage Factor, E (Asphalt Institute MS-19, March 1979)

Percentage Waste* Allowed for	Wastage Factor, E
1	1.01
2	1.02
3	1.03
4	1.04
5	1.05
6	1.06
7	1.07
8	1.08
9	1.09
10	1.10
11	1.11
12	1.12
13	1.13
14	1.14
15	1.15

* Due to traffic whip-off and handling

Table D.6. Surface Correction Factor, S

Existing	Correction, S	
PavementTexture	S.I. Metric (L/m^2)	U.S. Customary (gal/yd^2)
Black, flushed asphalt	-0.04 to -0.27	-0.01 to -0.06
Smooth, non-porous	0.00	0.00
Slightly porous & oxidized	+0.14	+0.03
Slightly pocked, porous & oxidized	+0.27	+0.06
Badly pocked, porous & oxidized	+0.40	+0.09

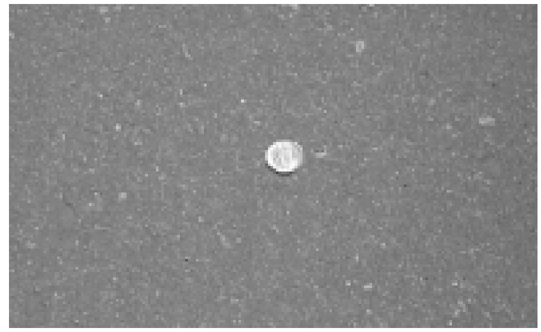

Figure D.8. Example of a smooth, nonporous surface

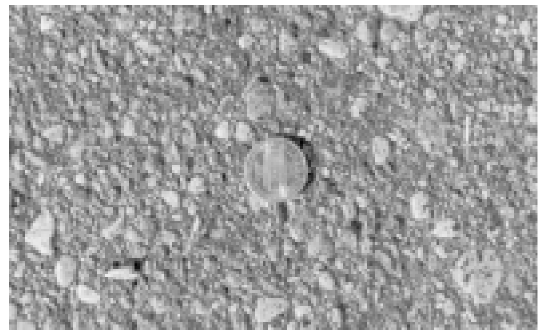

Figure D.9. Example of a slightly porous and oxidized surface

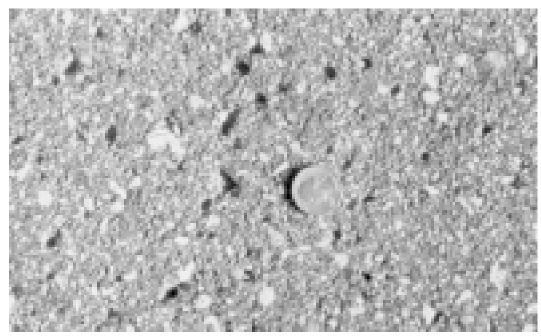

Figure D.10. Example of a slightly pocked, porous, and oxidized surface

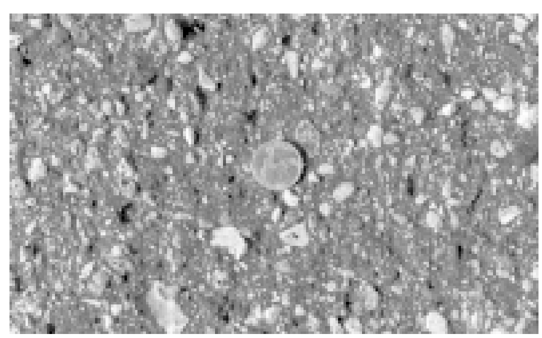

Figure D.11. Example of a badly pocked, porous, and oxidized surface

McLeod Seal Coat Design Equations

Once all of the lab testing is completed, the following equations are then used to determine the aggregate and binder application rates. While the results may need to be adjusted in the field, especially the binder application rate, they have shown to provide a close approximation of the correct quantity of materials.

Aggregate Design Equation

The aggregate application rate is determined from the following equations:

U.S. Customary Units:

$$C = 46.8(1-0.4V)HGE \quad \textbf{(4)}$$

Where:

C = Cover aggregate application rate, lbs/yd^2
V = Voids in the loose aggregate, in percent expressed as a decimal (Equation 2)
H = Average least dimension, inches (Equation 1)
G = Bulk specific gravity of the aggregate
E = Wastage factor for traffic whip-off (Table D.5)

S.I. Metric Units:

$$C = (1-0.4V)HGE \quad \textbf{(5)}$$

Where:

C = Cover aggregate application rate, kg/m^2
V = Voids in the loose aggregate, in percent expressed as a decimal (Equation 3)
H = Average least dimension, mm (Equation 1)
G = Bulk specific gravity of the aggregate
E = Wastage factor for traffic whip-off (Table D.5)

Binder Design Equation

Binder application rates are determined from the following equations:

U.S. Customary Units:

$$B = \frac{(2.244)(H)(V) + S + A}{R} \quad \textbf{(6)}$$

Where:

B = Binder application rate, $gallons/yd^2$
H = Average least dimension, inches
T = Traffic factor (based on expected vehicles per day, Table D.4)
V = Voids in loose aggregate, in decimal percent (Equation 2)
S = Surface condition factor, gal/yd^2 (based on existing surface, Table D.6)
A = Aggregate absorption factor, $gallons/yd^2$
R = Residual asphalt content of binder, in percent expressed as a decimal

S.I. Metric Units:

$$B = \frac{(0.40)(H)(V) + S + A}{R} \quad \textbf{(7)}$$

Where:

B = Binder application rate, $liters/m^2$
H = Average least dimension, mm
T = Traffic factor (based on expected vehicles per day, Table D.4)
V = Voids in loose aggregate, in decimal percent (Equation 3)
S = Surface condition factor, $liters/m^2$ (based on existing surface, Table D.6)
A = Aggregate absorption factor, $liters/m^2$
R = Residual asphalt content of binder, in percent expressed as a decimal.

One additional calculation has been added to the McLeod design to account for snow plow damage. After the binder design equation is done using the ALD, it is recalculated using the median particle size in place of the ALD. This will give the binder required if none of the chips lay flat. The average of these two values is then used as the starting point for the field test sections discussed in Chapter 7 of this manual. It has been found that if this is not done, insufficient binder will exist in the nontraffic areas and snow plows will shave off the stones in these areas.

The following example is given to demonstrate how to use the design equations to determine binder and cover aggregate application rates.

Seal Coat Design Example

A 150-pound (68 kg) sample of an FA-3 granite seal coat aggregate has been submitted for design. The traffic on the road to be sealed is 850 vehicles per day. The pavement surface is slightly pocked, porous, and oxidized. The binder will be a CRS-2 emulsion with 67% residual asphalt.

Step 1. Determine the Aggregate Gradation, Bulk Specific Gravity, and Percent Absorption

Gradation results: Table D.7

Step 2. Determine the Median Particle Size

The gradation results in the table above are then plotted on a gradation chart. The median particle size is determined by extending a horizontal line at the 50% passing mark until it intersects the gradation curve. A vertical line is then projected downward, which gives the median particle size. This is the theoretical size where half of the stones are larger and half smaller. It is considered to be theoretical because there may not actually be any stones that size.

Table D.7 Gradation results

Sieve Name	Sieve Opening U.S. Customary	Sieve Opening S.I. Metric	Percent Passing
½ inch	0.50 in.	12.5 mm	100
⅜ inch	0.375 in.	9.5 mm	92
¼ inch	0.25 in.	6.3 mm	85
No. 4	0.187 in.	4.75 mm	18
No. 8	0.0937 in.	2.36 mm	6
No. 16	0.0469 in.	1.18 mm	3
No. 50	0.0117 in.	300 µm	1
No. 200	0.0029 in.	75 µm	0.4

- Based on AASHTO T 84-94 the bulk specific gravity was determined to be 2.71.
- Based on AASHTO T 84-94 the aggregate absorption was determined to be 0.3%.

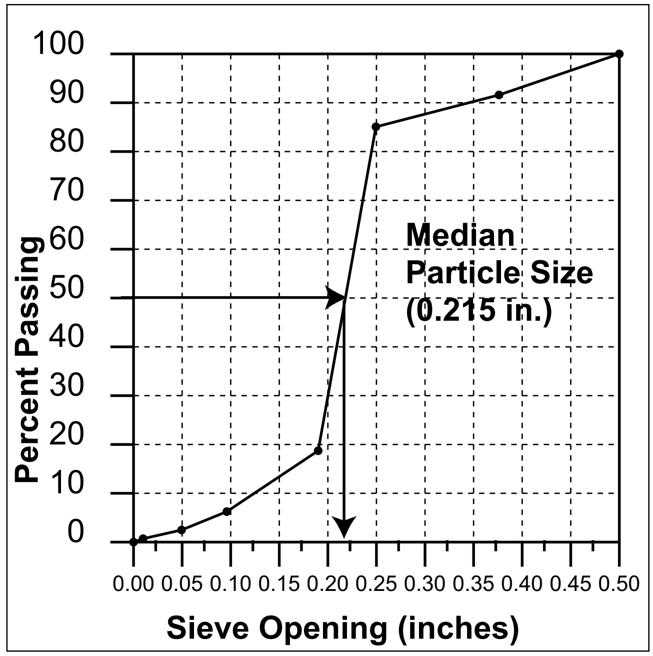

Figure D.12. Gradation chart for the design example, showing median particle size

Step 3. Determine the Flakiness Index (FI)

The aggregate used to determine the gradation is then broken down into the following fractions:

1. Passing the 1 in. sieve but retained on the ¾ in. sieve,
2. Passing the ¾ in. sieve but retained on the ½ in. sieve,
3. Passing the ½ in. sieve but retained on the ⅜ in. sieve,
4. Passing the ⅜ in. sieve but retained on the ¼ in. sieve, and
5. Passing the ¼ in. sieve but retained on the No. 4 sieve.

Since all of the material passed the ½ in. sieve, only the last three fractions are used. The aggregate particles in each fraction are tested to see if they fit through the slotted plate (Figure D.6).

The flakiness index is calculated as follows.

$$FL = \frac{(\text{Weight of Flat chips})}{(\text{Weight of Sample})} = \frac{(145.3)}{(361.90+145.3)} = \frac{(145.3)}{(507.2)} = 28.6\% \quad \textbf{(8)}$$

The results are shown in the next table.

Table D.8. Flakiness Index Test Results

Size Fraction	Weight Retained on Slot (grams)	Weight Passing Slot (grams)
$^{1}/_{2}$ to $^{3}/_{8}$ in.	54.2	12.3
$^{3}/_{8}$ to $^{1}/_{4}$ in.	123.3	43.5
$^{1}/_{4}$ in. to No. 4	184.4	89.5
Totals	**361.90**	**145.3**

Step 4. Determine the Average Least Dimension (H)

The average least dimension, or ALD, is the expected thickness of the seal coat in the wheelpaths after any flat chips have been oriented on their flattest side by traffic. It is calculated from the median particle size (M) and the flakiness index (FI) as follows:

U.S. Customary Units:

$$H = \frac{M}{1.139285 + (0.011506)(FI)} = \frac{0.215 \text{ in.}}{1.139285 + (0.011506)(28.6)} = 0.146 \text{ in.} \quad \textbf{(9)}$$

S.I. Metric Units:

$$H = \frac{M}{1.139285 + (0.011506)(FI)} = \frac{5.50 \text{ mm}}{1.139285 + (0.011506)(28.6)} = 3.75 \text{ mm} \quad \textbf{(10)}$$

Step 5. Determine the Loose Weight of the Aggregate (W)

A metal cylinder with a volume of 0.50 ft^3 (0.014 m^3) was loosely filled with aggregate until full as shown in Figure D.7. The weight of the aggregate was then determined. This was repeated three times with the results in the following table. The average of the three is then used to determine the loose unit weight of the aggregate.

Table D.9. Loose Unit Weight Test Results

Test Number	Weight of the Aggregate in the Cylinder (lbs)	Weight of the Aggregate in the Cylinder (kg)
1	45.25	20.57
2	45.32	20.60
3	45.29	20.59
Average	**45.29**	**20.59**

The loose unit weight (W) is calculated as follows:

U.S. Customary Units

$$W = \frac{\text{(Weight of aggregate)}}{\text{(Volume of cylinder)}} = \frac{(45.29 \text{ lbs})}{(0.50 \text{ ft}^3)} = 90.58 \text{ lbs/ft}^3 \quad \textbf{(11)}$$

S.I. Metric Units

$$W = \frac{\text{(Weight of aggregate)}}{\text{(Volume of cylinder)}} = \frac{(20.59 \text{ kg})}{(0.014 \text{ m}^3)} = 1{,}471 \text{ kg/m}^3 \quad \textbf{(12)}$$

Step 6. Determine the Voids in the Loose Aggregate (V)

Using Equations 13 and 14, the voids in the loose aggregate are calculated. The higher the voids, the more room for the asphalt binder and the more one-size the aggregate is.

U.S. Customary Units:

$$V = 1 - \frac{W}{62.4 \text{ G}} = 1 - \frac{90.58 \text{ lb/ft}^3}{(62.4)(2.71)} = 0.46 \quad \textbf{(13)}$$

S.I. Metric Units:

$$V = 1 - \frac{W}{1000 \text{ G}} = 1 - \frac{1{,}471 \text{ kg/m}^3}{(1000)(2.71)} = 0.46 \quad \textbf{(14)}$$

Since 0.46 is fairly close to 0.50, this is a fairly one-size aggregate.

Summarizing the above information:

Table D.10. Summary of Design Example Data

Test	U.S. Customary Units	S.I. Metric Units
Median Particle Size	0.215 inches	5.50 mm
Flakiness Index	28.6%	28.6%
Average Least Dimension	0.146 inches	3.75 mm
Loose Unit Weight	90.58 lbs/ft^3	1,470 kg/m^3
Voids in the Loose Aggregate	0.46	0.46
Traffic Volume	500–1000 vehicles/day Use 5% whip-off	500–1000 vehicles/day Use 5% whip-off
Surface Condition	Slightly pocked, porous and oxidized	Slightly pocked, porous and oxidized
Bulk Specific Gravity	2.71	2.71
Aggregate Absorption	0.31% No adjustment needed	0.31% No adjustment needed
Residual Asphalt Content of the Binder	0.67	0.67

Cover Aggregate Application Rate

U.S. Customary Units: **(15)**

C = 46.8(1–0.4 x V)(H)(G)(E) =
46.8(1–0.4 x 0.46)(0.146 in.)(2.71)(1.05) = 15.8 lbs/yd^2

Where:

C = Cover aggregate application rate, lbs/yd^2
V = Voids in the loose aggregate, in percent expressed as a decimal
H = Average least dimension, inches
G = Bulk specific gravity of the aggregate
E = Wastage factor for traffic whip-off (Table D.5)

S.I. Metric Units: **(16)**

C = 46.8(1–0.4 x V)(H)(G)(E) =
46.8(1–0.4 x 0.46)(0.146 in.)(2.71)(1.05) = 15.8 lbs/yd^2

Where:

C = Cover aggregate application rate, kg/m^2
V = Voids in the loose aggregate, in percent expressed as a decimal
H = Average least dimension, mm
G = Bulk specific gravity of the aggregate
E = Wastage factor for traffic whip-off (Table D.5)

The recommended results should be rounded up to the nearest pound or kilogram. Once the aggregate application rate has been determined, it is a good idea to test it. This is done by spreading the recommended amount of aggregate over a one square yard (or one square meter) plywood box. The aggregate should provide a one-stone thick layer. This will provide a good representation of how the seal coat should look in the field. **In the field, the aggregate application rate does not need to be adjusted to account for traffic or surface condition as does the binder.**

Binder Design Equation

The binder application rate is determined from the following equations:

U.S. Customary Units:

$$B = \frac{(2.244)(H)(T)(V) + S + A}{R} \quad \textbf{(17)}$$

Where:

B = Binder application rate, gallons/yd^2
H = Average least dimension, inches
T = Traffic factor (based on expected vehicles per day, Table D.4)
V = Voids in loose aggregate, in decimal percent (Equation 2)
S = Surface condition factor, gal/yd^2 (based on existing surface, Table D.6)
A = Aggregate absorption factor, gallons/yd^2
R = Residual asphalt content of binder, in decimal percent

Binder Application Rate for Wheelpaths:

$$B = \frac{(2.244)(0.146 \text{ in.})(0.70)(0.46) + 0.06 + 0.00}{0.67} = 0.25 \text{ gal/yd}^2 \quad \textbf{(18)}$$

This application rate should provide proper embedment of the chips once they have laid on their flattest side. In Minnesota, it is recommended that the binder application rate for nontraffic areas also be calculated and the average of the two be used as the starting point in the field. This is done by substituting the median particle size for the average least dimension.

Binder application rate for nonwheelpath areas:

$$B = \frac{(2.244)(0.215\text{ in.})(0.70)(0.46) + 0.06 + 0.00}{0.67} = 0.32\text{ gal/yd}^2 \qquad \textbf{(19)}$$

Take the average of the two as the starting point in the field:

Starting Application Rate in the Field =

$$\frac{0.25 + 0.32}{2} = 0.29\text{ gal/yd}^2 \qquad \textbf{(20)}$$

S.I. Metric Units:

$$B = \frac{(0.40)(H)(V) + S + A}{R} \qquad \textbf{(21)}$$

Where:

B = Binder application rate, liters/m^2
H = Average least dimension, mm
T = Traffic factor (based on expected vehicles per day, Table D.4)
V = Voids in loose aggregate, in decimal percent (Equation 3)
S = Surface condition factor, liters/m^2 (based on existing surface, Table D.6)
A = Aggregate absorption factor, liters/m^2
R = Residual asphalt content of binder, in decimal percent.

Application rate in the wheelpaths:

$$B = \frac{(0.40)(3.75\text{ mm})(0.70)(0.46) + 0.27\text{ L/m}^2 + 0.00}{0.67} = 1.12\text{ L/m}^2 \qquad \textbf{(22)}$$

The binder application rate in the nontraffic areas is:

$$B = \frac{(0.40)(5.50\text{ mm})(0.70)(0.46) + 0.27\text{ L/m}^2 + 0.00}{0.67} = 1.46\text{ L/m}^2 \qquad \textbf{(23)}$$

Once again, take the average as a starting point in the field.

Starting Application Rate in the Field =

$$\frac{1.46 + 1.12}{2} = 1.29\text{ L/m}^2 \qquad \textbf{(24)}$$

Summary

In summary, a good seal coat design incorporates many factors of the binder and aggregate. The results should yield a good starting point for field test sections. Experience has shown that the aggregate application rate determined from the equations is almost always the correct rate to apply in the field. However, since the binder application rate makes assumptions concerning the amount of texture and porosity of the existing pavement, the binder application rate will almost always need to be adjusted. Most of the time it will need to be adjusted upward (apply more binder).

A good tool to use in the field is a binder adjustment chart. This type of chart calculates the design application rate for all combinations of traffic (Table D.4) and surface condition (Table D.6). It can be used by the inspector to make adjustments in the field. Figure D.13 shows the binder adjustment chart for the above example.

Added to Appendix D by Alaska DOT&PF:

For Double Layer ASTs—Modifying McLeod's Method for Mix Designs Involving Two or More Cover Aggregate Layers

The Asphalt Institute (2) described a simple method for handling mix designs involving multiple layers of cover aggregate.

First, do a mix design for each layer of cover aggregate, as if it were to be the only layer (using the previously described methods). Also apply the following rules:

1. The maximum nominal size (top size) of each succeeding layer of cover aggregate should not be more than about half the size of the previous layer.
2. Make no allowance for wastage.
3. Except for the first course, make no correction for underlying surface texture.

Add together the amounts of emulsified asphalt determined for each layer of cover aggregate to obtain a total emulsified asphalt requirement.

McLeod Recommended:

For double-layer ASTs, apply 40% of the total requirement for the first layer of cover aggregate, and the remaining 60% for the second layer of cover aggregate. In rare cases where a triple-layer AST might be used, the total emulsified asphalt requirement is summed from all three layers, then apportioned for the first, second, and third cover aggregate layers in portions of 30%, 40%, and 30% respectively.

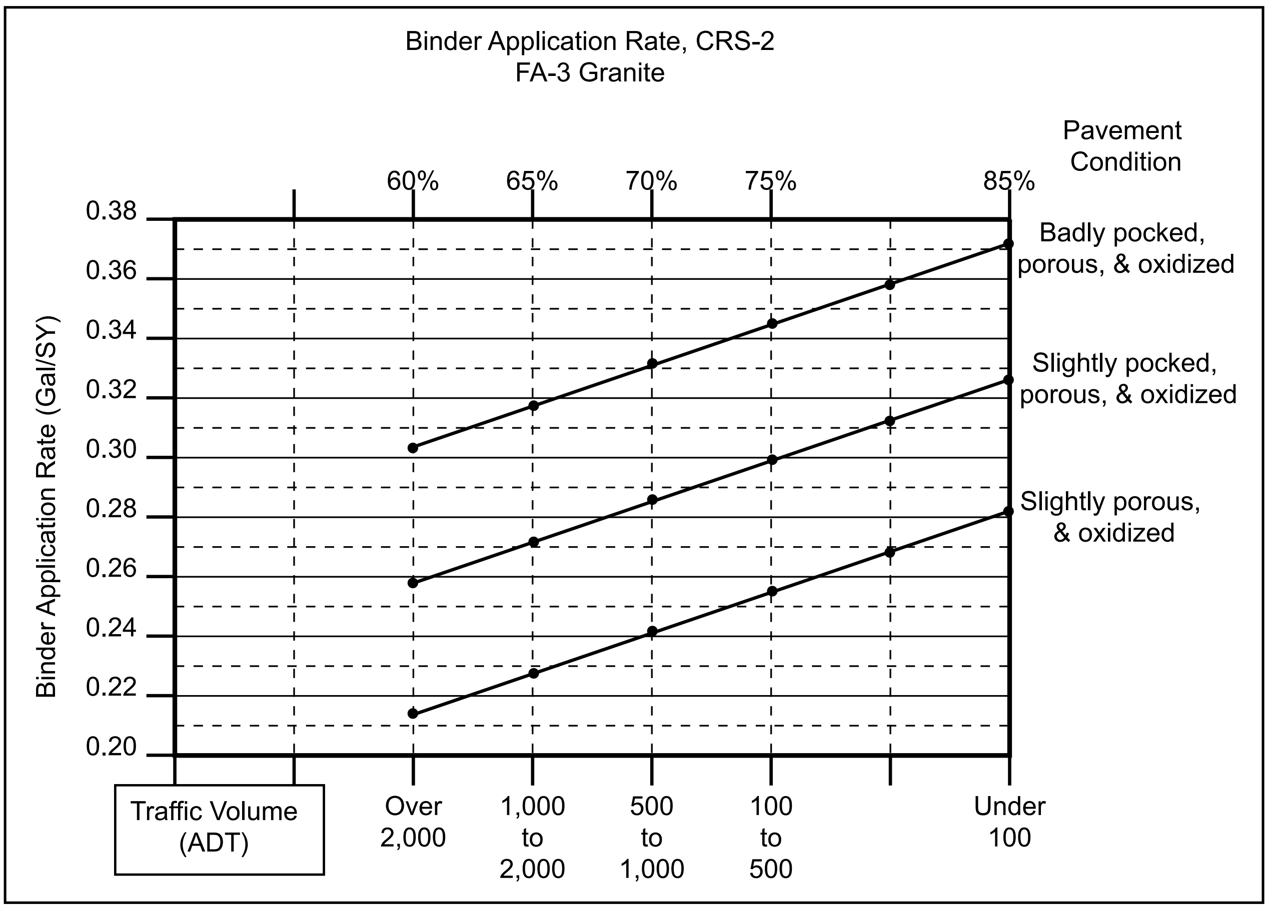

Figure D.13. Example of a binder adjustment chart

References for Appendix D

1. McLeod N. W., *A General Method of Design for Seal Coats and Surface Treatments.* Proceedings of the Association of Asphalt Paving Technologists, Volume 38. St. Paul, MN, 1969.
2. *A Basic Asphalt Emulsion Manual.* Manual Series No. 19 (MS-19). The Asphalt Institute. Lexington, KY, 1979.
3. *A Recommended Guideline for Single and Multiple Chip Seals Using Asphalt Emulsion*. Asphalt Emulsion Manufacturers Association. Annapolis, MD, 1985.
4. Bullard, D. J., Smith, R. E., and Freeman, T. J. *Development of a Procedure to Rate the Application of Pavement Maintenance Treatment*, Strategic Highway Research Program Report No. SHRP-M/FR-92-102. TRB, National Research Council, Washington D.C., 1992, pp 357-410.
5. *Standard Method of Determining the Flakiness Index and Average Least Dimension of Aggregates.* FLH Designation T 508. Central Federal Lands Highway Office. U.S. Department of Transportation.

Notes

Appendix E: Miscellaneous Tables

(From The Asphalt Institute, Manual Series No. 19)

Table E-1. Temperature-Volume Corrections for Emulsified Asphalts

˚C^{t}	˚F	M*	˚C^{t}	˚F	M*	˚C^{t}	˚F	M*
10.0	50	1.00250	35.0	95	0.99125	60.0	140	0.98000
10.6	51	1.00225	35.6	96	0.99100	60.6	141	0.97975
11.1	52	1.00200	36.1	97	0.99075	61.1	142	0.97950
11.7	53	1.00175	36.7	98	0.99050	61.7	143	0.97925
12.2	54	1.00150	37.2	99	0.99025	62.2	144	0.97900
12.8	55	1.00125	37.8	100	0.99000	62.8	145	0.97875
13.3	56	1.00100	38.3	101	0.98975	63.3	146	0.97850
13.9	57	1.00075	38.9	102	0.98950	63.9	147	0.97825
14.4	58	1.00050	39.4	103	0.98925	64.4	148	0.97800
15.0	59	1.00025	40.0	104	0.98900	65.0	149	0.97775
15.6	60	1.00000	40.6	105	0.98875	65.6	150	0.97750
16.1	61	0.99975	41.1	106	0.98850	66.1	151	0.97725
16.7	62	0.99950	41.7	107	0.98825	66.7	152	0.97700
17.2	63	0.99925	42.2	108	0.98800	67.2	153	0.97675
17.8	64	0.99900	42.8	109	0.98775	67.8	154	0.97650
18.3	65	0.99875	43.3	110	0.98750	68.3	155	0.97625
18.9	66	0.99850	43.9	111	0.98725	68.9	156	0.97600
19.4	67	0.99825	44.4	112	0.98700	69.4	157	0.97575
20.0	68	0.99800	45.0	113	0.98675	70.0	158	0.97550
20.6	69	0.99775	45.6	114	0.98650	70.6	159	0.97525
21.1	70	0.99750	46.1	115	0.98625	71.1	160	0.97500
21.7	71	0.99725	46.7	116	0.98600	71.7	161	0.97475
22.2	72	0.99700	47.2	117	0.98575	72.2	162	0.97450
22.8	73	0.99675	47.8	118	0.98550	72.8	163	0.97425
23.3	74	0.99650	48.3	119	0.98525	73.3	164	0.97400
23.9	75	0.99625	48.9	120	0.98500	73.9	165	0.97375
24.4	76	0.99600	49.4	121	0.98475	74.4	166	0.97350
25.0	77	0.99575	50.0	122	0.98450	75.0	167	0.97325
25.6	78	0.99550	50.6	123	0.98425	75.6	168	0.97300
26.1	79	0.99525	51.1	124	0.98400	76.1	169	0.97275
26.7	80	0.99500	51.7	125	0.98375	76.7	170	0.97250
27.2	81	0.99475	52.2	126	0.98350	77.2	171	0.97225
27.8	82	0.99450	52.8	127	0.98325	77.8	172	0.97200
28.3	83	0.99425	53.3	128	0.98300	78.3	173	0.97175
28.9	84	0.99400	53.9	129	0.98275	78.9	174	0.97150
29.4	85	0.99375	54.4	130	0.98250	79.4	175	0.97125
30.0	86	0.99350	55.0	131	0.98225	80.0	176	0.97100
30.6	87	0.99325	55.6	132	0.98200	80.6	177	0.97075
31.1	88	0.99300	56.1	133	0.98175	81.1	178	0.97050
31.7	89	0.99275	56.7	134	0.98150	81.7	179	0.97025
32.2	90	0.99250	57.2	135	0.98125	82.2	180	0.97000
32.8	91	0.99225	57.8	136	0.98100	82.8	181	0.96975
33.3	92	0.99200	58.3	137	0.98075	83.3	182	0.96950
33.9	93	0.99175	58.9	138	0.98050	83.9	183	0.96925
34.4	94	0.99150	59.4	139	0.98025	84.4	184	0.96900
						85.0	185	0.96875

Legend: t = *observed temperature in degrees Celsius (Fahrenheit)*

M = multiplier for correcting volumes to the basis of 15.6˚C (60˚F)

* Multiplier (M) for ˚C is a close approximation.

Table E-2. Linear Measurement Covered by Tank of Any Capacity for Various Widths and Rates of Application

To compute the number of linear feet (meters) that will be covered by a tank of any capacity, for various widths and rates of application, use the applicable formula:

$$\text{S.I. Metric: } L = \frac{C}{RW}$$

$$\text{U.S. Customary: } L = \frac{9C}{RW}$$

Where:

L = no. of linear meters (feet) that will be covered
C = capacityof tank in liters (gallons) (or quantity of asphalt in tank)
R = rate of application in liters per sq. meter (gallons per sq. yard)
W = width of application in meters (feet)

Table E-3. Linear Meters Covered by 4000 Liter Tank of Asphalt for Various Widths and Liters per Square Meter

Liters per Sq. Meter	Width—Meters								
	0.5	1.0	1.5	2.0	3.0	4.0	5.0	6.0	7.0
0.45	17778	8889	5926	4444	2963	2222	1778	1481	1270
0.68	11765	5882	3922	2941	1961	1471	1176	980	840
0.91	8791	4396	2930	2198	1465	1099	879	733	628
1.13	7080	3540	2360	1770	1180	885	708	590	506
1.36	5882	2941	1961	1471	980	735	588	490	420
1.58	5063	2532	1688	1266	844	633	506	422	362
1.81	4420	2210	1473	1105	737	552	442	368	316
2.04	3922	1961	1307	980	654	490	392	327	280
2.26	3540	1770	1180	885	590	442	354	295	253
2.72	2941	1471	980	735	490	368	294	245	210
3.17	2524	1262	841	631	421	315	252	210	180
3.62	2210	1105	737	552	368	276	221	184	158
4.07	1966	983	655	491	328	246	197	164	140
4.53	1766	883	589	442	294	221	177	147	126
5.66	1413	707	471	353	236	177	141	118	101
6.79	1178	589	393	295	196	147	118	98	84
7.92	1010	505	337	253	168	126	101	84	72
9.05	884	442	295	221	147	110	88	74	63

NOTE: See Table E-2 for formula used for calculation.

Table E-3a. Linear Feet Covered By 1000-gallon Tank of Emulsified Asphalt for Various Widths and Rates

Width—Feet

Gals. Sq.	1	2	6	7	8	9	10	11	12	14	16	18	20	22	24
0.10	90000	45000	15000	12857	11250	10000	9000	8182	7500	6429	5625	5000	4500	4091	3750
0.15	60000	30000	10000	8571	7500	6667	6000	5455	5000	4286	3750	3333	3000	2727	2500
0.20	45000	22500	7500	6429	5625	5000	4500	4091	3750	3214	2813	2500	2250	2045	1875
0.25	36000	18000	6000	5143	4500	4000	3600	3273	3000	2571	2250	2000	1800	1636	1500
0.30	30000	15000	5000	4286	3750	3333	3000	2727	2500	2143	1875	1667	1500	1363	1250
0.35	25714	12857	4286	3673	3214	2857	2571	2338	2143	1837	1607	1429	1286	1169	1071
0.40	22500	11250	3750	3214	2813	2500	2250	2045	1875	1607	1406	1250	1125	1022	937
0.45	20000	10000	3333	2857	2500	2222	2000	1818	1667	1429	1250	1111	1000	909	833
0.50	18000	9000	3000	2511	2250	2000	1800	1636	1500	1286	1125	1000	900	818	750
0.55	16364	8182	2727	2338	2046	1818	1636	1488	1364	1169	1023	909	818	744	682
0.60	15000	7500	2500	2143	1875	1667	1500	1364	1250	1071	938	833	750	682	625
0.65	13846	6923	2308	1978	1731	1538	1385	1259	1154	989	865	769	692	629	577
0.70	12857	6429	2143	1831	1607	1429	1286	1169	1071	918	804	714	643	584	535
0.75	12000	6000	2000	1714	1500	1333	1200	1091	1000	857	750	667	600	545	500
0.80	11250	5625	1875	1607	1406	1250	1125	1023	938	804	703	625	563	511	469
0.85	10588	5294	1765	1513	1324	1176	1059	963	882	756	662	588	529	481	441
0.90	10000	5000	1667	1429	1250	1111	1000	909	833	714	625	556	500	454	416
0.95	9474	4737	1579	1353	1184	1053	947	861	789	676	592	526	473	430	394
1.00	9000	4500	1500	1286	1125	1000	900	818	750	643	563	500	450	409	375
1.10	8182	4091	1364	1169	1023	909	818	744	682	584	511	454	409	372	341
1.20	7500	3750	1250	1071	938	833	750	682	625	535	469	416	375	341	312
1.25	7200	3600	1200	1029	900	800	720	655	600	514	450	400	360	327	300
1.30	6923	3462	1154	989	866	769	692	629	577	494	433	384	346	314	288
1.40	6429	3215	1072	918	804	714	643	584	536	459	402	357	321	292	268
1.50	6000	3000	1000	857	750	667	600	545	500	429	375	333	300	272	250
1.75	5143	2571	857	735	643	571	514	468	429	367	321	286	257	234	214
2.00	4500	2250	750	643	563	500	450	409	375	321	281	250	225	204	187
2.25	4000	2000	667	571	500	444	400	364	333	286	250	222	200	182	166
2.50	3600	1800	600	514	450	400	360	327	300	257	225	200	180	163	150
2.75	3273	1636	545	468	409	364	327	298	272	234	204	182	163	149	136
300	3000	1500	500	429	375	333	300	273	250	214	187	167	150	136	125

NOTE:See Table E-2 for formula used for calculation. For metric conversion factors refer to Table E-8.

Table E-4. Liters of Asphalt Required per 50 Linear Meters; Various Widths and Liters per Square Meter

Width—Meters

Liters per Sq. Meter	0.5	1.0	1.5	2.0	3.0	4.0	5.0	6.0	7.0
0.45	11.3	22.5	33.8	45.0	67.5	90.0	113	135	158
0.68	17.0	34.0	51.0	68.0	102	136	170	204	238
0.91	22.8	45.5	68.3	91.0	137	182	228	273	319
1.13	28.3	56.5	84.8	113	170	226	283	339	396
1.36	34.0	68.0	102	136	204	272	340	408	476
1.58	39.5	79.0	119	158	237	316	395	474	553
1.81	45.3	90.5	136	181	272	362	453	543	634
2.04	51.0	102	153	204	306	408	510	612	714
2.26	56.5	113	170	226	339	452	565	678	791
2.72	68.0	136	204	272	408	544	680	816	952
3.17	79.3	159	238	317	476	634	793	951	1110
3.62	90.5	181	272	362	543	724	905	1086	1267
4.07	102	204	305	407	611	814	1018	1224	1425
4.53	113	227	340	453	680	906	1133	1359	1586
5.66	142	283	425	666	849	1132	1415	1698	1981
6.79	170	340	509	679	1019	1358	1698	2037	2377
7.92	198	396	594	792	1188	1584	1980	2376	2772
9.06	226	453	679	906	1358	1810	2263	2715	3168

NOTE: Formula used for calculation: Q = 50 WR
Where:

Q = Quantity of asphalt required per 50 meters.
W = Width of application in meters.
R = Rate of application in liters per square meter.

Application rates for intermediate widths can be determined by adding columnar values or by use of above formula.

Table E-4a. Gallons of Emulsified Asphalt Required per 100 L.F.; Various Widths And Rates

Gals. per Sq. Yd.	Width—Feet														
1	2	6	7	8	9	10	11	11	12	14	16	18	20	22	24
0.10	1.1	2.2	6.7	7.8	8.9	10.0	11.1	12.2	13.3	15.6	17.8	20.0	22.2	24.4	26.7
0.15	1.7	3.3	10.0	11.7	13.3	15.0	16.7	18.3	20.0	23.3	26.7	30.0	33.3	36.7	40.0
0.20	2.2	4.4	13.3	15.6	17.8	20.0	22.2	24.4	26.7	31.1	35.6	40.0	44.4	48.9	53.3
0.25	2.3	5.6	16.7	19.4	22.2	25.0	27.8	30.6	33.3	38.9	44.4	50.0	55.6	61.1	66.7
0.30	3.3	6.7	20.0	23.3	26.7	30.0	33.3	36.7	40.0	46.7	53.3	60.0	66.7	73.3	80.0
0.35	3.9	7.8	23.3	27.2	31.1	35.0	38.9	42.8	46.7	54.4	62.2	70.0	77.8	85.5	93.3
0.40	4.4	8.9	26.7	31.1	35.6	40.0	44.4	48.9	53.3	62.2	71.1	80.0	88.9	97.8	107
0.45	5.0	10.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	70.0	80.0	90.0	100	110	120
0.50	5.6	11.1	33.3	38.9	44.4	50.0	55.5	61.1	66.7	77.8	88.9	100	111	122	133
0.55	6.1	12.2	36.7	42.8	48.9	55.0	61.1	67.2	73.3	85.5	97.8	110	122	134	147
0.60	6.7	13.3	40.0	46.7	53.3	60.0	66.7	73.3	80.0	93.3	107	120	133	147	160
0.65	7.2	14.4	43.3	50.6	57.8	65.0	72.2	79.4	86.7	101	115	130	144	159	173
0.70	7.8	15.6	46.7	54.4	62.2	70.0	77.8	85.5	93.3	109	124	140	156	171	187
0.75	8.3	16.7	50.0	58.3	66.7	75.0	83.3	91.7	100.	117	133	150	167	183	200
0.80	8.9	17.8	53.3	62.2	71.1	80.0	88.9	97.8	107.	124	142	160	178	196	213
0.85	9.4	18.9	56.7	66.7	75.5	85.0	94.4	104	113.	132	151	170	189	208	227
0.90	10.0	20.0	60.0	70.0	80.0	90.0	100	110	120.	140	160	180	200	220	240
0.95	10.6	21.1	63.3	73.9	84.4	95.0	106	116	127.	148	169	190	211	232	253
1.00	11.1	22.2	66.7	77.8	88.9	100	111	122	133.	156	178	200	222	244	267
1.10	12.2	24.4	73.3	85.5	97.8	110	122	134	147.	171	196	220	244	269	293
2.20	13.3	26.7	80.0	93.3	107	120	133	147	160.	187	213	240	267	293	320
1.25	13.9	27.8	93.3	97.2	111	125	139	153	167.	194	222	250	278	306	333
1.30	14.4	28.9	85.1	101	116	130	144	159	173.	202	230	260	288	318	347
1.40	15.6	31.1	93.3	109	124	140	156	171	187.	218	249	280	311	342	373
1.50	16.7	33.3	100	117	133	150	167	183	200.	233	267	300	333	367	400
2.75	19.4	38.9	117	136	156	175	194	214	230.	272	311	350	389	427	467
2.00	22.2	44.4	133	156	178	200	222	244	267.	311	356	400	444	489	533
2.25	25.0	50.0	150	175	200	225	250	275	300.	350	400	450	500	550	600
2.50	27.8	55.6	167	194	222	250	278	306	333.	389	444	500	556	611	667
2.15	30.6	61.1	183	214	244	275	306	336	367.	426	489	550	611	672	733
3.00	33.3	66.7	200	233	267	300	333	367	400.	467	533	600	667	733	800

Note: Formula used for calculation: $Q = \frac{100W}{9} - R = 11.11WR$

Where: Q = Quantity of asphalt required, in gallons per 100 ft.
R = Rate of application in gallons per sq. yd.
W = Width of application, in feet

Table E-5. Megagrams of Material Required per Kilometer for Various Widths and Kilograms per Square Meter

	Width—Meters											
kg/m²	1	2	3	4	5	6	7	8	9	10	15	20
5	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	75.0	100.0
10	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	150.0	200.0
20	20.0	40.0	60.0	80.0	100.0	120.0	140.0	160.0	180.0	200.0	300.0	400.0
30	30.0	60.0	90.0	120.0	150.0	180.0	210.0	240.0	270.0	300.0	450.0	600.0
40	40.0	80.0	120.0	160.0	200.0	240.0	280.0	320.0	360.0	400.0	600.0	800.0
50	50.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0	750.0	1000.0
60	60.0	120.0	180.0	240.0	300.0	360.0	420.0	480.0	540.0	600.0	900.0	1200.0
70	70.0	140.0	210.0	280.0	350.0	420.0	490.0	560.0	630.0	700.0	1050.0	1400.0
80	80.0	160.0	240.0	320.0	400.0	480.0	560.0	640.0	720.0	800.0	1200.0	1600.0
90	90.0	180.0	270.0	360.0	450.0	540.0	630.0	720.0	810.0	900.0	1350.0	1800.0
100	100.0	200.0	300.0	400.0	500.0	600.0	700.0	800.0	900.0	1000.0	1500.0	2000.0
200	200.0	400.0	600.0	800.0	1000.0	1400.0	1600.0	1800.0	2000.0	3000.0	3000.0	4000.0
300	300.0	600.0	900.0	1200.0	1500.0	1800.0	2100.0	2400.0	2700.0	3000.0	4500.0	6000.0
400	400.0	800.0	1200.0	1600.0	2000.0	2400.0	2800.0	3200.0	3600.0	4000.0	6000.0	8000.0
500	500.0	1000.0	1500.0	2000.0	2500.0	3000.0	3500.0	4000.0	4600.0	5000.0	7500.0	10000.0

NOTE: Formula used for calculation: M = RWL

where:
- M = Mass of material, megagrams per kilometer
- R = Rate of application, kg/m^2
- W = Width of application, meters
- L = Length of section, 1 kilometer

Table E-5a. Tons of Aggregate Required per Mile for Various Widths and Rates

	Spread Width (in Feet)						
Spread Rate lb/yd2	8 Tons Per Mile	9 Tons Per Mile	10 Tons Per Mile	12 Tons Per Mile	16 Tons Per Mile	18 Tons Per Mile	20 Tons Per Mile
5	12	13	15	18	23	26	29
10	23	26	29	35	47	53	59
15	35	40	44	53	70	79	88
20	47	53	59	70	94	106	117
25	59	66	73	88	117	132	147
30	70	79	88	108	141	158	176
35	82	92	103	123	164	185	205
40	94	106	117	141	188	211	235
45	106	119	132	158	211	238	264
50	117	132	147	176	235	264	293
60	141	158	176	211	282	317	352
75	176	198	220	264	352	396	440
100	235	264	293	352	469	528	587
150	352	396	440	528	704	792	880
200	469	528	587	704	939	1056	1173
250	587	660	733	880	1173	1320	1467
300	704	792	880	1056	1408	1584	1760

Table E-6. Quantities at Depths in Cylindrical Tanks in a Horizontal Position

Percent Depth Filled	Percent of Capacity	Percent Depth Filled	Percent of Capacity	Percent Depth Filled	Percent of Capacity	Percent Depth Filled	Percent of Capacity
1	0.20	26	20.73	51	51.27	76	81.50
2	0.50	27	21.86	52	52.55	77	82.60
3	0.90	28	23.00	53	53.81	78	83.68
4	1.34	29	24.07	54	55.08	79	84.74
5	1.87	30	25.31	55	56.34	80	85.77
6	2.45	31	26.48	56	57.60	81	86.77
7	3.07	32	27.66	57	58.86	82	87.76
8	3.74	33	28.84	58	60.11	83	88.73
9	4.45	34	30.03	59	61.36	84	89.68
10	5.20	35	31.19	60	62.61	85	90.60
11	5.98	36	32.44	61	63.86	86	91.50
12	6.80	37	33.66	62	65.10	87	92.36
13	7.64	38	34.90	63	66.34	88	93.20
14	8.50	39	36.14	64	67.56	89	94.02
15	9.40	40	37.39	65	68.81	90	94.80
16	10.32	41	38.64	66	69.97	91	95.55
17	11.27	42	39.89	67	71.16	92	96.26
18	12.24	43	41.14	68	72.34	93	96.93
19	13.23	44	42.40	69	73.52	94	97.55
20	14.23	45	43.66	70	74.69	95	98.13
21	15.26	46	44.92	71	75.93	96	98.66
22	16.32	47	46.19	72	77.00	97	99.10
23	17.40	48	47.45	73	78.14	98	99.50
24	18.50	49	48.73	74	79.27	99	99.80
25	19.61	50	50.00	75	80.39		

Table E-7. Area in Square Meters of Road Surface for Various Road Widths

Road Width	Per Lineal Meter	Per 50 m	Per Kilometer
2 m	2	100	2,000
2.5	2.5	125	2,500
3	3	150	3,000
3.5	3.5	175	3,500
4	4	200	4,000
4.5	4.5	225	4,500
5	5	250	5,000
5.5	5.5	275	5,500
6	6	300	6,000
6.5	6.5	325	6,500
7	7	350	7,000
7.5	7.5	375	7,500
8	8	400	8,000
8.5	8.5	425	8,500
9	9	450	9,000
9.5	9.5	475	9,500
10	10	500	10,000
10.5	10.5	525	10,500
11	11	550	11,000
11.5	11.5	575	11,500
12	12	600	12,000
15	15	750	15,000
20	20	1,000	20,000
25	25	1,250	25,000

Table E-7a. Area in Square Yards of Road Surface For Various Road Widths

Road Width	Per Lineal Foot	Per 100 ft	Per Mile
6 ft	0.67	66.67	3,520
7	0.78	77.78	4,107
8	0.89	88.89	4,693
9	1.00	100.00	5,280
10	1.11	111.11	5,867
11	1.22	122.22	6,453
12	1.33	133.33	7,040
13	1.44	144.44	7,627
14	1.56	155.56	8,213
15	1.67	166.77	8,800
16	1.78	177.78	9,387
17	1.89	188.89	9,973
18	2.00	200.00	10,560
20	2.22	222.22	11,733
22	2.44	244.44	12,907
24	2.67	266.67	14,080
25	2.78	277.78	14,667
26	2.89	288.89	15,253
28	3.11	311.11	16,427
30	3.33	333.33	17,600
32	3.56	355.56	18,773
34	3.78	377.78	19,947
36	4.00	400.00	21,120
38	4.22	422.22	22,293
40	4.44	444.44	23,467
50	5.56	555.56	29,333
60	6.67	666.67	35,200
70	7.78	777.78	41,067
75	8.33	833.33	44,000
80	8.89	888.89	46,933

Table E-8. Conversion Factors U.S. Customary To Metric Units

To convert from	To	Multiply by
acre	meter^2 (m^2)	4046.856
acre	hectometer^2 (hm^2)	0.404686
Atmosphere (technical = l kgf/cm^2)	kilopascal (kPa)	98.06650
barrel (42 gal.)	decimeter^3 (dm^3) or liter (l)	158.9873
BTU (International Table)	kilojoule (kJ)	1.055056
bushel	decimeter^3 (dm^3)	35.2391
dyne	micronewton (µN)	10.0000
dyne/centimeter^2	pascal (Pa)	0.1000
Fahrenheit (temperature)	Celsius (˚C)	$t_c = (t_f-32)/1.8$
foot	meter (m)	0.30480
foot^2	meter^2 (m^2)	0.092903
foot^3	meter^3 (m^3)	0.028317
	liter (l)	28.3170
foot-pound-force	joule (J)	1.355818
foot/minute	meter/second (m/s)	0.00508
foot/second^2	meter/second^2 (m/s^2)	0.30480
gallon (U.S. liquid)	decimeter^3 (dm^3) or liter (l)	3.785412
	meter^3 (m^3)	0.003785
gallon/minute	decimeter^3/second (dm^3/s) or liter/second (l/s)	0.06309
gallon/yard^2	decimeter^3/meter^2 (dm^3/m^2) or liter/meter^2 (l/m^2)	4.527314
horsepower (electric)	kilowatt (kW)	0.7460
inch	millimeter (mm)	25.4000
inch^2	centimeter^2 (cm^2)	6.45160
inch^2	millimeter^2 (mm^2)	645.1600
inch^3	centimeter^3 (cm^3)	16.38706
inch/second	meter/second (m/s)	0.02540
inch of mercury (60˚F)	pascal (Pa)	3376.85
inch/second^2	meter/second^2 (m/s^2)	0.02540
kilogram (kg)	ton (metric)	0.00100
kip (1000 lbf)	kilonewton (kN)	4.448222
kip/inch^2	megapascal (MPa)	6.894757
mile (U$ statute)	kilometer (km)	1.609344
wale^2	kilometer^2 (km^2)	2.589988
mile/hour	kilometer/hour (km/hr)	1.609344
minute (angle)	radian (rad)	0.00029089
ounce-force	newton (N)	0.2780139
ounce-mass	gram (g)	28.34952
ounce-fluid	centimeter^3 (cm^3)	29.57353
	liter (l)	0.029574

pint (U.S. liquid)	liter (l)	0.4731765
poise (absolute viscosity)	pascal-second (Pa-s)	0.100000
pound-force (lbf)	newton (N)	4.448222
	kilonewton (kN)	0.004448
pound-force-inch	newton-meter (N.m)	0.1129848
pound-force/foot^2	pascal (Pa)	47.88026
pound-force/inch^2 (psi)	kilopascal (kPa)	6.894757
pound-mass	kilogram (kg)	0.4535924
pound-mass/foot^2	kilogram/meter^7 (kg/m^2)	4.882428
	kilogram/meter^3 (kg/m^3)	16.01846
pound-mass/foot^3	megagram/meter^3 (Mg/ms)	0.016018
pound-mass/inch^3	kilogram/decimeter^3 (kg/dm^3)	27.67990
pound-mass/yard^2	kilogram/meter^2 (kg/m^2)	0.542492
pound-mass/yard^3	kilogram/meter^3 (kg/m^3)	0.593276
pound-mass/gallon (U.S. liquid)	kilogram/meter^3 (kg/m^3)	119.8264
	kilogram/meter^3 (kg/dm^3)	0.119826
psi	kilopascal (kPa)	6.894757
quart (U.S. liquid)	decimeter^3 (dm^3) or liter (l)	0.9463529
ton (metric)	kilogram (kg)	1000.0000
ton (short—2000 lb)	kilogram (kg)	907.1847
ton (long—2240 lb)	kIlogram (kg)	1016.0461
ton-mass/yard^3	kilogram/meter^3 (kg/m^3)	1186.5527
yard	meter (m)	0.91440
yard^2	meter^2 (m^2)	0.8361274
yard^3	meter^3 (m^3)	0.7645549

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