DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

JUN 5 2001

FROM: HQ AFCESA/CESC
139 Barnes Drive
Tyndall AFB FL 32403-5319

SUBJECT: **Engineering Technical Letter (ETL) 01-7: Large Aggregate Asphalt Mixtures**

1. Purpose. This ETL provides mix design guidance and a construction specification for large aggregate asphalt mixtures to construct heavy-duty Air Force pavements (equivalent design for 75-blow Marshall mix design applications).

2. Application. This ETL is applicable to all Air Force facilities with pavement construction responsibility.

2.1. Authority: Unified Facilities Criteria (UFC) 3-260-02, *Pavement Design for Airfields*.

2.2. Coordination: Major command (MAJCOM) pavement engineers.

2.3. Effective Date: Immediately.

2.4. Ultimate Recipients:

- Base civil engineers responsible for design, construction, maintenance, and repair of pavements.
- U.S. Army Corps of Engineers (COE) and Navy offices responsible for design and construction of Air Force pavements.

3. Referenced Publications.

3.1. Air Force:

- UFC 3-260-02, *Pavement Design for Airfields*
- UFC 3-250-03, *Standard Practice Manual for Flexible Pavements*

3.2. Asphalt Institute (AI):

- Manual Series No. 2 (MS2), *Mix Design Methods for Asphalt Concrete Hot-Mix Types*
- Superpave Series No. 2 (SP2), *Superpave Level 1 Mix Design*

3.3. National Asphalt Pavement Association (NAPA):

- NAPA Education Foundation, *Hot Mix Asphalt Materials, Mixture Design and Construction*

3.4. U.S. Army COE:

- COE CRD-C 649-95, *Standard Test Method for Unit Weight, Marshall Stability, and Flow of Bituminous Paving Mixtures*
- COE CRD-C 650-95, *Standard Test Method for Density and Percent Voids in Compacted Bituminous Paving Mixtures*
- COE CRD-C 651-95, *Standard Gyratory Testing Machine Method for Design of Hot-Mix Bituminous Pavement Mixtures*
- COE CRD-C 71, *Test for Ultimate Tensile Strain Capacity of Concrete*

3.5. American Society for Testing and Materials (ASTM):

- ASTM C 29/C 29M, *Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate*
- ASTM C 88, *Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate*
- ASTM C 136, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*
- ASTM C 117, *Standard Test Methods for Materials Finer than 75-mm (No. 200) Sieve in Mineral Aggregates by Washing*
- ASTM C 127, *Standard Test Method for Specific Gravity and Absorption of Fine Aggregate*
- ASTM C 128, *Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate*
- ASTM C 131, *Standard Test Method for Resistance to Degradation of Small-size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine*
- ASTM C 183, *Standard Practice for Sampling and the Amount of Testing of Hydraulic Cement*
- ASTM C 566, *Standard Test Method for Total Moisture Content of Aggregate by Drying*
- ASTM C 1252, *Standard Test Methods for Uncompacted Void Content of Fine Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading)*
- ASTM D 75, *Practice for Sampling Aggregates*
- ASTM D 140, *Standard Practice for Bituminous Materials*
- ASTM D 242, *Mineral Filler for Bituminous Paving Mixtures*
- ASTM D 946, *Standard Specification for Penetration-graded Asphalt Cement for Use in Pavement Construction*
- ASTM D 995, *Mixing Plants for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures*
- ASTM D 1461, *Standard Test Method for Moisture or Volatile Distillates in Bituminous Paving Mixtures*
- ASTM D 1559, *Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus*
- ASTM D 2041, *Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures*

- ASTM D 2172, *Standard Test Method for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures*
- ASTM D 2419, *Sand Equivalent Value of Soils and Fine Aggregate*
- ASTM D 2489, *Standard Practice for Estimating Degree of Particle Coating of Bituminous Aggregate Mixtures*
- ASTM D 2726, *Standard Test Method for Bulk Specific Gravity and Density of Non-absorptive Compacted Bituminous Mixtures*
- ASTM D 2950, *Density of Bituminous Concrete in Place by Nuclear Method*
- ASTM D 3203, *Standard Test Method for Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures*
- ASTM D 3381, *Standard Specification for Viscosity-graded Asphalt Cement for Use in Pavement Construction*
- ASTM D 3387, *Compaction and Shear Properties of Bituminous Mixtures by Means of the U.S. Army Corps of Engineers Gyratory Testing Machine (GTM)*
- ASTM D 3665, *Practice for Random Sampling of Construction Materials*
- ASTM D 3666, *Standard Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials*
- ASTM D 4125, *Standard Test Methods for Asphalt Content of Bituminous Mixtures by the Nuclear Method*
- ASTM D 4318, *Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*
- ASTM D 4791, *Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate*
- ASTM D 4867/D 4867M, *Standard Test Method for Effect of Moisture on Asphalt Concrete Paving Mixtures*
- ASTM D 5444, *Standard Test Method for Mechanical Size Analysis of Extracted Aggregate*
- ASTM D 5581, *Standard Test Method for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus (6-Inch Diameter Specimen)*
- ASTM D 6307*, Standard Test Method for Asphalt Content of Hot-Mix Asphalt by Ignition Method*

3.6. American Association of State Highway and Transportation Officials (AASHTO):

- AASHTO MP1, *Performance-Graded Asphalt Binder.*

4. Acronyms and Terms:

AASHTO - American Association of State Highway and Transportation Officials
AI - Asphalt Institute
AMRL - AASHTO Materials Reference Laboratory
ASTM - American Society of Testing and Materials
C - Celsius
COE - Corps of Engineers
ETL - Engineering Technical Letter
F - Fahrenheit

FOD	- foreign object damage
GSI	- gyratory stability index
GTM	- gyratory testing machine
in	- inch
JMF	- job mix formula
kg	- kilogram
kN	- kilonewton
lb	- pound force
MAJCOM	- major command
mm	- millimeter
MPa	- megapascal
MS2	- AI Manual Series No. 2
psi	- pound per square inch
QA	- quality assurance
QC	- quality control
SHRP	- Strategic Highway Research Program
SP2	- AI Superpave Series No. 2
TSR	- tensile strength ratio
UFC	- Unified Facilities Criteria
wpf	- weighted pay factor

5. Background.

5.1. In recent years, premature rutting has occurred in many asphalt concrete pavements. Rutting is defined as a permanent deflection of the pavement surface that develops in the wheel paths under channelized traffic due to deformation in the top 76 to 101 millimeters (3 to 4 inches) of the asphalt concrete. The increase in rutting has been primarily caused by heavier wheel loads and higher tire pressures.

5.2. The performance of asphalt concrete mixtures is greatly influenced by properties of the aggregate blend. The aggregate properties that significantly influence the performance of asphalt mixtures are size, shape, and gradation. Past performance of heavy-duty highway pavements illustrates that large aggregate asphalt mixtures (38 millimeters [1.5 inches] maximum aggregate size) in the intermediate and binder courses can minimize or eliminate rutting in heavy-duty asphalt pavements. The primary benefits of using large aggregate asphalt mixtures are as follows:

- Resistant to heavy loads.
- Resistant to high tire pressures.
- Requires less crushing to produce aggregates.
- Lower asphalt content.
- Reduced cost.

6. Applications. Large aggregate asphalt mixtures may be used for intermediate and binder courses in any flexible pavement structure. A surfacing material should be placed over the large aggregate asphalt mixture to prevent raveling and foreign object damage (FOD) potential. The type of surfacing will be site specific and determined by the function of the pavement and the type of traffic. A high-quality dense-graded asphalt mixture (19 millimeters [0.75 inch] maximum aggregate size) should be used to surface airfield pavements (i.e., runways, taxiways, and aprons). All other heavy-duty pavements not affected by FOD potential may use other surfacing techniques like microsurfacing, slurry seal, or chip seal to surface the large aggregate asphalt mixture.

7. Mix Design.

7.1. The Marshall mix design procedure is recommended for Air Force paving projects (UFC 3-260-02 and UFC 3-250-03, *Standard Practice Manual for Flexible Pavements*). This design procedure uses compaction molds 101 millimeters in diameter that limits the maximum aggregate size to 25 millimeters (1 inch). To conduct laboratory mix designs and quality control (QC) tests for large aggregate asphalt mixtures, specimens 152 millimeters (6 inches) in diameter are required to determine the optimum asphalt content and job mix formula (JMF).

7.2. The primary modifications to current conventional asphalt mix design procedure are compaction equipment and compactive effort. Large aggregate asphalt mixtures require a larger volume of compacted material, which requires a greater compactive effort. A JMF for large aggregate asphalt mixtures can be determined using procedures outlined in UFC 3-260-02 and UFC 3-250-03, or AI MS2, *Mix Design Methods for Asphalt Concrete Hot-Mix Types*, with one of the following compaction techniques:

7.2.1. ASTM D 5581, *Standard Test Method for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus (6-Inch Diameter Specimen)* – 152-millimeter (6-inch) mechanical hammer.

7.2.2. ASTM D 3387 *Compaction and Shear Properties of Bituminous Mixtures by Means of the U.S. Army Corps of Engineers Gyratory Testing Machine (GTM)* – 152-millimeter COE GTM.

7.2.3. AI SP2, *Superpave Level 1 Mix Design* – 152-millimeter Strategic Highway Research Program (SHRP) gyratory compactor.

7.3. Guidance for each compaction procedure is summarized in Attachment 1. Recommended material requirements and mixture properties are presented in Attachment 2.

8. Construction. Production and placement techniques of large aggregate asphalt mixtures are very similar to conventional dense-graded asphalt mixtures; however, careful attention is needed in several areas to ensure a uniform, smooth, high-quality asphalt pavement.

8.1. Good aggregate stockpile practices and uniform gradations are required.

8.2. Storage of large aggregate asphalt mixtures in surge bins or silos may produce a segregated mix.

8.3. Plant mixing time may need to be increased to ensure adequate particle coating.

8.4. Coarse aggregate particles tend to accumulate in paver hopper wings and should be discarded.

8.5. The paver hopper and area in front of the screed should remain full of large aggregate asphalt mixture throughout the day's placement to decrease the possibility of segregation.

8.6. Paver speed should be at the rate that matches uninterrupted plant production; slow speed improves surface texture and reduces segregation.

8.7. Compaction equipment and rolling patterns should be evaluated and adequate field compaction verified in a test section.

9. Contact: Recommendations for improvements to this ETL are encouraged and should be furnished to: HQ AFCESA/CESC, 139 Barnes Drive, Suite 1, Tyndall AFB, FL 32408-5319, Attention: Mr Jim Greene, DSN 523-6334, commercial (850) 283-6334, FAX DSN 523-6219, Internet james.greene@tyndall.af.mil.

Michael J. Cook, Colonel, USAF
Director of Technical Support

3 Atchs
1. Mix Design Guidance for Large Aggregate Asphalt Mixtures
2. Large Aggregate Asphalt Mixture Guide Specification for Heavy-Duty Pavements
3. Distribution List

MIX DESIGN GUIDANCE FOR LARGE AGGREGATE ASPHALT MIXTURES

A1.1. Laboratory tests are conducted on laboratory-compacted samples with densities equal to densities anticipated in the in-place asphalt concrete after being subjected to traffic. A final selection of aggregate blend and asphalt content will be based on these data with due consideration to relative costs of the various mixes. The procedures set forth in this attachment are directly applicable to all mixes containing large aggregate with a 38-millimeter maximum aggregate size. The JMF for large aggregate asphalt mixtures should be determined using procedures outlined in UFC 3-260-02 and UFC 3-250-03, or AI MS2.

A1.2. The selection of materials for use in designing the paving mix are described in UFC 3-260-02 and UFC 3-250-03. The initial mix design tests will usually be conducted in a central testing laboratory on samples of stockpile materials submitted by the contractor. The procedure for proportioning stockpile samples to produce a blend of materials to meet a specified gradation are presented in UFC 3-260-02 and UFC 3-250-03. The final mix design will be based on samples taken from the asphalt plant and will usually be conducted in a field laboratory near the plant.

A1.3. As a preliminary step in mixture design and manufacture, it is necessary to determine the approximate proportions of the different available stockpiled materials required to produce the designed gradation of aggregate. This step is necessary to determine whether a suitable blend can be produced and, if so, the approximate proportion of each aggregate to be fed from the cold feeder bins into the dryer. Sieve analyses are conducted on material from each of the stockpiles. These estimated percentages are most easily determined by trial-and-error calculations. Two or three trials are normally required to obtain the desired blended gradation.

A1.4. The quantity of asphalt required for a particular aggregate is very important in paving mixture design. An estimate for the optimum amount of asphalt based on total weight of mix is normally made to start the laboratory tests. Laboratory tests usually are conducted for a minimum of five asphalt contents: two above, two below, and one at the estimated optimum content. Incremental changes of 1% of asphalt may be used for preliminary work, but increments of 0.5% are generally used when the optimum asphalt content can be estimated and for final design.

A1.5. The Marshall mix design concepts are the recommended procedures to produce a mix design (JMF) for large aggregate asphalt mixtures. The primary modifications to the current conventional asphalt mix design procedures are the laboratory compaction requirements. A JMF for large aggregate asphalt mixtures can be produced using one of the three different compaction techniques listed in Table A1. Each compaction procedure produces specimens 152 millimeters in diameter that range in height from 88 to 101 millimeters (3.5 to 4 inches). If the COE GTM method or the SHRP gyratory compactor is used for design, it should also be used for field control testing. If either gyratory compaction process cannot be used for control testing, the modified-Marshall apparatus (ASTM D 5581) can be used by developing a correlation between the gyratory compactor and the modified-Marshall specimens for the job mix. Care should be taken to ensure that excess breakage of the aggregate particles is not occurring during modified-Marshall compaction.

Table A1. Compaction Requirements for Large Aggregate Asphalt Mixtures.

Test Method	Compaction Equipment	Compaction Effort
ASTM D 5581	152-mm (6-in) mechanical hammer (modified Marshall)	150 blows per side
ASTM D 3387	152-mm COE GTM	1.38 MPa (200 psi), 60 revolutions, 1°
AI SP2	152-mm SHRP gyratory compactor	0.6 MPa (87 psi), 75 revolutions, 1.25°

A1.6. After the laboratory design method has been selected and test specimens have been prepared, Marshall mix properties should be determined. Plots of data for stability, flow, unit weight, percent voids total mix, and percent voids filled with asphalt should be made to evaluate mixture properties. Mixture property curves have been found to follow a reasonably consistent pattern for mixes made with various grades of asphalt cement. Typical mixture property trends include the following:

A1.6.1. Flow. The flow value increases with increasing asphalt content at a progressive rate, except at asphalt contents significantly below optimum.

A1.6.2. Stability. The Marshall stability increases with increasing asphalt content up to a point, after which it decreases.

A1.6.3. Unit Weight. The curve for unit weight of total mix is similar to the curve for stability, except that the peak of the unit-weight curve is normally at a slightly higher asphalt content than the peak of the stability curve.

A1.6.4. Voids Total Mix. Voids total mix decreases with increasing asphalt content in the lower range of asphalt contents. There is a minimum void content for each aggregate blend and compactive effort, and the voids cannot be decreased below this minimum without increasing the compactive effort. The void content of the compacted mix approaches this minimum void content as the asphalt content of the mix is increased.

A1.6.5. Voids Filled with Asphalt. Percent voids filled with asphalt increases with increasing asphalt content and approaches a maximum value in much the same manner as the voids total mix discussed above approaches a minimum value.

A1.7. Previous testing has indicated that the optimum asphalt content is one of the most important factors in the proper design of an asphalt paving mixture. Typical optimum asphalt contents for large aggregate mixtures range between 3.5 and 5.5%. Extensive research and pavement behavior studies have resulted in the establishment of certain criteria for determining the optimum asphalt content for a given blend of aggregates. Criteria have also been established to determine whether the aggregate will furnish a satisfactory paving mix at the selected optimum asphalt content. The optimum asphalt content for large aggregate mixtures should be a 4% voids total mix (air voids). The remaining mixture properties listed in Table A2 should be checked to verify acceptability of the optimum asphalt content. Additionally, the gyratory stability index (GSI) should be equal to or less than 1 for samples compacted using ASTM D 3387. If the optimum asphalt content selected using 4% voids total mix does not produce a GSI equal to or less than 1, the asphalt content should be reduced to meet the GSI requirement.

Table A2. Large Aggregate Asphalt Concrete Mixture Properties.

Mixture Property	Criteria
Stability (minimum)	17.8 kN (4000 lb)
Flow (maximum), 0.25 mm (0.01 in)	24
Voids total mix	3-5%
Voids filled with asphalt	70-80%

LARGE AGGREGATE ASPHALT MIXTURE GUIDE SPECIFICATION FOR HEAVY-DUTY PAVEMENTS

A2.1. Guide Specification Notes.

A2.1.1. Modifications must be made to this guide specification prior to publication to consider the notes located throughout the document. These notes are instructions to the editor of this specification, and must be removed prior to publication.

A2.1.2. This guide specification only pertains to the large aggregate asphalt aspects of the project and not to any surface preparation aspects dealing with base courses, milling, tack and prime coats, or with the application of a surface course. Surface preparation and application aspects should be covered by either including the appropriate paragraphs in this guide specification or by adding other specifications to the project documents.

A2.1.3. This specification uses a Quality Assurance/Quality Control (QA/QC) construction management philosophy. QA refers to the actions performed by the government or designated representative to assure the final product meets the job requirements. Results of QA testing are the basis for pay. QC refers to the actions of the contractor to monitor the construction and production processes and to correct these processes when out of control. Results of QC testing are reported daily on the process control charts maintained by the contractor. QC is covered in paragraph A2.4.15, while QA is covered in paragraph A2.5.

A2.2. General.

A2.2.1. Description. This item must consist of pavement courses composed of mineral aggregate and asphalt material mixed in a central mixing plant and placed on a prepared course. Large aggregate mixtures designed and constructed in accordance with these specifications must to the lines, grades, thicknesses, and typical cross sections shown on the plans. Each course or layer must be constructed to the depth, typical section, or elevation required by the plans, and must be rolled, finished, and approved before the placement of the next course.

A2.2.2. Submittals. *Note 1: List the location of the construction project office in the blank below. This material should be retained by the project office until the project is complete.*

A2.2.2.1. The contractor is responsible for developing the mix design. Sufficient materials will be provided to the __________________________ at least 14 days prior to test section construction for verification of mix design. Items that will be submitted at this time include:

A2.2.2.1.1. Each mixture component in sufficient quantity to produce 225 kilograms

(500 pounds) of blended mixture in accordance with paragraph A2.3.3.

A2.2.2.1.2. Proposed JMF in accordance with paragraph A2.3.3.

A2.2.2.1.3. QC test plan in accordance with paragraph A2.4.15.

A2.2.2.1.4. Testing laboratory certification in accordance with paragraph A2.4.15.2.

A2.2.2.1.5. Asphalt cement grade certification and 18-liter (5-gallon) sample in accordance with paragraph A2.3.2.

A2.2.2.1.6. Aggregate test results in accordance with paragraph A2.3.1.

A2.2.2.2. QC test results will be provided during the construction process within 24 hours of placement.

A2.2.3. Method of Measurement. *Note 2: Delete this paragraph if the work is in one lump-sum contract price. Lump-sum contracts should not be used when the job exceeds 907 metric tons (1000 tons).*

The amount paid for will be the number of 2000-pound tons of hot-mix asphalt used in the accepted work. Hot-mix asphalt must be weighed after mixing, and no deduction will be made for weight of asphalt cement material incorporated herein.

A2.2.4. Basis of Payment. *Note 3: Delete this paragraph if the work is in one lump-sum contract price. Lump-sum contracts should not be used when the job exceeds 907 metric tons (1000 tons).*

Quantities of mixtures, determined as specified in paragraph A2.2.3, will be paid for at respective contract unit prices or at reduced prices adjusted in accordance with paragraph A2.5. Payment will constitute full compensation for furnishing all materials, equipment, plant, and tools; and for all labor and other incidentals necessary to complete work required by this section of the specification.

A2.3. Products.

A2.3.1. Aggregates. Aggregates must consist of crushed stone, crushed gravel, crushed slag, screenings, natural sand and mineral filler, as required. The portion of material retained on the No. 4 (4.75 mm) sieve is coarse aggregate. The portion of material passing the No. 4 (4.75 mm) sieve and retained on the No. 200 (0.075 mm) sieve is fine aggregate. The portion passing the No. 200 (0.075 mm) sieve is defined as mineral filler. All aggregate test results and samples must be submitted to the contracting officer at least 14 days prior to start of construction.

A2.3.1.1. Coarse Aggregate. Coarse aggregate must consist of clean, sound, tough, durable particles, free from films of material that would prevent thorough coating and bonding with the asphalt material, and free from organic matter and other deleterious substances. The coarse aggregate particles will meet the following requirements:

A2.3.1.1.1. The percentage of loss must not be greater than 40% after 500 revolutions when tested in accordance with ASTM C 131, *Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine*.

A2.3.1.1.2. The percentage of loss must not be greater than 12% after five cycles when tested in accordance with ASTM C 88, *Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate*, using magnesium sulfate.

Note 4: Delete the requirement for magnesium sulfate in climates where freeze-thaw does not occur; however, in moderate climates this can be a part of the specification if experience has shown that this test separates good-performing aggregates from poor-performing aggregates.

A2.3.1.1.3. At least 75% by weight of coarse aggregate must have at least two or more fractured faces when tested in accordance with COE CRD-C 171, *Test for Ultimate Tensile Strain Capacity of Concrete*. Fractured faces must be produced by mechanical crushing.

A2.3.1.1.4. The particle shape must be essentially cubical and the aggregate must not contain more than 20%, by weight, of flat and elongated particles (3:1 ratio of maximum to minimum) when tested in accordance with ASTM D 4791, *Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate*.

A2.3.1.1.5. Slag must be air-cooled, blast furnace slag, and must have a compacted weight of not less than 1200 kilograms per cubic meter (75 pounds per cubic foot) when tested in accordance with ASTM C 29/C 29M, *Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate*.

A2.3.1.2. Fine Aggregate. Fine aggregate must consist of clean, sound, tough, and durable particles. The aggregate particles must be free from coatings of clay, silt, or any objectionable material, and must contain no clay balls. The fine aggregate particles must meet the following requirements:

A2.3.1.2.1. The quantity of natural sand (noncrushed material) added to the aggregate blend must not exceed 15% by weight of total aggregate.

A2.3.1.2.2. The fine aggregate must have a sand equivalent value greater than 45 when tested in accordance with ASTM D 2419, *Sand Equivalent Value of Soils and Fine Aggregate*.

A2.3.1.2.3. The fine aggregate portion of the blended aggregate must have an uncompacted void content greater than 45% when tested in accordance with

ASTM C 1252, *Standard Test Methods for Uncompacted Void Content of Fine Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading)*, Method A.

Note 5: The lower limit for uncompacted void content should be set at 45 for fine aggregate angularity unless local experiences indicate that a lower value can be used. There are some aggregates that have a good performance record and have an uncompacted void content less than 45. In no case should the limit be set less than 43.

A2.3.1.3. Mineral Filler. Mineral filler must be nonplastic material meeting the requirements of ASTM D 242, *Mineral Filler for Bituminous Paving Mixtures*. Grain size must conform to Table A3.

Table A3. Grain Size.

Grain Size	Percent Finer
0.05 mm (0.00197 in)	70-100%
0.02 mm (0.00078 in)	35-65%
0.005 mm (0.00197 in)	10-22%

A2.3.1.4. Aggregate Gradation. The combined aggregate gradation must conform to gradations specified in Table A4, when tested in accordance with ASTM C 136, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*, and ASTM C 117, *Standard Test Methods for Materials Finer than 75-mm (No. 200) Sieve in Mineral Aggregates by Washing*. Combined aggregate gradation must not vary from the low limit on one sieve to the high limit on the adjacent sieve, or vice versa, but grade uniformly from coarse to fine.

Table A4. Aggregate Gradation.

Sieve Size	Percent by Weight Passing
37.5 mm (1.5 in)	100%
25.0 mm (1 in)	81-93%
19.0 mm (0.75 in)	73-85%
12.5 mm (0.5 in)	63-77%
9.5 mm (0.375 in)	56-70%
4.75 mm (No. 4)	44-58%
2.36 mm (No. 8)	35-49%
1.18 mm (No. 16)	27-41%
0.60 mm (No. 30)	19-33%
0.30 mm (No. 50)	13-25%
0.15 mm (No. 100)	9-17%
0.075 mm (No. 200)	3-6%

A2.3.2. Asphalt Cement Binder.

A2.3.2.1. Asphalt cement binder must conform to ASTM D 3381, *Standard Specification for Viscosity-Graded Asphalt Cement for Use in Pavement Construction*, Table 2, Viscosity Grade_____, AASHTO MP1, *Performance-Graded Asphalt Binder*, PG Grade____, and ASTM D 946, *Standard Specification for Penetration-Graded Asphalt Cement for Use in Pavement Construction*, Penetration Grade____. Certified test data indicating specification compliance must be provided by the supplier at the time of delivery of each binder load to the mix plant. Copies of these certifications will be submitted to the contracting officer. The supplier is defined as the last source of any modification to the binder.

Note 6: When selecting PG-graded asphalt cements it is recommended that the asphalt meet the requirement for 98% reliability. Also consider local experience of the state Department of Transportation and availability of desired asphalt grade.

A2.3.2.2. The contracting officer may sample and test the binder at the mix plant at any time before or during mix production. Samples for this verification testing must be obtained by the contractor in accordance with ASTM D 140, *Standard Practice for Bituminous Materials*, and in the presence of the contracting officer. These samples must then be passed on to the contracting officer for verification testing, which must be at no cost to the contractor. Samples of the asphalt cement specified must be submitted for approval not less than 14 days before construction of the test section.

A2.3.3. Mix Design. The asphalt mix must be composed of a mixture of well-graded aggregate, mineral filler (if required), and asphalt material. The aggregate fractions must be sized, handled in separate size groups, and combined in such proportions that the resulting mixture meets the grading requirements of the JMF.

A2.3.3.1. No hot-mix asphalt for payment must be produced until a JMF has been approved by the contracting officer. The hot-mix asphalt must be designed using procedures contained in AI MS2 and the criteria shown in Tables A5 and A6.

Table A5. Compaction Requirements for Large Aggregate Asphalt Mixtures.

Test Method	Compaction Equipment	Compaction Effort
ASTM D 5581	152-mm (6-in) mechanical hammer (modified Marshall)	150 blows per side
ASTM D 3387	152-mm COE GTM	1.38 MPa (200 psi), 60 revolutions, 1°
AI SP2	152-mm SHRP gyratory compactor	0.6 MPa (87 psi), 75 revolutions, 1.25°

Table A6. Large Aggregate Asphalt Concrete Mixture Properties.

Mixture Property	Criteria
Stability (minimum)	17.8 kN (4000 lb)
Flow (maximum), 0.25 mm (0.01 in)	24
Voids total mix	3-5%
Voids filled with asphalt	70-80%

A2.3.3.2. If the tensile strength ratio (TSR) of the composite mixture, as determined by ASTM D 4867/D 4867M, *Standard Test Method for Effect of Moisture on Asphalt Concrete Paving Mixtures*, is less than 75, the aggregates must be rejected or the asphalt mixture treated with an approved anti-stripping agent. The amount of anti-stripping agent added must be sufficient to produce a TSR of not less than 75. If an anti-stripping agent is required, it must be provided by the contractor at no additional cost.

A2.3.3.3. When the water-absorption value of the entire blend of aggregate does not exceed 2.5%, as determined in accordance with ASTM C 127, *Standard Test Method for Specific Gravity and Absorption of Fine Aggregate*, and ASTM C 128, *Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate*, the aggregate is designated as nonabsorptive. The theoretical specific gravity computed from the apparent specific gravity, or ASTM D 2041, *Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures*, will be used in computing voids total mix and voids filled with bitumen; the mixture must meet the requirements in Table A6.

A2.3.3.4. When the water-absorption value of the entire blend of aggregate exceeds 2.5 percent as determined in accordance with ASTM C 127 and ASTM C 128, the aggregate is designated as absorptive. The theoretical specific gravity computed from ASTM D 2041 must be used in computing percentages of voids total mix and voids filled with bitumen; the mixture must meet the requirements given in Table A6.

A2.3.3.5. The JMF for each mixture must be in effect until a new formula is approved in writing by the contracting officer. Should a change in sources of materials be made, a new mix design must be performed and a new JMF approved by the contracting officer before the new material is used. The contractor is allowed to adjust the JMF within the limits specified in Table A7 to optimize mix volumetric properties. Any adjustment in the JMF must be approved by the contracting officer. If adjustments are needed that exceed these limits, a new mix design must be developed.

Table A7. Job Mix Tolerances.

Mix Design Element	Tolerance
Aggregate passing 4.75 mm (No. 4) or larger sieves	±4%
Aggregate passing 2.36, 1.18, 0.60, and 0.30 mm (Nos. 8, 16, 30, and 50) sieves	±3
Aggregate passing 0.15 and 0.075 mm (Nos. 100 and 200) sieves	±1%
Asphalt cement content	±0.25%
Mixing temperature	±14 °C (±25 °F)

A2.3.3.6. The JMF must be submitted in writing by the contractor to the contracting officer for approval at least 14 days prior to the start of the test section and must include, as a minimum:

- Percent passing each aggregate sieve size.
- Percent of asphalt cement.
- Percent of each aggregate stockpile and mineral filler to be used.
- Asphalt viscosity grade, penetration grade, or performance grade.
- Number of blows of hammer per side of molded specimen.
- Laboratory mixing temperature.
- Laboratory compaction temperature.
- Temperature-viscosity relationship of the asphalt cement.
- Plot of the combined gradation on the 0.45 power gradation chart, stating the nominal maximum size.
- Graphical plots of stability, flow, air voids, voids in the mineral aggregate, and unit weight versus asphalt content (see AI MS2).

- Specific gravity and absorption of each aggregate stockpile.
- Percent natural sand.
- Percent fractured faces (in coarse aggregate).
- Fine aggregate angularity
- Percent flat or elongated particles (in coarse aggregate).
- TSR.
- Anti-stripping agent (if required) and amount.
- List of all modifiers and amount.

A2.4. Execution.

A2.4.1. Test Section.

A2.4.1.1. Prior to full production, the contractor must place a test section for each JMF used. The contractor must construct a test section 76 to 152 meters (250 to 500 feet) long and two paver-passes wide placed in two lanes, with a longitudinal cold joint. The test section must be of the same depth as the course it represents. The underlying grade or pavement structure upon which the test section is to be constructed must be the same as the remainder of the course represented by the test section. The equipment used in construction of the test section must be the same equipment to be used on the remainder of the course represented by the test section. The test section must be placed as part of the project pavement as approved by the contracting officer.

A2.4.1.2. One random sample of hot-mix asphalt must be taken at the plant. From this mix sample, triplicate Marshall specimens must be compacted and tested for stability, flow, and laboratory air voids. A portion of the same mix sample must be tested for aggregate gradation and asphalt content. Four randomly selected cores must be taken from the finished pavement mat along with four randomly selected cores from the longitudinal joint and tested for density. Random sampling must be in accordance with procedures contained in ASTM D 3665, *Practice for Random Sampling of Construction Materials*. The test results must be within the tolerances shown in Table A8 for work to continue. If all test results meet the specified requirements, the test section must remain as part of the project pavement. If test results exceed the tolerances shown, the test section must be removed and replaced at no cost to the government and another test section must be constructed.

A2.4.1.3. If the initial test section should prove to be unacceptable, the necessary adjustments to the JMF, plant operation, placing procedures, and/or rolling procedures must be made. A second test section must then be placed. Additional test sections, as required, must be constructed and evaluated for conformance to the specifications. Full production must not begin until an acceptable section has been constructed and accepted by the contracting officer.

Table A8. Test Section Requirements for Material and Mixture Properties.

Property	Specification Limit
Aggregate gradation - percent passing (individual test result) 4.75 mm (No. 4) and larger sieve	JMF ±8%
Aggregate gradation - percent passing (individual test result) 2.36 mm, 1.18 mm, 0.60 mm, and 0.30 mm (Nos. 8, 16, 30 and 50) sieve	JMF ±6%
Asphalt content (individual test result)	JMF ±0.5%
Laboratory air voids (average of 3 specimens)	JMF ±1%
Stability (average of 3 specimens), minimum	17.8 kN (4000 lb)
Flow, 0.25 mm (0.01 in) (average of 3 specimens), maximum	24
Mat density, percent of Marshall (average of 4 random cores)	97-100.5%
Joint density, percent of Marshall (average of 4 random cores)	95.5-100.5%

Note 7: Table A8 applies only to the test section. The limits in Table A9 apply to a number of tests run from a lot. This is why the limits listed in Table A8 are different from those listed in Table A9.

A2.4.2. Testing Laboratory. It is intended that the laboratory used to develop the JMF meet the requirements of ASTM D 3666, *Standard Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials*. A certification signed by the manager of the laboratory stating that it meets these requirements or clearly listing all deficiencies must be submitted to the contracting officer prior to the start of construction. The certification must, at a minimum, contain the following information:

- Qualifications of personnel (laboratory manager, supervising technician, testing technicians).
- A listing of equipment to be used in developing the job mix.
- A copy of the laboratory's QC system.
- Evidence of participation in the AASHTO Materials Reference Laboratory (AMRL) program.

A2.4.3. Weather Limitations. The hot-mix asphalt must not be placed when the surface temperature of the existing pavement or base course is below 5 °C (40 °F).

A2.4.4. Asphalt Mixing Plant. Plants used for the preparation of hot-mix asphalt must conform to the requirements of ASTM D 995, *Mixing Plants for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures*, with the following changes:

A2.4.4.1. Truck Scales. The asphalt mixture must be weighed on approved scales furnished by the contractor, or on certified public scales at the contractor's expense. Scales must be inspected and sealed at least annually by a calibration laboratory approved by the contracting officer.

A2.4.4.2. Testing Facilities. The contractor must provide laboratory facilities at the plant for the use of the Government's acceptance testing and the contractor's QC testing, in accordance with paragraph A2.4.15.

A2.4.4.3. Inspection of Plant. The contracting officer must have access at all times to all areas of the plant for: checking adequacy of equipment; inspecting operation of the plant; verifying weights, proportions, and material properties; checking the temperatures maintained in the preparation of the mixtures; and for taking samples.

A2.4.4.4. Storage Bins and Surge Bins. Use of surge bins or storage bins for temporary storage of hot-mix asphalt will be permitted as follows:

A2.4.4.4.1. The asphalt mixture may be stored in surge bins for no more than three hours.

A2.4.4.4.2. The asphalt mixture may be stored in insulated storage bins for no more than eight hours. The bins must be such that mix drawn from them meets the same requirements as mix loaded directly into trucks.

A2.4.5. Hauling Equipment. Trucks used for hauling hot-mix asphalt must have tight, clean, and smooth metal beds. To prevent the mixture from adhering to them, the truck beds must be lightly coated with a minimum amount of paraffin oil, lime solution, or other approved material. Petroleum-based products must not be used as a release agent. Each truck must have a suitable cover to protect the mixture from adverse weather. Truck beds must be insulated or heated, and covers (tarps) will be securely fastened when necessary to ensure that the mixture will be delivered to the site at the specified temperature.

A2.4.6. Asphalt Pavers.

A2.4.6.1. Asphalt pavers must be self-propelled, with an activated screed, heated as necessary, and must be capable of spreading and finishing courses of hot-mix asphalt which will meet the specified thickness, smoothness, and grade. The paver must have sufficient power to propel itself and the hauling equipment without adversely affecting the finished surface.

A2.4.6.2. The paver must have a receiving hopper of sufficient capacity to permit a uniform spreading operation. The hopper must be equipped with a distribution system to place the mixture uniformly in front of the screed without segregation. The screed must effectively produce a finished surface of the required evenness and texture without tearing, shoving, or gouging the mixture.

A2.4.6.3. If an automatic grade control device is used, the paver must be equipped with a control system capable of automatically maintaining the specified screed elevation. The control system must be automatically actuated from either a reference line and/or through a system of mechanical sensors or sensor-directed mechanisms or devices which will maintain the paver screed at a predetermined transverse slope and at the proper elevation to obtain the required surface. The transverse slope controller must be capable of maintaining the screed at the desired slope within ±0.1%. A transverse slope controller must not be used to control grade. The controls must be capable of working in conjunction with any of the following attachments:

- Ski-type device of not less than 9.14 meters (30 feet) in length.
- Taut stringline (wire) set to grade.
- Short ski or shoe.
- Laser control.

Note 8: Delete the information on automatic grade control if not needed. This information is needed when the design establishes required elevations for the hot-mix asphalt surface. Most overlay specifications specify an overlay thickness and do not specify actual grades.

A2.4.7. Rollers. Rollers must be in good condition and must be operated at slow speeds to avoid displacement of the asphalt mixture. The number, type, and weight of rollers must be sufficient to compact the mixture to the required density while it is still in a workable condition. Equipment which causes excessive crushing of the aggregate must not be used.

A2.4.8. Preparation of Asphalt Binder Material. The asphalt cement material must be heated in a manner that will avoid local overheating and provide a continuous supply of the asphalt material to the mixer at a uniform temperature. The temperature of the neat asphalt cement material delivered to the mixer must be sufficient to provide a suitable viscosity for adequate coating of the aggregate particles, but must not exceed 160 °C (325 °F). Modified asphalts must be heated to no more than 175 °C (350 °F) when added to the aggregates.

A2.4.9. Preparation of Mineral Aggregate. The aggregate for the mixture must be heated and dried prior to mixing. The maximum temperature and rate of heating must be such that no damage occurs to the aggregates. The temperature of the aggregate and mineral filler must not exceed 175 °C when the asphalt cement is added. The temperature must not be lower than is required to obtain complete coating and uniform distribution on the aggregate particles and to provide a mixture of satisfactory workability.

A2.4.10. Preparation of Hot-Mix Asphalt Mixture. The aggregates and the asphalt cement must be weighed or metered and introduced into the mixer in the amount specified by the JMF. The combined materials must be mixed until the aggregate obtains a uniform coating of asphalt binder and is thoroughly distributed throughout the mixture. Wet mixing time must be the shortest time that will produce a satisfactory mixture, but no less than 25 seconds for batch plants. The wet mixing time for all plants must be established by the contractor, based on the procedure for determining the percentage of coated particles described in ASTM D 2489, *Standard Practice for Estimating Degree of Particle Coating of Bituminous Aggregate Mixtures*, for each individual plant and for each type of aggregate used. The wet mixing time will be set to achieve at least 95% of coated particles. For continuous-mix plants, the minimum mixing time must be determined by dividing the weight of its contents at operating level by the weight of the mixture delivered per second by the mixer. The moisture content of all hot-mix asphalt upon discharge from the plant must not exceed 0.5% by total weight of mixture as measured by ASTM D 1461, *Standard Test Method for Moisture or Volatile Distillates in Bituminous Paving Mixtures*.

A2.4.11. Preparing Underlying Surface. Immediately before placing the hot-mix asphalt, the underlying course must be cleaned of all dust and debris. A [prime coat] [and/or] [tack coat] must be applied, according to the contract specifications.

Note 9: If the underlying surface to be paved is an unbound granular layer, a prime coat should be applied, especially if this layer will be exposed to weather for an extended period of time prior to covering with an asphalt mixture. Benefits derived from a prime coat include an additional weatherproofer of the base, improving the bond between the base and large aggregate asphalt layer, and preventing the base from shifting under construction equipment. If the prime coat requirement is not a separate pay item and is waived from this contract for some reason, an adjustment to the contract price should be made. If the underlying surface to be paved is an existing asphalt or concrete layer, a tack coat should always be used to ensure an adequate bond between layers. Tack and prime coat requirements need to be covered somewhere in the contract documents.

A2.4.12. Transporting and Placing.

A2.4.12.1. The hot-mix asphalt must be transported from the mixing plant to the site in clean, tight vehicles. Deliveries must be scheduled so that placing and compacting of mixture is uniform with minimum stopping and starting of the paver. Adequate artificial lighting must be provided for night placements. Hauling over freshly placed material must not be permitted until the material has been compacted, as specified, and allowed to cool to 60 °C (140 °F). [The contractor must use a material transfer vehicle to deliver mix to the paver.]

Note 10: A material transfer vehicle has been shown to provide a pavement with improved smoothness and less segregation. A material transfer vehicle is recommended when doing runway construction.

A2.4.12.2. The mix must be placed and compacted at a temperature suitable for obtaining density, surface smoothness, and other specified requirements. Upon arrival, the mixture must be placed to the full width by an asphalt paver. It must be struck off in a uniform layer of such depth that, when the work is completed, it must have the required thickness and conform to the grade and contour indicated. The speed of the paver must be regulated to eliminate pulling and tearing of the asphalt mat. Unless otherwise permitted, placement of the mixture must begin along the centerline of a crowned section or on the high side of areas with a one-way slope. The mixture must be placed in consecutive adjacent strips having a minimum width of 3 meters (10 feet). The longitudinal joint in one course must offset the longitudinal joint in the course immediately below by at least 0.3 meter (1 foot); however, the joint in the surface course must be at the centerline of the pavement. Transverse joints in one course must be offset by at least 3 meters from transverse joints in the previous course. Transverse joints in adjacent lanes must be offset a minimum of 3 meters.

A2.4.12.3. On isolated areas where irregularities or unavoidable obstacles make the use of mechanical spreading and finishing equipment impractical, the mixture may be spread and luted by hand tools.

A2.4.13. Compacting Mixture.

A2.4.13.1. After placing, the mixture must be thoroughly and uniformly compacted by rolling. The surface must be compacted as soon as possible in a manner that does not cause undue displacement, cracking, or shoving. The sequence of rolling operations and the type of rollers used must be at the discretion of the contractor, except the contractor will not apply more than three passes with a vibratory roller in the vibrating mode.

A2.4.13.2. The speed of the roller must at all times be sufficiently slow to avoid horizontal displacement of the hot mixture and be effective in compaction. Any displacement occurring as a result of reversing the direction of the roller, or from any other cause, must be corrected at once. Sufficient rollers must be furnished to allow the placement rate to match the maximum production rate of the hot-mix plant. Rolling must continue until the surface is of uniform texture, true to grade and cross section, and the required field density is obtained. To prevent adhesion of the mixture to the roller, the wheels must be kept properly moistened, but excessive water will not be permitted.

A2.4.13.3. In areas not accessible to the roller, the mixture must be thoroughly compacted with hand tampers. Any mixture that becomes loose and broken, mixed with dirt, contains check-cracking, or in any way defective must be removed full depth and replaced with fresh hot mixture and immediately compacted to conform to the surrounding area. This work must be done at the contractor's expense. Skin patching must not be allowed.

A2.4.14. Joints. The formation of all joints must be made in such a manner as to ensure a continuous bond between the courses and obtain the required density. All joints must have the same texture as other sections of the course and meet the requirements for smoothness and grade.

A2.4.14.1. Transverse Joints. The roller must not pass over the unprotected end of the freshly laid mixture except when necessary to form a transverse joint. When necessary to form a transverse joint, it must be made by means of placing a bulkhead or by tapering the course. The tapered edge must be cut back to its full depth and width on a straight line to expose a vertical face prior to placing the adjacent lane. The cutback material must be removed from the project site. In both methods, all contact surfaces must be given a light tack coat of asphalt material before placing any fresh mixture against the joint.

A2.4.14.2. Longitudinal Joints. Longitudinal joints that are irregular, damaged, uncompacted, cold, or otherwise defective must be cut back a minimum of 50 millimeters (2 inches) with a cutting wheel to expose a clean, sound surface for the full depth of the course. All cutback material must be removed from the project. All contact surfaces must be given a light tack coat of asphalt material prior to placing any fresh mixture against the joint. The contractor will be allowed to use an alternate method if it can be demonstrated that density, smoothness, and texture can be met.

A2.4.15. Contractor QC. *Note 11: The contractor may be able to meet the QC requirements of this section with in-house capability, or the contractor may have to hire a material testing firm to provide the required QC testing.*

A2.4.15.1. General. The contractor must develop an approved QC plan. No hot-mix asphalt for payment must be produced until the QC plan has been approved by the contracting officer. The plan must address all elements that affect the quality of the pavement, including, but not limited to:

- Mix design.
- Aggregate grading.
- Quality of materials.
- Stockpile management.
- Proportioning.
- Mixing and transportation.
- Mixture volumetrics.
- Moisture content of mixtures.
- Placing and finishing.
- Joints.
- Compaction.
- Surface smoothness.

A2.4.15.2. Testing Laboratory.

A2.4.15.2.1. The contractor must provide a fully equipped asphalt laboratory located at the plant or job site. The effective working area of the laboratory must be a minimum of 14 square meters (150 square feet), with a ceiling height of not less than 2.3 meters (7.5 feet). Lighting must be adequate to illuminate all working areas. It must be equipped with heating and air conditioning units to maintain a temperature of 24 °C ± 2.3° (75 °F ± 5°).

A2.4.15.2.2. Laboratory facilities must be kept clean and all equipment must be maintained in proper working condition. The contracting officer must be permitted unrestricted access to inspect the contractor's laboratory facility and witness QC activities. The contracting officer will advise the contractor in writing of any noted deficiencies concerning the laboratory facility, equipment, supplies, or testing personnel and procedures. When the deficiencies are serious enough to adversely affect test results, the incorporation of the materials into the work must be suspended immediately and must not be permitted to resume until the deficiencies are satisfactorily corrected.

A2.4.15.3. QC Testing. The contractor must perform all QC tests necessary to control the production and construction processes applicable to these specifications, and as set forth in the QC program. The testing program must include, but must not be limited to, tests for the control of asphalt content, aggregate gradation, temperatures, aggregate moisture, moisture in the asphalt mixture, laboratory air voids, stability, flow, in-place density, grade and smoothness. A QC testing plan must be developed as part of the QC program.

A2.4.15.3.1. Asphalt Content. A minimum of two tests to determine asphalt content will be performed per lot (a lot is defined in paragraph A2.5) by either the extraction method in accordance with ASTM D 2172, *Standard Test Method for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures* (Method A or B), the ignition method in accordance with ASTM D 6307, *Standard Test Method for Asphalt Content of Hot-Mix Asphalt by Ignition Method*, or the nuclear method in accordance with ASTM D 4125, *Standard Test Methods for Asphalt Content of Bituminous Mixtures by the Nuclear Method*, provided the nuclear gauge is calibrated for the specific mix being used. For the extraction method, the weight of ash, as described in ASTM D 2172, must be determined as part of the first extraction test performed at the beginning of plant production, and as part of every tenth extraction test performed thereafter, for the duration of plant production. The last weight of ash value obtained must be used in the calculation of the asphalt content for the mixture.

A2.4.15.3.2. Gradation. Aggregate gradations must be determined at least twice per lot from mechanical analysis of recovered aggregate in accordance with ASTM D 5444, *Standard Test Method for Mechanical Size Analysis of Extracted Aggregate*. When asphalt content is determined by the nuclear method, aggregate gradation must be determined from hot bin samples on batch plants, or from the cold feed on drum-mix plants. For batch plants, aggregates must be tested in accordance with ASTM C 136 using actual batch weights to determine the combined aggregate gradation of the mixture.

A2.4.15.3.3. Temperatures. Temperatures must be checked, at least four times per lot, at necessary locations to determine the temperature at the dryer, the asphalt cement in the storage tank, the asphalt mixture at the plant, and the asphalt mixture at the job site.

A2.4.15.3.4. Aggregate Moisture. The moisture content of aggregate used for production must be determined a minimum of once per lot in accordance with ASTM C 566, *Standard Test Method for Total Moisture Content of Aggregate by Drying*.

A2.4.15.3.5. Moisture Content of Mixture. The moisture content of the mixture must be determined at least once per lot in accordance with ASTM D 1461, or an approved alternate procedure.

A2.4.15.3.6. Laboratory Air Voids, Marshall Stability, and Flow. Mixture samples must be taken at least four times per lot and compacted into specimens using 150 blows per side with the Marshall hammer as described in ASTM D 1559, *Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus*. After compaction, the laboratory air voids of each specimen will be determined, as well as the Marshall stability and flow.

Note: ASTM D 1559 has been canceled. ASTM is currently in the process of replacing ASTM D 1559 with two new standard tests, available in 2002. Continue to use ASTM D 1559 until the replacement tests are published.

A2.4.15.3.7. In-Place Density. The contractor must conduct any necessary testing to ensure the specified density is achieved in accordance with the specification. A nuclear gauge may be used to monitor pavement density in accordance with ASTM D 2950, *Density of Bituminous Concrete in Place by Nuclear Method*.

A2.4.15.3.8. Grade and Smoothness. The contractor will conduct the necessary checks to ensure the grade and smoothness requirements are met in accordance with paragraph A2.5.

A2.4.15.3.9. Additional Testing. Any additional testing which the contractor deems necessary to control the process may be performed at the contractor's option.

A2.4.15.3.10. Monitoring. The contractor must submit all QC test results to the contracting officer on a daily basis as the tests are performed. The contracting officer reserves the right to monitor any of the contractor's QC testing and to perform duplicate testing as a check of the contractor's QC testing.

A2.4.15.4. Sampling. When directed by the contracting officer, the contractor must sample and test any material that appears inconsistent with similar material being sampled, unless such material is voluntarily removed and replaced or deficiencies corrected by the contractor. All sampling must be in accordance with standard procedures specified.

A2.4.15.5. Control Charts.

A2.4.15.5.1. For process control, the contractor must establish and maintain linear control charts on both individual samples and the running average of the last four samples for the parameters listed in Table A9, as a minimum. These control charts must be posted in a location satisfactory to the contracting officer and must be kept current at all times. The control charts must identify the project number, the test parameter being plotted, the individual sample numbers, the action and suspension limits listed in Table A9 applicable to the test parameter being plotted, and the contractor's test results. Target values from the JMF must also be shown on the control charts as indicators of central tendency for the cumulative percent passing, asphalt content, and laboratory air voids parameters. When the test results exceed either applicable action limit, the contractor must take immediate steps to bring the process back in control. When the test results exceed either applicable suspension limit, the contractor must halt production until the problem is solved.

A2.4.15.5.2. The contractor must use the control charts as part of a process control system for identifying trends so that potential problems can be corrected before they occur. Decisions concerning mix modifications must be made based on analysis of the results provided in the control charts. The QC plan must indicate the appropriate action which must be taken to bring the process into control when certain parameters exceed their action limits.

Table A9. Action and Suspension Limits for Parameters Plotted on Individual and Running Average Control Charts.

Parameter Plotted	Individual Samples		Running Average of Last Four Samples	
	Action Limit	Suspension Limit	Action Limit	Suspension Limit
4.75 mm (No. 4) sieve, cumulative percent passing, deviation from JMF target	±6%	±8%	±4%	±5%
0.6 mm (No. 30) sieve, cumulative percent passing, deviation from JMF target	±4%	±6%	±3%	±4%
0.075 mm (No. 200) sieve, cumulative percent passing, deviation from JMF target	±1.4%	±2.0%	±1.1%	±1.5%
Stability (minimum)	8.01 kN (1800 lb)	7.56 kN (1700 lb)	8.45 kN (1900 lb)	8.01 kN (1800 lb)
Flow, 0.25 mm (0.01 in)	8-16	7-17	9-15	8-16
Asphalt content, deviation from JMF target value	±0.4%	±0.5%	±0.2%	±0.3%
Laboratory air voids, deviation from JMF target value	No specific action and suspension limits set since this parameter is used to determine percent payment (paragraph A2.5)			
In-place mat density, percent of Marshall density	No specific action and suspension limits set since this parameter is used to determine percent payment (paragraph A2.5)			
In-place joint density, percent of Marshall density	No specific action and suspension limits set since this parameter is used to determine percent payment (paragraph A2.5)			

A2.5. Material Acceptance and Percent Payment. *Note 12: It is highly recommended to keep the Government's QA testing separate and distinct from the contractor's QC testing; however, it is recognized that some Government agencies do not have the in-house testing capability to provide the QA testing required of this section. It is recommended that an independent material testing company be hired by the Government to provide the QA testing for the Government. The cost of this testing to assure good long-term performance is very small relative to the overall cost of the construction, and especially compared to the cost of a pavement failure. Although not recommended, this guide specification may be modified to require the Contractor to hire an independent material-testing laboratory to perform the QA testing described in this* *section. The results would need to be forwarded daily to the contracting officer as the basis for acceptance and pay. This should only be done if the Government agency has no way of hiring an independent testing laboratory to perform the QA testing.*

A2.5.1. General.

A2.5.1.1. This section deals with the Government's QA program for this project, which will be separate and distinct from the contractor's QC program covered in paragraph A2.4.15. Testing for acceptability of work will be performed by the contracting officer or by an independent laboratory hired by the contracting officer. Acceptance of the plant-produced mix and in-place requirements will be on a lot-to-lot basis. A standard lot for all requirements will be equal to 1800 metric tons (2000 tons).

A2.5.1.2. Where appropriate, adjustment in payment for individual lots of hot-mix asphalt will be made based on in-place density, laboratory air voids, grade, and smoothness in accordance with the following paragraphs. Grade and surface smoothness determinations will be made on the lot as a whole. Exceptions or adjustments to this will be made in situations where the mix within one lot is placed as part of both the intermediate and surface courses; thus grade and smoothness measurements for the entire lot cannot be made. To evaluate laboratory air voids and in-place (field) density, each lot will be divided into four equal sublots.

Note 13: The QA testing program in this section includes material tests to determine laboratory air voids and in-place density, which are needed to determine percent payment. The project engineer may choose to have additional tests conducted by the QA test agency to monitor aggregate gradation, asphalt content, Marshall stability and flow. These tests would serve as a check to the contractor's QC testing. Marshall stability and flow could be done at minimal cost since the specimens have to be made for laboratory air void determination. This additional testing, if conducted, is not included as part of this section since the parameters are not used as a basis of pay. Paragraph A2.4.15.3.9 addresses duplicate testing.

A2.5.2. Percent Payment.

A2.5.2.1. When a lot of material fails to meet the specification requirements for 100% pay as outlined in the following paragraphs, that lot must be removed and replaced, or accepted at a reduced price which is computed by multiplying the unit price by the lot's pay factor. The lot pay factor is determined by taking the lowest computed pay factor based on either laboratory air voids, in-place density, grade or smoothness (each discussed below). Pay factors based on different criteria (i.e., laboratory air voids and in-place density) of the same lot will not be multiplied together to get a lower lot pay factor.

A2.5.2.2. At the end of the project, an average of all lot pay factors will be calculated. If this average lot pay factor exceeds 95%, then the percent payment for the entire project will be 100% of the bid price. If the average lot pay factor is less than 95%, then each lot will be paid for at the unit price multiplied by the lot's pay factor. For any lots less than 1800 metric tons (2000 tons), a weighted lot pay factor will be used to calculate the average lot pay factor.

A2.5.3. Sublot Sampling. One random mixture sample for determining laboratory air voids, theoretical maximum density, and for any additional testing the contracting officer desires, will be taken from a loaded truck delivering mixture to each sublot, or other appropriate location for each sublot. All samples will be selected randomly, using commonly recognized methods of assuring randomness (ASTM D 3665) and employing tables of random numbers or computer programs. Laboratory air voids will be determined from three laboratory-compacted specimens of each sublot sample in accordance with ASTM D 1559 (see note at paragraph A2.4.15.3.6). The specimens will be compacted within two hours of the time the mixture was loaded into trucks at the asphalt plant. Samples will not be reheated prior to compaction and insulated containers will be used as necessary to maintain the temperature.

A2.5.4. Additional Sampling and Testing. The contracting officer reserves the right to direct additional samples and tests for any area that appears to deviate from the specification requirements. The cost of any additional testing will be paid for by the contracting officer. Testing in these areas will be in addition to the lot testing, and the requirements for these areas will be the same as those for a lot.

A2.5.5. Laboratory Air Voids.

A2.5.5.1. Laboratory air voids will be calculated by determining the Marshall density of each laboratory-compacted specimen using ASTM D 2726, *Standard Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures*, and determining the theoretical maximum density of every other sublot sample using ASTM D 2041. Laboratory air void calculations for each sublot should use the latest theoretical maximum density values obtained, either for that sublot or the previous sublot.

A2.5.5.2. The mean absolute deviation of the four laboratory air void contents (one from each sublot) from the JMF air void content will be evaluated and a pay factor determined from Table A10. All laboratory air void tests will be completed and reported within 24 hours after completion of construction of each lot.

A2.5.5.3. An example computation of mean absolute deviation for laboratory air voids is provided here. Assume that the laboratory air voids are determined from four random samples of a lot (where three specimens were compacted from each sample). The average laboratory air voids for each sublot sample are determined to be 3.5, 3.0, 4.0, and 3.7. Assume that the target air voids from the JMF is 4.0.

$$\text{Mean absolute deviation} = \frac{|3.5 - 4.0| + |3.0 - 4.0| + |4.0 - 4.0| + |3.7 - 4.0|}{4}$$

$$= \frac{0.5 + 1.0 + 0.0 + 0.3}{4} = \frac{1.8}{4} = 0.45$$

The mean absolute deviation for laboratory air voids is determined to be 0.45. It can be seen from Table A10 that the lot's pay factor based on laboratory air voids is 100%.

Table A10. Pay Factor Based on Laboratory Air Voids.

Mean Absolute Deviation of Lab Air Voids from JMF	Pay Factor
0.60 or less	100%
0.61-0.80	98%
0.81-1.00	95%
1.01-1.20	90%
Above 1.20	Reject (0%)

A2.5.6. In-Place Density.

A2.5.6.1. For determining in-place density, one random core will be taken from the mat (interior of the lane) of each sublot, and one random core will be taken from the joint (immediately over joint) of each sublot. Each random core will be the full thickness of the layer being placed. When the random core is less than 25 millimeters thick, it will not be included in the analysis. In this case, another random core will be taken. After air drying to a constant weight, cores obtained from the mat and from the joints will be used for in-place density determination.

A2.5.6.2. The average in-place mat and joint densities are expressed as a percentage of the average Marshall density for the lot. The Marshall density for each lot must be determined as the average Marshall density of the four random hot-mix samples (three specimens compacted per sample). The average in-place mat density and joint density for a lot are determined and compared with Table A11 to calculate a single pay factor per lot based on in-place density, as described below. First, a pay factor for both mat density and joint density are determined from Table A11. The area associated with the joint is then determined. It must be considered to be 3 meters wide times the length of completed longitudinal construction joint in the lot. In no case must this area exceed the total lot size. The length of joint to be considered will be that length where a new lane has been placed against an adjacent lane of hot-mix asphalt pavement; either an adjacent freshly paved lane or one paved at any time previously. The area associated with the joint is expressed as a percentage of the total lot area. A weighted pay factor for the joint is determined based on this percentage (see paragraph A2.5.6.3). The pay factor for mat density and the weighted pay factor for joint density are compared and the lowest selected. This selected pay factor is the pay factor based on density for the lot. When the Marshall density on both sides of a longitudinal joint is different, then the average of these two densities will be used as the Marshall density needed to calculate the percent joint density. All density tests for a lot will be completed and reported within 24 hours after the construction of that lot.

Table A11. Pay Factor Based on In-Place Density.

Average Mat Density (4 Cores)	Pay Factor	Average Joint Density (4 Cores)
98.0-100.0	100.0%	Above 96.5
97.9	100.0%	96.4
97.8, 100.1	99.9%	96.3
97.7	99.8%	96.2
97.6, 100.2	99.6%	96.1
97.5	99.4%	96.0
97.4, 100.3	99.1%	95.9
97.3	98.7%	95.8
97.2, 100.4	98.3%	95.7
97.1	97.8%	95.6
97.0, 100.5	97.3%	95.5
96.9	96.3%	95.4
96.8, 100.6	94.1%	95.3
96.7	92.2%	95.2
96.6, 100.7	90.3%	95.1
96.5	87.9%	95.0
96.4, 100.8	85.7%	94.9
96.3	83.3%	94.8
96.2, 100.9	80.6%	94.7
96.1	78.0%	94.6
96.0, 101.0	75.0%	94.5
Below 96.0, above 101.0	Reject	Below 94.5

A2.5.6.3. Calculation of a pay factor based on in-place density is illustrated below:

Assume the following test results for field density made on the lot:

Average mat density - 97.2% (of lab density)

Average joint density - 95.5% (of lab density)

Total area of lot – 2787 square meters (30,000 square feet)

Length of completed longitudinal construction joint – 609 meters (2000 feet)

Step 1: Determine pay factor based on mat density and on joint density (Table A11):

Mat density of 97.2% = 98.3 pay factor

Joint density of 95.5% = 97.3 pay factor

Step 2: Determine ratio of joint area (length of longitudinal joint x 10 feet) to mat area (total paved area in the lot):

Multiply the length of completed longitudinal construction joint by the specified 10-foot width and divide by the mat area (total paved area in the lot)

(2000 feet x 10 feet)/30,000 square feet = 0.6667 ratio of joint area to mat area (ratio)

Step 3: Weighted pay factor (wpf) for joint is determined as indicated below:

wpf = joint pay factor + (100 - joint pay factor) (1 - ratio)

wpf = 97.3 + (100 - 97.3) (1 - 0.6667) = 98.2%

Step 4: Compare weighted pay factor for joint density to pay factor for mat density and select the smaller:

Pay factor for mat density - 98.3%, wpf for joint density - 98.2%

Select the smaller of the two values as pay factor based on density: = 98.2%

Note 15: The grade and surface smoothness requirements described in the following paragraphs are for the final wearing surface only. If there is a requirement to test and control the grade and smoothness for the intermediate courses, then slight modifications to this specification will be required. An example of when this may be necessary is if the intermediate courses will be exposed to traffic.

A2.5.7. Grade.

A2.5.7.1. The final surface of the large aggregate asphalt must conform to the elevations and cross sections shown and must vary not more than [(0.75) (1.25) millimeter (0.03) (0.05) foot] tolerance from the plan grade established and approved at site of work. Finished surfaces at juncture with other pavements must coincide with finished surfaces of abutting pavements. Deviation from the plan elevation will not be permitted in areas of pavements where closer conformance with planned elevation is required for the proper functioning of drainage and other appurtenant structures involved.

Note 15: In the following paragraphs, use 0.75-millimeter (0.03-foot) tolerance for runways or 1.25-millimeter (0.05-foot) tolerance for taxiways and aprons.

A2.5.7.2. The final surface of the large aggregate asphalt will be tested for conformance with specified plan grade requirements. The grade will be determined by running lines of levels at intervals of 8 meters (25 feet) or less longitudinally and transversely to determine the elevation of the completed pavement surface. The contracting officer will inform the contractor in writing of the results of the grade-conformance tests within five working days after the completion of a particular lot incorporating the final surface. When more than 5% of all measurements made within a lot are outside the [(0.75) (1.25) millimeter (0.03) (0.05) foot] tolerance, the pay factor based on grade for that lot will be 95%. In areas where the grade exceeds the tolerance by more than 50%, the contractor must remove the surface lift full depth. The contractor will then replace with hot-mix asphalt to meet specification requirements at no additional cost to the Government. Diamond grinding can also be used at the contracting officer's discretion to remove high spots to meet grade requirements. Skin patching for correcting low areas, or planing or milling for correcting high areas, will not be permitted.

A2.5.8. Surface Smoothness.

A2.5.8.1. Except for grade changes, the final surface for both lane interiors and across joints must not deviate from the testing edge of a 3.5-meter (12-foot) straightedge more than the tolerances shown in Table A12 for the respective pavement category and direction.

Table A12. Surface Smoothness Tolerances.

Pavement Category	Direction of Testing	Tolerance
Runways and taxiways	Longitudinal	3 mm (0.125 in)
	Transverse	6 mm (0.25 in)
Calibration hardstands and compass swinging bases	Longitudinal	5 mm (0.1875 in)
	Transverse	5 mm (0.1875 in)
All other airfields and helicopter paved areas	Longitudinal	6 mm (0.25 in)
	Transverse	6 mm (0.25 in)

A2.5.8.2. After completion of final rolling of a lot, the final surface will be tested by the contracting officer or by the contracting officer's representative with a 3.5-meter straightedge. Measurements will be made parallel to and across all joints at equal distances along the joint not to exceed 8 meters. Location and deviation from straightedge of all measurements will be recorded. When more than 5% of all measurements along the joints or along the mat within a lot exceed the specified surface smoothness tolerance, the pay factor based on smoothness will be 95%. Any joint or mat area that exceeds the surface smoothness tolerances by more than 50% will be corrected. The contractor will remove the surface lift full depth in the deficient area and replace with hot-mix asphalt to meet specification requirements, at no additional cost to the Government. Diamond grinding can also be used to remove high spots to meet surface requirements, but only with the approval of the contracting officer. Skin patching for correcting low areas, or planing or milling for correcting high areas, will not be permitted.

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