Materials Application Rates
For Dense-Graded
Asphalt Surface Treatments
Using High Float Emulsion

Prepared by:
Robert L. McHattie, P.E.
Inkworks
2324 Waterford Road
Fairbanks, AK 99709-5399

Prepared for:
Alaska Department of Transportation and Public Facilities
Research and Technology Transfer
2301 Peger Road
Fairbanks, AK 99709-5399

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**13. ABSTRACT (Maximum 200 words)**

Asphalt surface treatment (AST) pavements using high float emulsions and dense-graded aggregates have been used for more than 20 years in Alaska. However, the normally positive economics of these pavements have sometimes been offset by problems during or after construction.

The general intent of this report is to provide information that improves the constructability and long-term performance of high float pavements. Alaska DOT&PF engineers and contractors argued that most problems could be solved if a mix design method were devised to ensure compatibility between emulsion and aggregate and optimum application rates of emulsion and aggregate. This is the first documented attempt to pursue this goal by developing a high float mix design method for use in Alaska. This report presents an outline of the mix design method, an example application of the method and discusses reasons supporting each element of the mix design method.

The mix design method determines application rates of high float emulsion and dense-graded aggregate based on simple volumetric calculations. The method recommends development of new laboratory test methods for determining aggregate density and emulsion/aggregate bond. The method requires that 15 percent additional aggregate be added to the design amount determined through voids calculations. The additional aggregate is intended to aid compaction of an otherwise very thin layer of AST pavement (AST thickness usually less than 1 inch). Before brooming, the additional aggregate also protects the AST from direct traffic action while curing allows development of aggregate/asphalt bonding.

**14. KEY WORDS:**
- high float, emulsion, pavement, asphalt surface treatment, Alaska, dense-graded asphalt surface treatment, dense-graded AST
Preface

For more than 20 years, dense-graded high float emulsion surface treatments have often been selected by the Alaska Department of Transportation and Public Facilities (DOT&PF) as the preferred low-cost alternative for primary and maintenance paving in Alaska. Such pavements have been constructed using “recipes” that defined the relative amounts of aggregate and high float emulsion to be applied during construction. These standardized aggregate/emulsion applications sometimes produced poor performance. The results were, in short, unpredictable.

This report addresses the variables that control the asphalt emulsion and aggregate content of dense-graded high float emulsion asphalt surface treatments. The report also proposes a standardized method of “mix design” for the high float emulsion surface treatment.
### METRIC (SI*) CONVERSION FACTORS

#### APPROXIMATE CONVERSIONS TO SI UNITS

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<td>psi pound-force per square inch</td>
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<td>kPa kilopascals</td>
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**Note:** Volumes greater than 1000 L shall be shown in m³

#### APPROXIMATE CONVERSIONS FROM SI UNITS

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<th>To Find Symbol</th>
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<td>m³ meters cubed</td>
<td>1.308</td>
<td>cubic yards yd³</td>
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**Note:** These factors conform to the requirement of FHWA Order 5190.1A *SI is the symbol for the International System of Measurements

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- **TEMPERATURE (exact)**
  - °F Fahrenheit: 5/9 (°F-32)
  - °C Celsius: 9/5 °C+32

- **ILLUMINATION**
  - fc Foot-candles: 10.76 lux
  - fl foot-lamberts: 3.426 cd/m²

- **FORCE and PRESSURE or STRESS**
  - lbf pound-force: 4.45 newtons
  - psi pound-force per square inch: 6.89 kPa

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![Temperature and Illumination Chart](chart.png)

**Note:** The chart includes temperature and illumination values for Fahrenheit and Celsius scales, as well as foot-candles and foot-lamberts for illumination.
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1. Introduction

In Alaska DOT&PF terminology, so called “high float pavements” are a special form of asphalt surface treatment (AST) using dense-graded aggregate. High float AST pavements have been constructed in many areas of Alaska’s highway system. In Alaska, these pavements are constructed using an HFMS-2 or HFMS-2s anionic high float emulsion and well-graded (dense-graded), crushed aggregate similar to standard base course materials. Application rates of 0.75 gallon/yd$^2$ of high float emulsion and 75 pounds/yd$^2$ of aggregate became the standard prescription for most projects.

Under the best conditions, high float pavements are relatively inexpensive, easy to construct, and provide good service for roads with a low volume of traffic. However, like other forms of asphalt surface treatment, successful construction of high float pavements is particularly dependent on good weather and the proper application rates of asphalt and aggregate materials. Many areas of high float pavement apparently failed simply because they were constructed using too much or too little asphalt cement. Excess asphalt cement can migrate to the pavement surface (a condition known as “flushing,” or more commonly, “bleeding”) during warm weather, creating a slick, hazardous condition. Insufficient asphalt cement causes loss of paving aggregate, leading to raveling, potholing or, in some cases, large areas of total pavement loss.

In simplest terms, a high float emulsion AST is constructed by first applying a specified amount of high float emulsion to the surface of the base course using an asphalt distributor. The emulsion application is quickly followed by a specified amount of dense-graded aggregate that is applied with an aggregate spreader. In Alaska, high float emulsion and aggregate application rates became nearly standardized in general accord with those used by the Canadian transportation agency in the Yukon Territory. With minor variations, these application rates are used by DOT&PF designers at the time of this writing. DOT&PF Maintenance and Operations (M&O) personnel have experimentally deviated from application rates recommended by the designers, and some M&O managers have empirically developed application rate rules-of-thumb that deviate significantly from designer-recommended rates. DOT&PF has not developed a “best practice” for defining aggregate and emulsion application rates for this pavement type.

When determining correct application rates for a particular project, designers sometimes varied application rates above or below the rates normally used. Such variations were based on anecdotal reports, field observations, and/or contacts with asphalt paving technologists, although the performance results of such changes were mixed. Adjustment of application rates during the construction process (field adjustment) was commonly done but the practice has not always produced good results. The results of such adjustments are neither predictable nor reproducible. During construction there are few useful visual or otherwise obvious indicators that can be relied on for correctly adjusting application rates. Even worse, the result of a bad field adjustment (or lack of adjustment) is not necessarily immediately apparent, sometimes not for several years. For example, bleeding often begins years after construction, following several consecutive days of unusually warm weather.
2. Objectives and Methods

Objectives
High float pavements will be improved if a better method can be found to define the application rates of emulsion and aggregate before construction. High float pavement performance can be greatly improved if some form of rational “mix design” procedure can be developed. Such a procedure must account for aggregate compaction characteristics, asphalt/aggregate bonding, and perhaps other aggregate or emulsion-related variables as well. Hereafter, the writer uses the term “high float mix design” or simply “mix design” as referring to the rational proportioning of high float emulsion and aggregate for use in a high float AST. Hereafter, the term “high float design” or “design” refers to all aspects of the high float AST design, including the design of the entire AST pavement structure (pavement, base, subbase, etc.) as well as the mix design itself.

This study is aimed at developing a rational method for determining correct application rates of high float emulsion and dense-graded cover aggregate for specific emulsion and aggregate materials. The report in fact formulates a high float mix design methodology.

Research Methods
The writer examined:

1. Literature sources on the performance of asphalt surface treatments and the effects of emulsion/aggregate variables.

2. Literature sources on relationships between allowable asphalt content and aggregate voids.

3. Methods (including the McLeod method) for designing asphalt surface treatments.

4. Asphalt content data from high float AST samples collected from projects completed within DOT&PF’s Northern Region.

The writer also contacted individuals within government agencies and private business who were known to have first-hand knowledge of high float pavement technology.

3. Literature Research and Personal Contacts

All AST mix design methods identified in the literature search for this study target the use of non-graded, i.e., predominantly single-size, aggregate (chips). AST pavements using chips, often referred to as “chip jobs,” are the single-layer and double-layer ASTs fully described in Alaska’s Asphalt Surface Treatment Guide. The basics of AST mix design for chip jobs were worked out by about the late 1960s. AST (chip job) mix design work before 1968 is summarized in a report by Herrin and Marek. Billy Connor, an Alaska DOT&PF
researcher, reported on state-of-the-practice AST technology intended for Alaska applications in 1985.³ The chip job mix design in common use today was presented by Norman McLeod in 1969.⁴ *Alaska’s Asphalt Surface Treatment Guide* includes the McLeod method as an appendix. **Mix design methods identified in the literature do not work for dense-graded aggregates such as those used in Alaska’s high float ASTs.**

McConnaughay Inc. of West Lafayette, Indiana (phone 765-583-0498), provides franchise services including technical advice for Emulsion Products of Alaska, a principal supplier of high float emulsion in Alaska. Larry Ostermeyer, an expert on high float emulsion applications, has long represented McConnaughay Inc. on technical matters concerning high float ASTs in Alaska. During the course of this study, the writer contacted Ostermeyer to inquire whether mix design methods had been developed for dense-graded high float ASTs. Ostermeyer indicated he knew of no such documented mix design methods. In the past, Ostermeyer has recommended emulsion and aggregate application rates based on laboratory compaction studies (using project-specific aggregates) and simple volumetric calculations. He recommends that laboratory-determined application rates be adjusted during the paving process as required.

The Asphalt Institute (TAI) and the Asphalt Emulsion Manufacturers Association (AEMA) now include only very simplified guidelines for AST mix design in the third edition of their *Basic Asphalt Emulsion Manual.*⁵ Most highway agencies regard this manual as the standard reference for asphalt emulsion applications. The manual includes several mix design methods that address combinations of emulsion and dense-graded aggregate. Unfortunately though, these mix design methods are for plant mixes or road-mixed materials (involves a blending operation) and are not applicable to the high float AST’s simple “spread it-and-roll it” technology.

Canadian pavement researchers Martineau and Ferguson reported successful, routine placement of dense-graded high float ASTs more than 30 years ago in Saskatchewan.⁶ In the comments section of the paper, Martineau claimed a failure rate of less than 1 percent for high float ASTs. Furthermore, aggregate loss through brooming was claimed to be less than 5 percent after allowing a single day of curing time. The paper does not contain a mix design method.

A 1990 review of Canadian practice for AST pavements⁷ addressed the use of laboratory mix designs by the various provinces. The report indicated that all Canadian agencies that used chip-type ASTs also used laboratory mix designs for determining starting application rates for emulsion and aggregate. Field adjustments are allowed by project supervisory personnel as necessary. Most Canadian transportation agencies use a variation of the N.W. McLeod mix design method, as found in older manuals published by TAI. None of the Canadian transportation agencies employ a mix design method for ASTs using dense-graded aggregates. According to the report (see reference 7, page 8), most Canadian agencies that construct ASTs using high float emulsion and dense-graded aggregate feel that rule-of-thumb application rates work because “the procedure is a very forgiving one, which allows considerable latitude in rate variation.”
At the present time, Alaska closely patterns its specifications after Canadian specifications used by the Yukon Territorial Government, Highways and Public Works. Canadian high float AST experts Bruce Fulcher and Paul Knysh were contacted through the director of transportation engineering, Department of Highways and Public Works, Yukon, Canada (phone 867-633-7928). Fulcher and Knysh are considered to possess the highest level of expertise and experience with respect to the many miles of successful high float ASTs in the Yukon. Both have also provided much high float AST assistance to Alaska in the past. From these conversations, the writer confirmed that no AST mix design method is presently used for dense-graded high float pavements. During these discussions, two important points were made:

1. Yukon high float ASTs are constructed using aggregate sources with well known properties. Repetitive use of familiar aggregate sources has allowed Yukon engineers to develop emulsion/aggregate application rates, through trial and error, that work for those sources.
2. The Yukon uses an aggregate application rate that is much higher than Alaska’s rate for a given maximum aggregate particle size. Yukon aggregate applications typically exceed those used in Alaska by approximately 10 to 20 percent while the emulsion application rate is typically somewhat less. According to Fulcher, application rates favored in the Yukon at present are:
   - high float emulsion (containing ~ 65% residual asphalt) ------ 0.63 gal/yd^2
   - dense-graded, minus 0.75 inch aggregate --------------------------- 83 to 92 lbs/yd^2

4. The Time-Varying Nature of a High Float Pavement

Mix design application rates influence all aspects of high float construction and performance. However, in addition to the mix design itself, the quality of a high float AST depends on many other factors associated with construction methods, materials properties, weather, and time. To better understand the nature of the high float AST pavement as explained in this section, the reader must be aware of the construction specifications for this type of pavement. If you are unfamiliar with these specifications, please read them now — refer to the latest DOT&PF Northern Region high float pavement construction specifications provided as Appendix A of this report. The present form of the Appendix A specifications evolved, with almost constant minor changes, over about the last 10 years. They represent Alaska DOT&PF’s latest thinking on construction of high float pavements.

The final quality of a high float AST develops with time, and its ultimate performance characteristics, good or bad, may not become apparent for several years. The following process has been observed by the writer and others. Depending on the many variables involved, the course of the process may differ greatly. Consequently, high float AST pavements that seem similar during or shortly after construction may in time perform quite differently. Materials application rates are responsible for many of the ultimate performance differences. Construction methods, weather, and emulsion/aggregate bond development are also critical factors.
Each stage in the process is briefly described, followed by a commentary concerning potential problems associated with that stage. Notice that an asphalt content (residual asphalt cement derived from the high float emulsion) may be “correct” at one stage of the process and cause problems at another.

**Stage 1. Application of Materials**
The high float AST process begins with application of a prescribed amount of high float emulsion, followed by the prescribed amount of aggregate.

**Assumptions:** The materials are mutually compatible. Application rates of the two materials are appropriate, and required application rates are actually being delivered. Alaska’s application rates usually intended enough aggregate to produce a compacted layer thickness equivalent to the maximum aggregate particle size and approximately enough emulsion to fill the aggregate voids. There are also the general assumptions that material application practices and construction equipment meet specification requirements.

**Observed Problems:** Problems are usually not visually obvious at this stage of the process. Poor calibration of the emulsion distributor or aggregate spreader may result in too little or too much material being applied.

**Stage 2. Initial Densification by Rolling**
A series of roller passes increases the density of the cover aggregate while pressing it down and into the emulsion. Observations in Alaska indicate that essentially none of the AST aggregate particles are pressed into the top of the base course material during rolling.

**Assumptions:** The emulsion will rise uniformly within the aggregate mass and fill the available voids. With sufficient roller passes, the density of the dense-graded aggregate and emulsion composite material will increase to approach that of normal asphalt concrete \((\geq 140 \text{ lb/ft}^3\text{ bulk density})\). There is also the general assumption that compaction practices and equipment meet specifications.

**Observed Problems:** Depending on the “wetting” properties of the aggregate, the emulsion may not rise evenly as expected into the aggregate void structure. The limited thickness of the aggregate layer (aggregate is usually placed at a thickness equivalent to the largest aggregate particle size) can reduce compaction effectiveness. It is very possible that the rollers may “walk” on top of the large aggregate particles and leave the smaller particles in a state of compaction equivalent to a loose or rodded unit weight. This problem is exacerbated because the spreading process places many of the largest aggregate particles on top of smaller aggregate particles thus ensuring that the layer remains somewhat thicker than the size of the largest aggregate particle. Limited DOT&PF laboratory testing on typical high float aggregates have suggested dry unit weights of less than 120 lb/ft\(^3\) in the loose state and rodded dry unit weights in the range of 120 lb/ft\(^3\) to 127 lb/ft\(^3\). A lower than expected compacted density will leave higher than expected voids in the aggregate. The result is that it will appear the emulsion application is too low. Adding more emulsion to fill the voids in loose material will have detrimental effects later. On the other hand, if no additional emulsion is added, the top portion of fine aggregate is vulnerable to loss immediately after construction.
Stage 3. Action of Time, Temperature, and Traffic
After rolling, a time period passes where the newly constructed high float AST is allowed to compact under vehicular traffic. It is during this time that the high float emulsion cures and the aggregate particles are bonded together by residual asphalt cement.

Assumptions: The amount of residual asphalt cement remains constant after construction. Density of the aggregate mass will not greatly increase above that achieved during rolling. A strong bond will develop between the aggregate particles and the residual asphalt cement (residual asphalt cement available for bonding is roughly 65 to 70 percent, by weight, of the emulsion). A significant percentage of the originally applied aggregate will not be lost due to traffic action.

Observed Problems: Dirty aggregate particles or aggregate particles that were poorly compacted during rolling may remain unbonded, and some of the unbonded materials may be lost to traffic action. If, after aggregate loss, traffic manages to increase the density of the remaining AST materials significantly, bleeding may result. The potential for bleeding increases greatly if a significant amount of aggregate is lost (no place for the asphalt cement to go but the road surface). This problem is compounded if additional emulsion was added for reasons described in stage 2 and/or a period of hot weather occurs.

Stage 4. Brooming
Brooming of the AST surface removes nearly all aggregate particles that failed to become a well-bonded part of the AST pavement during stages 2 or 3. Brooming is considered necessary to minimize the chance of windshield breakage and to prepare the AST surface to receive painted traffic markings.

Assumptions: The amount of residual asphalt cement remains constant after construction. The process of bond development between the aggregate particles and the residual asphalt cement has developed to near maximum. Aggregate particles not bonded by the time brooming is done would remain unbonded and must therefore be removed (by brooming). Brooming does not remove critical amounts of aggregate. There is also the general assumption that brooming practices and equipment meet specifications.

Observed Problems: A significant percentage of aggregate is often lost during brooming. DOT&PF construction personnel report aggregate loss usually in the range of 20 to 30 percent. An unintended, unpredictable amount of aggregate loss means that all control has been lost over the asphalt content of the remaining AST pavement. Assuming that the application rates of emulsion and aggregate were intended to fill the voids with emulsion (true), and further assuming that the high float emulsion contains the usual 68 percent asphalt cement, a 30 percent aggregate loss means that remaining voids are nearly filled with asphalt cement. Additional compaction can cause bleeding. Section 6 of this report discusses the important concept of unintended aggregate loss.

Stage 5. Final Densification - Continued Action of Time, Temperature, Traffic
The densification process continues through the kneading action of vehicle tires. Given enough time and occasional periods of extremely warm weather, significant compaction can
occur. Observations indicate that essentially none of the AST aggregate particles are pressed into the top of the base course material during long-term densification.

Assumptions: The amount of residual asphalt cement remains constant after construction. Very little long-term densification will occur. Few elongated and tabular aggregate particles exist in the aggregate mass that will rotate to a flatter orientation. Observed Problems: Significant densification often occurs, especially in wheelpaths. Aggregate particles that are elongated or tabular (thin, elongated particles, per Alaska Test Method-306) will reorient through the action of traffic so that the smallest dimension is vertical. Bleeding often occurs in the wheelpaths. Bleeding (if it eventually occurs) may not happen until several years after construction following a period of extreme warm weather.

Based on the described process, mix design success requires that:

- Dependable application rates for emulsion/aggregate are achieved.
- Aggregate is completely wetted during initial compaction.
- A strong asphalt/aggregate bond develops before aggregate is lost through brooming or traffic.
- The expected level of initial AST densification must occur during rolling.
- Significant (unintended) quantities of aggregate are not lost to brooming or traffic.
- Significant densification of the AST does not occur after construction rolling.

Each item in the above list influences the mix design emulsion content greatly. Of the six items, wetting of the aggregate and bond development are probably the most difficult to ensure.

5. A Mix Design Approach

The objective is to define a combination of emulsion/aggregate materials that are volumetrically compatible. Volumetric compatibility means that an application rate of high float emulsion is selected such that available voids throughout the design aggregate thickness will be filled. The emulsion/aggregate combination must also bond compatibly, compact well during the construction process, and resist post-construction compaction.

The mix design method proposed here defines emulsion content using simple volumetric calculations and accounts for the moisture content of the aggregate prior to addition of the emulsion. The method addresses each of the requirements stated at the end of the previous section of this report, either specifically or by implication.

5.1. Mix Design Outline

Certain specifications are mentioned in the following outline to emphasize their importance and to make the reader aware that these specifications are critical to the mix design’s success (refer to Appendix A for Alaska DOT&PF specifications at the time of this publication).
1. Select a graded aggregate, and set specification requirements.
   1.1. Select maximum particle size.
   1.2. Test for asphalt/aggregate bond using project aggregate and a simple laboratory test method to determine acceptability of the aggregate. Develop a test method in which the aggregate moisture content is adjusted to that of the stockpile.
   1.3. Set specification requirements.
      Important inclusions in contract special provisions (see Appendix A) are
      • limitations on thin, elongated particles
      • limitations on minus #200 sieve size fraction
      • limitations on clay content
      • aggregate soundness and abrasion resistance standards

2. Determine the compacted density of aggregate.
   2.1. Requires laboratory compaction test. Develop a compaction test method using Superpave gyratory compaction equipment and moderate compactive effort. Increase moisture content of the aggregate to a saturated condition immediately before compaction (using water only).

3. Calculate aggregate application rate.
   3.1. Calculate the application rate required to produce a layer equivalent in thickness to the size of the largest aggregate particle at the density determined by laboratory test (item 2.1).
      Variables are the
      • compacted density of aggregate and the
      • required thickness.
   3.2. Add 15 percent extra aggregate to facilitate initial compaction and protect the AST layer during curing and asphalt/aggregate bond development. This extra material is intended to be sacrificial, i.e., it will be lost through traffic action or broomed away. Canada’s Yukon normally uses significantly more aggregate than is used in Alaska. The 15 percent suggested here is based on discussions (cited previously in this report) with Canadian engineers.
   3.3. Calculate total aggregate application rate in terms of lbs/yd$^2$.

4. Select an emulsion and set specifications (HFMS-2s).
   4.1. Include high float emulsion specifications in contract special provisions.

5. Calculate emulsion application rate based on available voids in the aggregate.
   5.1. Requires standard laboratory test for bulk specific gravity of aggregate.
   5.2. Calculate volume of voids available for emulsion using simple computations. Variables are:
      • compacted density of aggregate (determined by laboratory testing),
      • natural moisture content (will limit space available for emulsion fill, and
      • bulk specific gravity of aggregate.
   5.3. Calculate emulsion application rate in terms of gal/yd$^2$. 

8
6. Calculate percent residual asphalt cement by total weight of AST “mix.”
   Variables are:
   • specific gravity of emulsion,
   • specific gravity of emulsion’s residual asphalt cement, and
   • asphalt cement percent of emulsion (by weight).
6.1. Requires standard laboratory tests for specific gravity of emulsion, specific
   gravity of the residual asphalt cement, and weight percent of residual asphalt
   cement in the emulsion.

5.2. A Mix Design Example

Mix design input, including required test results:
   Maximum size aggregate = 0.75 inch
   Design thickness of AST = 0.75 inch
   Percent asphalt cement in emulsion = 68 percent
   Specific gravity of the emulsion = Sp.G.E = 1.02
   Specific gravity of residual asphalt cement = Sp.G.R = 1.05
   Bulk specific gravity of aggregate = Sp.G.A = 2.67 (from laboratory test)
   Dry Compacted density of aggregate = 130 lbs/ft³ (from laboratory test)
   Natural moisture content of aggregate in stockpile = 3 percent (from laboratory test)
   Test for asphalt/aggregate bond at stockpile moisture content (assume that this was
determined from laboratory test and found to be adequate)

Calculate aggregate application rate:
   For a thickness of 0.75 inch, a compacted aggregate density of 130 lbs/ft³ is equivalent to:

   \[ \text{aggregate dry density} \times 9 \frac{\text{ft}^2}{\text{yd}^2} \times \frac{\text{design AST thickness}}{12 \text{ in/ft}} \]

   \[ 130 \times 9 \times \frac{0.75}{12} = 73 \frac{\text{lbs}}{\text{yd}^2} \]

   Plus add 15% to aid compaction and curing: 73 + (0.15 x 73) = 84 lbs/yd²

Calculate emulsion application rate:
   Calculate total void space in a cubic foot of aggregate available to be filled with emulsion.
   Includes void space not occupied by natural moisture (at 3% natural moisture content):

   \[ \text{Volume occupied by solids} = \frac{\text{aggregate dry density}}{\text{Sp.G.A} \times \text{unit weight of water}} \]
\[ \frac{130}{2.67 \times 62.4} = 0.78 \text{ ft}^3/\text{ft}^3 \text{ of AST} \]

Volume occupied by natural moisture = \[ \frac{\text{aggregate dry density} \times \text{aggregate moisture } \%}{\text{unit weight of water}} = \]

\[ \frac{130 \times 3}{100 \times 62.4} = 0.063 \text{ ft}^3/\text{ft}^3 \text{ of AST} \]

Volume available for emulsion = 1 – (volume of solids + volume of natural water) =

\[ 1 - (0.78 + 0.063) = 0.157 \text{ ft}^3/\text{ft}^3 \text{ of AST} \]

Convert volume available for emulsion from (ft\(^3\)/ft\(^3\) of AST) to (gal/ft\(^3\) of AST) =

\[ (0.157 \text{ ft}^3/\text{ft}^3 \text{ of AST}) \times 7.48 \frac{\text{gal}}{\text{ft}^3} = 1.17 \text{ gal/ft}^3 \text{ of AST} \]

Convert from (gal/ft\(^3\) of AST) to gal/yd\(^2\) for an AST thickness of 0.75 inches =

\[ (1.17 \text{ gal/ft}^3 \text{ of AST}) \times 9 \frac{\text{ft}^2}{\text{yd}^2} \times \frac{\text{design AST thickness}}{12 \text{ in}/\text{ft}} = \]

\[ 1.17 \times 9 \times \frac{0.75}{12} = 0.66 \text{ gal/yd}^2 \]

The void spaces can hold no more emulsion than this.

**Calculate percent asphalt cement by total weight of AST “mix”:**
This calculation is based on the residual asphalt content of the AST.

**Definition:**

\[ \text{percent asphalt cement by total weight of AST "mix"} = 100 \times \frac{\text{weight of residual asphalt}}{\text{total weight}} \]

Volume of emulsion per cubic foot of AST = 0.157 ft\(^3\) (calculated previously)

Therefore, weight of residual asphalt cement per cubic foot of AST =
Note that the expression in brackets above, converts weight percent to volume percent.

Percent asphalt cement by total weight of AST mix =

\[
100 \times \frac{6.80 \text{ lbs per ft}^3 \text{ of AST}}{(\text{aggregate dry density} + 6.80 \text{ lbs per ft}^3 \text{ of AST})} =
\]

\[
100 \times \frac{6.80}{130 + 6.80} = 5.0\%
\]

The natural moisture content of the stockpiled aggregate can drastically limit the amount of void space available for emulsion. This of course controls the final asphalt content of the AST. In this mix design example, if the moisture content varies between 2 and 5 percent while other variables remain constant, the maximum attainable residual asphalt cement contents are:

- 2% moisture --------------------------------------- 5.6% asphalt cement (total weight)
- 3% moisture --------------------------------------- 5.0% asphalt cement
- 4% moisture --------------------------------------- 4.3% asphalt cement
- 5% moisture --------------------------------------- 3.7% asphalt cement

These calculations show that the high float mix design must compensate for aggregate moisture. Above about 3.5 percent moisture, the remaining aggregate voids simply cannot accommodate enough asphalt cement to ensure that the aggregate particles will remain bonded. This discussion emphasizes the importance of frequently monitoring the moisture content of an AST aggregate stockpile during construction. Run stockpile moisture tests at least daily. During rainy periods perform more frequent testing and/or the stockpile may have to be protected. Adjust the mix design amount of high float emulsion downward if the stockpile’s moisture content exceeds that assumed in the mix design.

The reader should do the calculations necessary to verify the following statement. Using the previous example and mix design calculations described above, it is easily shown that the emulsion application rate for a mix design that assumed 3 percent aggregate moisture content is almost 0.1 gal/yd\(^2\) too high for an aggregate that actually contains 4 percent moisture.
6. Significance of Unintended Aggregate Loss

The mix design process must define application rates for emulsion and aggregate that will minimize the amount of unintended aggregate loss. Unintended loss of aggregate means loss of voids that are, by volumetric computation, supposed to contain emulsion (and eventually residual asphalt cement). Loss of this aggregate means loss of control over the asphalt content of the remaining AST materials. If enough voids are lost, the remaining asphalt cement has no place to go except up, to the road surface. The result is bleeding.

It is a simple matter to estimate aggregate loss. You must know:
(1) original asphalt content (calculated from application rates of emulsion and aggregate),
and
(2) the final asphalt content (based on field sampling and laboratory determination of asphalt content).

Figure 1 quantifies the relationship between unintended aggregate loss and the increasing asphalt cement content of the remaining AST.

For example: Estimate the percent aggregate loss assuming an original asphalt content of 5 percent and a final asphalt content of 7 percent.
Solution: Extend a vertical line from an original asphalt content of 5 percent. Intersect this line with a horizontal extended from a final asphalt content of 7 percent. Find the percent aggregate loss at the intersection of the lines. In this case aggregate loss is about 30 percent.

Figure 1. High Float Aggregate Loss Estimate Chart
We will use Figure 1 to estimate unintended aggregate loss on nine actual sections of high float AST roadway. Results are presented in Table 1.

High float AST samples were cut from existing pavements within the DOT&PF Northern Region. The final asphalt content of each sample was determined in the laboratory using a burn-off oven technique (NCAT method). The approximate original asphalt content at all sampled locations is calculated based on known application rates of emulsion = 0.75 gal/yd$^2$ and aggregate = 75 lbs/yd$^2$. For this calculation it is assumed that: the HF emulsion contained 68 percent residual asphalt cement, the specific gravity of the emulsion was 1.02, the specific gravity of the residual asphalt cement was 1.05, and the original AST thickness was 0.75 inch.

**Calculate approximate original asphalt cement (ac) content (by total weight)**

Weight of residual asphalt in a cubic foot of high float AST =

\[
0.75 \text{ gal} / \text{yd}^2 \times \frac{12 \text{ in}}{0.75 \text{ in} \text{AST}} \times \frac{1 \text{ ft}^2}{9 \text{ yd}^2} \times \frac{\% \text{ residual ac in emulsion}}{100} \times \frac{\text{Sp.G.}_R}{\text{Sp.G.}_E} \times \gamma_w \frac{\text{lbs}}{\text{gal}} \times \text{AST of ft per lbs} =
\]

where: \( \gamma_w = \text{water density} = 62.4 \frac{\text{lbs}}{\text{ft}^3} \times \frac{1 \text{ ft}^3}{7.48 \text{ gal}} = 8.34 \frac{\text{lbs}}{\text{gal}} \)

then:

\[
0.75 \times \frac{12}{0.75} \times \frac{1}{9} \times \left[ \frac{68}{100} \frac{100}{1.05} \times \frac{1.05}{1.02} \right] \times 8.34 \times 1.05 = 7.7 \text{ lbs per ft}^3 \text{ of AST}
\]

Weight of aggregate in a cubic foot of high float AST =

\[
75 \frac{\text{lbs}}{\text{yd}^2} \times \frac{12 \text{ in}}{0.75 \text{ inch AST thickness}} \times \frac{1}{9} \frac{\text{yd}^2}{\text{ft}^2} =
\]

\[
75 \times \frac{12}{0.75} \times \frac{1}{9} = 133.3 \text{ lbs per ft}^3 \text{ of AST}
\]
Asphalt cement content (% by total weight) = 100 x \( \frac{7.7}{133.3 + 7.7} \) = 5.5%

Using Figure 1, percent aggregate loss for sampled high float AST pavements is estimated in Table 1.

**Table 1. Percent aggregate loss for sampled high float AST pavements, estimated using Figure 1**

<table>
<thead>
<tr>
<th>Location Identification</th>
<th>Original Asphalt Content</th>
<th>Final Asphalt Content</th>
<th>Estimate Percent Aggregate Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taylor Highway</td>
<td>5.5%</td>
<td>8.5%</td>
<td>38%</td>
</tr>
<tr>
<td>Taylor Highway, MP 23-44, M.P. 34</td>
<td>5.5%</td>
<td>7.8%</td>
<td>32%</td>
</tr>
<tr>
<td>Taylor Highway, MP 23-45</td>
<td>5.5%</td>
<td>7.1%</td>
<td>25%</td>
</tr>
<tr>
<td>Elliott Highway, Eureka-Baker Creek</td>
<td>5.5%</td>
<td>10.6%</td>
<td>50%</td>
</tr>
<tr>
<td>Elliott Highway, MP 123</td>
<td>5.5%</td>
<td>6.8%</td>
<td>21%</td>
</tr>
<tr>
<td>Dalton Highway, Mile 111-144, Southbound WP</td>
<td>5.5%</td>
<td>9.2%</td>
<td>44%</td>
</tr>
<tr>
<td>Dalton Highway, MP 105</td>
<td>5.5%</td>
<td>5.6%</td>
<td>0%</td>
</tr>
<tr>
<td>Tofty Road, Shoulder &amp; Wheelpath</td>
<td>5.5%</td>
<td>7.0%</td>
<td>24%</td>
</tr>
<tr>
<td>Minto Road</td>
<td>5.5%</td>
<td>10.2%</td>
<td>49%</td>
</tr>
</tbody>
</table>

Table 1 suggests that a large aggregate loss may be normal for Alaska’s high float ASTs. Hot mix asphalt concrete pavements containing asphalt contents as high as most of those shown in the table (see final asphalt content column) would almost certainly bleed during hot weather. This is undesirable!

How does the mix design method presented in this report prevent unintended aggregate loss? In the writer’s opinion, the trick is to:

1. Define the application rate of aggregate so that the compacted aggregate thickness is about equivalent to the largest particle size. This is the design aggregate thickness.
2. Define an emulsion application rate such that essentially all the available voids in the design aggregate thickness are filled.
3. The writer contends that a layer of aggregate no thicker than the largest particle size is not readily compactable. Therefore, add enough extra aggregate thickness to facilitate compaction of the design aggregate thickness. The mix design method discussed in this report assumes that 15 percent of additional aggregate is used. The design method
assumes that some or all of the extra 15 percent aggregate will be lost, i.e., sacrificed as an aid to compaction and curing.

7. Conclusions

The general intent of this report is to provide information that improves the constructability and long-term performance of high float pavements. The normally positive economics of these pavements have sometimes been offset by problems during or after construction. Alaska DOT&PF engineers and contractors argued that most problems could be solved if a mix design method could be devised that would ensure emulsion/aggregate compatibility and ensure that the application rates of emulsion and aggregate are optimum. This is the first documented attempt to develop a high float mix design method for use in Alaska. The mix design method presented in this report determines application rates of high float emulsion and dense-graded aggregate based on simple volumetric calculations. In the method, voids available for filling with emulsion are calculated based on the aggregate’s compacted density and bulk specific gravity. The available voids are then decreased to account for the moisture content of the aggregate (assumed moisture during construction). Based on information gained from field observations and various information sources, the method requires development of new laboratory tests for determining aggregate density and emulsion/aggregate bond.

Prior practice and the mix design method presented in this report specified an aggregate spread rate that produces an AST layer thickness no greater than the maximum aggregate particle size. The writer contends that such a thin layer cannot be compacted well. Therefore, based on field observations and Canadian information sources, the mix design method presented here requires that 15 percent additional aggregate be added to the design amount. The additional aggregate is expected to aid compaction of an otherwise very thin layer of AST pavement. Before brooming, the additional aggregate also protects a new AST from direct traffic action while the emulsion cures, allowing the aggregate and the residual asphalt cement to bind together.

8. Recommendations for Implementation & Further Research

Implementation
This report is the first step in developing a high float emulsion AST mix design. The method may require certain basic changes and will certainly require verification and calibration in the field. However, the report presents concepts, data, and computational methods that can be of immediate value to anyone involved in the design or construction of high float ASTs.

The writer recommends that this report be distributed to design and construction sections of the Alaska DOT&PF in regions where high float emulsion ASTs are constructed. A useful seminar-type presentation of the report’s general concepts could be made in about 30 to 45
minutes. During seminar presentations, exhibit samples of high float emulsion, typical dense-graded high float aggregate, and small samples of high float AST pavement. Seminar presentations should also include photos that show the various stages of AST construction, as well as final performance successes and failures.

As part of the implementation process, the specification presented as Appendix A needs at least two modifications:

1) The materials application rates indicated in the specification (Pre HFST Design Estimating Factor) will be replaced by estimated application rates defined by the mix design.

2) Include minimum temperature requirements for the high float emulsion at the time of application. This specification would be included in Section 405-3.05 APPLYING HIGH FLOAT ASPHALT EMULSION MATERIAL. Recommended wording is: Application temperature of asphalt material shall be 150°-180°F. A similar temperature requirement was included in all except the most recent version of the Alaska DOT&PF high float pavement specification. The writer considers emulsion temperature monitoring to be a necessary tool to help ensure that the aggregate will be properly wetted by the emulsion during initial compaction. Cooler emulsions are more viscous, and flow characteristics necessary for permeating aggregate pour spaces therefore will be reduced.

Further Research
Two new laboratory test methods are required to perform the mix design as it is discussed in this report:

1) Develop a simple test for asphalt/aggregate bond using project aggregate. This test will determine basic acceptability of the emulsion/aggregate combination. Immediately prior to testing, the aggregate moisture content must be adjusted to that of the stockpile.

2) Develop a compaction test method using Superpave gyratory compaction equipment and moderate compactive effort. Increase moisture content of the aggregate to a saturated condition immediately prior to compaction (using water only).

The mix design method requires field verification and calibration—and probably modification. After developing the two laboratory test methods mentioned previously, one or more high float AST projects should be constructed using materials application rates determined using the mix design method presented in this report. Required data collection:

- As-built materials application rates for areas to be sampled
- As-built aggregate gradations for areas to be sampled
- Aggregate stockpile moisture contents during construction
- Record field adjustments to mix design and reasons for making adjustments
- Measure/estimate percent of aggregate broomed from roadway
- Core sampling from several wheelpath and non-wheelpath areas
  - immediately post brooming
  - 1 year after construction
• 3 years after construction
  (photograph and describe AST condition at the time of each sampling)
• Laboratory determinations for all samples
  • nominal AST thickness
  • residual asphalt cement content
  • aggregate gradation
• Collect similar data from non-mix designed high float ASTs to the extent possible.

Quantify changes with time with respect to: continuing aggregate loss, gradation, asphalt content (by total weight of asphalt concrete), thickness, surface condition. Determine whether the mix designed AST has performed acceptably or not. Compare performance of mix designed high float ASTs with non-mix-designed high float ASTs. Modify: the mix design method, new laboratory tests or specifications according to research findings as necessary.
Appendix A

High Float AST
Specification Special Provisions
for
Cantwell Gravel Roads Project, 2005

Prepared By

Alaska Department of Transportation
& Public Facilities, Northern Region
Design Section

(The reader should be aware that minor changes to this specification, including test number designations, may have been made since this publication)
Delete Section 405 in its entirety and substitute the following:

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

405-2.02 AGGREGATES. Use aggregates for cover coat material (cover aggregate) that meet the requirements of Subsection 703-2.05 and Table 703-5HF, Cover Aggregate for High Float Surface Treatment, Grading B, except that the following quality requirements shall apply:

- Percent of Wear: AASHTO T 96
- Degradation Value: ATM T-13
- Percent Fracture: WAQTC TM-1
- Sodium Sulfate Soundness: AASHTO T 104
- Thin - Elongated Pieces: ATM T-9
- Plasticity Index*: AASHTO T 90

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

The test sampling location(s) will be determined by the Engineer, before crushing operations begin. Cover the cover coat material stockpiles 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.

405-2.03 SURFACE TREATMENT BLOTTER MATERIAL. Use suitable clean sand as blotter material. Unless otherwise required by the Engineer, use blotter sand that passes the No. 10 sieve, and has no more than 0.5% material passing the No. 200 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, submit a representative 70-pound sample of the cover aggregate and a one gallon 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 aggregate gradation, source of cover aggregate, or high float emulsion supplier require submittal of new samples in the same manner as the original submittals.

405-2.05 COMPOSITION OF SURFACE TREATMENT. The Engineer will determine the initial application rates of asphalt and cover aggregate materials per Subsection 405-2.04. The Engineer may adjust application rates as required by field conditions or changed materials.
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.

<table>
<thead>
<tr>
<th>Material</th>
<th>Pre HFST Design Estimating Factor (per sq. yd)</th>
<th>Specified Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover Gradation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grading B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grading C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grading D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HFMS-2s Asphalt</td>
<td>0.75 gal</td>
<td>± 0.04 gal per sq. yd</td>
</tr>
<tr>
<td>Cover Aggregate</td>
<td>75 LB</td>
<td>± 3 lb per sq. yd</td>
</tr>
</tbody>
</table>

**CONSTRUCTION REQUIREMENTS**

405-3.01 **GENERAL.**
1. Longitudinal joints are allowed only at the centerline.

2. Perform the work in such a manner that asphalt and cover aggregate applications are completed full width by the end of each shift.

405-3.02 **WEATHER LIMITATIONS.**
1. Apply HFST only when the ambient air temperature is 50°F or above as measured in the shade away from any heat source.

2. Do not apply HFST 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. Apply HFST only when weather conditions allow for proper construction of the HFST and adequate curing time likely is prior to predicted inclement weather or freeze-up. Do not apply HFST before June 1st or after August 1st.

405-3.03 **EQUIPMENT.**
1. Distributor.

Use distributors that are designed, equipped, maintained and operated such that asphalt material, at even heat, may be applied uniformly on variable widths of surface up to half the roadway width plus 6 inches, at the specified rate, from 0.4 to 0.8 gallons per square yard, 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 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 of the same manufacture, type and size.
• The spray bar height set to provide triple overlap of the asphalt emulsion being applied by the spray nozzles.

Before the application of asphalt, 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 prior to the commencement of the operation. Perform any adjustments, maintenance and other requirements prior to use.
• Calibrate the distributor in accordance with the manufacturer’s recommendations. The Engineer may require the Contractor to prove the accuracy of the distributor prior to commencing the asphalt application and any time thereafter if deemed necessary by the Engineer. Any change in settings on the distributor after calibrating requires 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, immediately cease application of the asphalt material. Do not 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.**

Use an aggregate spreader that is capable of evenly applying cover aggregate material to the specified roadway width in a maximum of two passes. The aggregate spreader used must 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 in the various hoppers.

Stopping the aggregate spreader to refill the receiving hopper is permitted provided that the spreader is backed up at least 20 feet from the last cover aggregate application. It is permitted to slow down the aggregate spreader to allow trucks to backup 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. Operate the forward speed of the aggregate spreader during calibration at 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, equipped with not less than nine tires staggered back and front, inflated to 60 psi. Establish equal pressure in each tire, and equip each roller with a suitable tire pressure gauge for checking tire inflation pressure.

405-3.04 PREPARATION OF SURFACE.

1. Apply HFST only to fully shaped and compacted grade that has been approved by the Engineer prior to application of HFST. Apply HFST 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. Roll the surface with a steel wheeled soil compactor immediately prior to application of asphalt materials. Do not leave windrows of materials that may impede drainage on or adjacent to the surface treatment area.

2. Apply HFST only when the prepared surface is damp. Prior to the asphalt application, the Engineer may require dampening the surface by applying a fine spray of water to the prepared surface. Do not apply HFST 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 must not exceed that which trucks loaded with cover aggregate can immediately cover.

2. Perform the first pass over the segment of roadway being surfaced, following a string line, set either on the shoulder or on the centerline, whichever is on the driver’s side of the distributor. Perform the second pass with the centerline joint on the driver’s side of the distributor.

3. Do not allow any equipment or vehicles on the sprayed asphalt surface at any time prior to cover aggregate application.

4. Do not allow the spread of asphalt material to be more than 6 inches wider than the width covered by the cover aggregate from the spreader. Do not, under any circumstance, perform HFST operations in such a manner that asphalt material chills, sets up, dries, or otherwise impairs retention of the cover aggregate.

5. When not spreading, park the distributor such that the spray bar or mechanism will not drip asphalt material onto the surface of the roadway.

Correct any skipped areas or deficiencies. Make junctions of spreads carefully to prevent an excess of asphalt material.
405-3.06 APPLICATION OF COVER AGGREGATE MATERIAL.

1. Use cover aggregate that has a temperature of no less than 40°F and a 2%-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. Apply cover aggregate within 1.5 minutes after application of the asphalt material or as directed by the Engineer. Keep the increment as constant as possible, but adjust it within the limit as needed to meet changing conditions. Whenever it is apparent that the time limit will be exceeded, make a transverse joint by placing construction paper (roofing felt or similar product) on the prepared surface and end the HFST operations on the paper. Remove the paper and properly dispose of it and touch up the edges of the applied HFST prior to restarting HFST operations.

3. Immediately after cover aggregate is spread, cover deficient areas with additional material. Roll the full width of the aggregate with pneumatic tire rollers immediately after placement of cover aggregate and continue rolling until at least six complete coverage's are obtained or until cover aggregate is bound tightly to the satisfaction of the Engineer. Complete the rolling operation within 500 feet of the cover aggregate application. If the rolling cannot be completed within this distance, slow the high float application operation. Do not allow pneumatic tire roller speed to exceed 5 miles per hour. Maintain a spare pneumatic tired roller on the project during high float application, in addition to those rollers necessary to accomplish this specification.

4. Accomplish spreading such a manner 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. Sweep between one and two weeks following the application of cover coat material or as directed by the Engineer. Prior to sweeping, remove ridges of loose aggregate created by traffic 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. Apply blotter material as directed by the Engineer and immediately roll it with a pneumatic-tired roller (as described above) with tire pressures adjusted to 90-100 psi.

405-3.08 TRAFFIC CONTROL. Do not operate construction equipment at speeds exceeding 15 per hour on a freshly applied surface treatment, for a period of up to 24 hours, or 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 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. Control traffic on the HFST by pilot cars to a speed not exceeding 15 miles per hour for a period of 12 hours, or 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. Sweeping and/or blading of excess cover aggregate 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 yard for cover aggregate material, complete in place. Payment will be made under:

<table>
<thead>
<tr>
<th>Pay Item</th>
<th>Pay Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>405(1) HFMS-2s Asphalt for Surface Treatment</td>
<td>Ton</td>
</tr>
<tr>
<td>405(3) Aggregate for Surface Treatment, Grading B</td>
<td>Square Yard</td>
</tr>
</tbody>
</table>
SECTION 702

ASPHALT MATERIALS

702-2.04 STORAGE AND APPLICATION TEMPERATURES. Add the following to Table 702-1:

<table>
<thead>
<tr>
<th>Type and Grade of Material</th>
<th>Spray °F</th>
<th>Mix °F</th>
<th>Storage °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFMS-2s</td>
<td>150-180</td>
<td></td>
<td>125-185</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Percent by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grading B</td>
</tr>
<tr>
<td>1 in.</td>
<td>100</td>
</tr>
<tr>
<td>3/4 in.</td>
<td>75-95</td>
</tr>
<tr>
<td>5/8 in.</td>
<td>-</td>
</tr>
<tr>
<td>1/2 in.</td>
<td>-</td>
</tr>
<tr>
<td>3/8 in.</td>
<td>50-80</td>
</tr>
<tr>
<td>No. 4</td>
<td>35-65</td>
</tr>
<tr>
<td>No. 8</td>
<td>20-50</td>
</tr>
<tr>
<td>No. 16</td>
<td>-</td>
</tr>
<tr>
<td>No. 40</td>
<td>8-30</td>
</tr>
<tr>
<td>No. 50</td>
<td>-</td>
</tr>
<tr>
<td>No. 200</td>
<td>0-5</td>
</tr>
<tr>
<td>0.005 mm</td>
<td>0-3*</td>
</tr>
</tbody>
</table>

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.
References


