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

JAN 9 2004

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

SUBJECT: **Engineering Technical Letter (ETL) 04-8, Stone Matrix Asphalt (SMA) for Air Force Pavements**

1. Purpose. This ETL provides a guide specification for use of SMA in pavement projects.

2. Application. This ETL is applicable to all Air Force organizations with pavement maintenance and repair responsibility.

2.1. Authority: Air Force Policy Directive (AFPD) 32-10, *Installations and Facilities.*

2.2. Effective Date: Immediately.

2.3. Intended Users: Base civil engineers (BCE) responsible for maintenance and repair of pavements.

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

3. Acronyms and Terms:

AASHTO	–	American Association of State Highway and Transportation Officials
AFPD	–	Air Force Policy Directive
AI	–	Asphalt Institute
AMRL	–	AASHTO Material Reference Laboratory
ASTM	–	American Society for Testing and Materials
BCE	–	base civil engineer
C	–	Celsius
CDT	–	California Department of Transportation
COE	–	Corps of Engineers
cu	–	cubic
ESAL	–	equivalent single axle load
ETL	–	Engineering Technical Letter
F	–	Fahrenheit
FAA	–	Federal Aviation Administration
FHWA	–	Federal Highway Administration
ft	–	feet

HMA	–	hot-mix asphalt
HQ AFCESA	–	Headquarters, Air Force Civil Engineer Support Agency
HQ USAFE	–	Headquarters, United States Forces in Europe
JMF	–	job mix formula
kg	–	kilograms
kPa	–	kiloPascals
lbs	–	pounds
m	–	meters
MAJCOM	–	major command
ml	–	milliliters
mm	–	millimeters
mm/km	–	millimeters per kilometer
MP	–	Materials Provisional
MPa	–	megaPascals
MS	–	Manual Series
NATO	–	North Atlantic Treaty Organization
NAVFAC	–	Naval Facilities Engineering Command
PG	–	Performance Graded
PMA	–	polymer modified asphalt
psi	–	pounds per square inch
QA	–	quality assurance
QC	–	quality control
SGC	–	Superpave gyratory compactor
SMA	–	stone matrix asphalt
sq	–	square
UFC	–	Unified Facilities Criteria
UFGS	–	Unified Facilities Guide Specification
US	–	United States
USACE	–	United States Army Corps of Engineers
VCA	–	voids in the coarse aggregate
VMA	–	voids in the mineral aggregate
wpf	–	weighted pay factor

4. Explanation.

4.1. General. SMA has become a popular asphalt mix for surfacing heavy-use roads and airfields in Europe. As a result of the wide acceptance of SMA in Europe, this ETL is primarily intended for use at Headquarters, United States Forces in Europe (HQ USAFE) and North Atlantic Treaty Organization (NATO) bases. However, as SMA continues to become more accepted worldwide, this ETL has applicability to all Air Force installations. SMA has been used in Europe for approximately 35 years. It provides both good rutting resistance and skid resistance. Its high asphalt content provides a highly durable mixture that tends to be compacted easily and is resistant to fatigue and reflective cracking. SMA has proven to be cost effective compared to hot-mix asphalt (HMA) because the thinner layer applications offset the cost of higher binder and coarse aggregate contents. In addition, a well-designed SMA requires relatively little maintenance, which can contribute to lower life-cycle costs. SMA mixtures consist of coarse aggregate, fine aggregate, mineral filler, and asphalt cement, with or without a modifier. The coarse aggregate content is typically approximately 70 percent (by weight), providing for stone-to-stone contact to provide strength. This high coarse aggregate content generally results in a mix with a gap gradation. Such a gradation, coupled with the high asphalt cement content, can cause the asphalt to "drain" from the mix. To avert that problem, a modifier is often added to stiffen the asphalt. The modifier may be a polymer and/or fiber (cellulose or mineral). Normally used in the surface course of pavement construction, SMA has an appearance similar to an open graded friction course; however, it has a low air voids content, similar to that of a densely graded HMA.

4.2. Performance. SMA has displayed superior highway performance in Europe and is rapidly gaining acceptance in the United States (US), with over 2 million tons of SMA used in the US during the past 5 years. SMA has been placed on the runway at one HQ USAFE military airfield and has shown excellent performance to date.

4.3. Applications. SMA can be specified in place of HMA in all pavement applications. It has advantages on runways due to its excellent rutting resistance and skid resistance. It should be considered for use in other areas whenever rutting or reflective cracking are design concerns.

4.4. Unified Facilities Guide Specification (UFGS). The guide specification provided as Attachment 1, *Stone Matrix Asphalt (SMA) for Airfield Pavements*, will soon be published as UFGS 02740. Though the specification title refers only to airfield pavements, the specification covers the requirements for SMA mixes suitable for paving both heavy duty roadways and airfields.

5. Point of Contact: Recommendations for improvements to this ETL are encouraged and should be furnished to Mr. Jim Greene, HQ AFCESA/CESC, DSN 523-6334, commercial (850) 283-6334.

JEFFREY L. LEPTRONE, Colonel, USAF
Director of Technical Support

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1. UFGS 02740, *Stone Matrix Asphalt (SMA) for Airfield Pavements*
2. Distribution List

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USACE / NAVFAC / AFCESA **UFGS-02740 (October 2003)**

Preparing Activity: USACE

UNIFIED FACILITIES GUIDE SPECIFICATION
****

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STONE MATRIX ASPHALT (SMA)
FOR AIRFIELD PAVEMENTS

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USACE / NAVFAC / AFCESA **UFGS-02740 (October 2003)**

Preparing Activity: USACE

UNIFIED FACILITIES GUIDE SPECIFICATION

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SECTION 02740
STONE MATRIX ASPHALT (SMA) FOR AIRFIELD PAVEMENTS
10/03

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NOTE: This guide specification covers the requirements for stone matrix asphalt (SMA) for both heavy duty roadway and airfield pavements.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents**, including their organization designation and telephone number, is on the Internet.**

Use of electronic communication is encouraged. This guide specification includes tailoring options for requirements of the Federal Aviation Administration (FAA) and requirements of other agencies where there are differences in technical requirements, contracting methods, or terminology. Selection or deselection of a tailoring option will include or exclude that option in the section, but editing the resulting section to fit the project is still required.
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PART 1 GENERAL

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NOTE: Modifications must be made to this guide specification during conversion to a project specification in accordance with the NOTES which are located throughout the document. These NOTES are instructions to the designer, and will not appear in the project specification.

This guide specification only pertains to the stone matrix asphalt aspects of the project and not to any surface preparation requirements dealing with aggregate base courses, milling, or tack and prime coats. Surface preparation requirements should be covered by either including

them in this guide specification or by adding pertinent sections to the project documents.

This specification utilizes a Quality Assurance and Quality Control (QA/QC) construction management philosophy. Quality Assurance refers to the actions performed by the Government or designated representative Engineer to assure the final product meets the job requirements. Results of QA testing are the basis for pay. Quality Control 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. Quality Control is covered in paragraph CONTRACTOR QUALITY CONTROL. Quality Assurance is covered in paragraph MATERIAL ACCEPTANCE AND PERCENT PAYMENT.

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1.1 REFERENCES

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NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest change (Notice) to this guide specification.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM C 88	(1999a) Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
ASTM C 117	(1995) Materials Finer than 75-micrometer (No. 200) Sieve in Mineral Aggregates by Washing
ASTM C 127	(2001) Specific Gravity and Absorption of Coarse Aggregate
ASTM C 128	(2001) Specific Gravity and Absorption of Fine Aggregate
ASTM C 131	(2003) Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C 136	(2001) Sieve Analysis of Fine and Coarse Aggregates

ASTM C 566	(1997) Total Evaporable Moisture Content of Aggregate by Drying
ASTM C 612	(2000) Mineral Fiber and Board Thermal Insulation
ASTM C 1252	(1998) Uncompacted Void Content of Fine Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading)
ASTM D 75	(1997) Practice for Sampling Aggregates
ASTM D 140	(2001) Sampling Bituminous Materials
ASTM D 242	(2000) Mineral Filler for Bituminous Paving Mixtures
ASTM D 946	(1982; R 1999) Penetration-Graded Asphalt Cement for Use in Pavement Construction
ASTM D 995	(2002) Mixing Plants for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures
ASTM D 1461	(2001) Moisture or Volatile Distillates in Bituminous Paving Mixtures
ASTM D 2041	(2000) Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
ASTM D 2172	(2001) Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
ASTM D 2419	(2002) Sand Equivalent Value of Soils and Fine Aggregate
ASTM D 2489	(2002) Degree of Particle Coating of Bituminous-Aggregate Mixtures
ASTM D 2726	(2000) Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixture
ASTM D 2950	(1997) Density of Bituminous Concrete in Place by Nuclear Method
ASTM D 3203	(2000) Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
ASTM D 3381	(1999) Viscosity-Graded Asphalt Cement for Use in Pavement Construction
ASTM D 3665	(2002) Random Sampling of Construction Materials

ASTM D 3666	(2002) Minimum Requirements for Agencies Testing and Inspecting Bituminous Paving Materials
ASTM D 4125	(2000) Asphalt Content of Bituminous Mixtures by the Nuclear Method
ASTM D 4318	(2000) Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D 4791	(1999) Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
ASTM D 5444	(1998) Mechanical Size Analysis of Extracted Aggregate
ASTM D 5821	(2001) Determining the Percentage of Fractured Particles in Coarse Aggregate
ASTM D 6307	(1999) Asphalt Content of Hot-Mix Asphalt by Ignition Method
ASTM D 6373	(1999) Performance Graded Asphalt Binder
ASTM D 6390	(1999) Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures

ASPHALT INSTITUTE (AI)

AI MS-2	(1994) Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

AASHTO MP8	(2001) Standard Specification for Designing Stone Matrix Asphalt (SMA)

CALIFORNIA DEPARTMENT OF TRANSPORTATION (CDT)

CDT Test 526	(1978) Operation of California Profilograph and Evaluation of Profiles
CDT Test 303	(2000) Standard Method of Test for Centrifuge Kerosene Equivalent and Approximate Bitumen Ratio (ABR)

CORPS OF ENGINEERS (COE)

COE CRD-C 171	(1995) Test Method for Determining Percentage of Crushed Particles in Aggregate

UNIFIED FACILITIES CRITERIA (UFC)

UFC 3-250-03	(2001) Standard Practice Manual for Flexible Pavements

UNIFIED FACILITIES GUIDE SPECIFICATIONS (UFGS)

UFGS 01330	(2002) SUBMITTAL PROCEDURES

1.2 DESCRIPTION OF WORK

The work shall consist of pavement courses composed of mineral aggregate and asphalt material, either using a stabilizer or modified with or without a stabilizer, mixed in a central mixing plant and the hot mixture is placed with an asphalt paver on a prepared course. Stone matrix asphalt (SMA) mixtures designed and constructed in accordance with these specifications shall conform to the lines, grades, thicknesses, and typical cross sections shown on the plans.

1.3 SUBMITTALS

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NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.

Indicate submittal classification in the blank space following the name of the item requiring the submittal by using "G" when the submittal requires Government approval. Submittals not classified as "G" will show on the submittal register as "Information Only". For submittals requiring Government approval, a code of up to three characters should be used following the "G" designation to indicate the approving authority; codes of "RE" for Resident Engineer approval, "ED" for Engineering approval, and "AE" for Architect-Engineer approval are recommended.

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Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government. The following shall be submitted in accordance with UFGS 01330:

Placement Plan:

SD-03 Product Data
Mix Design; G, [_____]
Proposed JMF.
Contractor Quality Control; G, [_____]
Quality control plan.

SD-04 Samples
Asphalt Cement Binder; [_____], [_____]
20 liters [5 gallons] sample for mix design verification.
Aggregates; [_____], [_____]

Sufficient materials to produce 90 kg [200 lbs] of blended mixture for mix design verification.

SD-06 Test Reports
Aggregates; G, [_____]
QC Monitoring; [_____], [_____]
Aggregate and QC test results.

SD-07 Certificates
Asphalt Cement Binder; G, [_____]
Copies of certified test data.
Testing Laboratory; [_____], [_____]
Certification of compliance.

1.4 METHOD OF MEASUREMENT

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NOTE: For unit-price contracts, include first paragraph and delete the second paragraph. For lump-sum contracts, delete the first paragraph and include the second paragraph. Lump-sum contracts should not be used when the job exceeds 1000 metric tons [1000 short tons].

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[The amount paid for will be the number of [metric] [short] tons of SMA used in the accepted work. The SMA shall be weighed after mixing, and no adjustment will be made for weight of asphalt cement material incorporated herein.]

[Measurement of the quantity of SMA, per [metric] [short] ton placed and accepted, shall be made for the purposes of assessing the pay factors stipulated in this section.]

1.5 BASIS OF PAYMENT

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NOTE: For unit-price contracts, include first paragraph and delete the second paragraph. For lump-sum contracts, delete the first paragraph and include the second paragraph. Include prescriptive unit price based on the Government/Engineer estimate for payment adjustment. Lump-sum contracts should not be used when the job exceeds 1000 metric tons [1000 tons].

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[Quantities of SMA mixture, determined as specified above, will be paid for at respective contract unit prices or at reduced prices adjusted in accordance with MATERIAL ACCEPTANCE AND PERCENT PAYMENT. Payment shall 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.]

[The measured quantity of SMA will be paid for and included in the lump-sum contract price. If less than 100 percent payment is due based on the pay factors stipulated in paragraph MATERIAL ACCEPTANCE AND PERCENT PAYMENT, a unit price of [_____] per ton shall be used for purposes of calculating the payment reduction.]

1.6 ASPHALT MIXING PLANT

Plants used for the preparation of SMA shall conform to the requirements of ASTM D 995 with the following changes:

a. Truck Scales. The asphalt mixture shall be weighed on approved scales furnished by the Contractor, or on certified public scales at the Contractor’s expense. Scales shall be inspected and sealed at least annually by an approved calibration laboratory.

b. Testing Facilities. The Contractor shall provide laboratory facilities at the plant for the use of the Government Engineer’s acceptance testing and the Contractor’s quality control testing.

c. Inspection of Plant. The Contracting Officer/Engineer shall 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. The Contractor shall provide assistance, as requested, for the Government Engineer to procure any desired samples.

d. Storage Bins. The SMA mixture may be stored in non-insulated storage bins for a period of time not to exceed 1 hour. The SMA mixture may be stored in insulated storage bins for a period of time not exceeding 4 hours. The mix drawn from bins shall meet the same requirements as mix loaded directly into trucks.

1.7 HAULING EQUIPMENT

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

1.8 ASPHALT PAVERS

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

1.8.1 Receiving Hopper

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

1.8.2 Automatic [Grade] [Screed] Controls

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NOTE: Select automatic grade control when the design requires elevations for the SMA surface. Most specifications require an overlay thickness and do not specify actual grades; therefore, select or delete the information below within the brackets.

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[The automatic grade control device shall consist of a control system capable of automatically maintaining the paver screed at the specified elevation. The control system shall 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 shall be capable of maintaining the screed at the desired slope within plus or minus 0.1 percent. A transverse slope controller shall not be used to control grade. The controls shall be capable of working in conjunction with any of the following attachments:

a. Ski-type device of not less than 9.14 meters [30 feet] in length.

b. Taut stringline set to grade.

c. Short ski or shoe for joint matching.

d. Laser control.]

[The automatic screed control device shall consist of a control system capable of automatically controlling the elevation of the paver screed according to the inputs received. The control system shall be automatically actuated from a system of mechanical sensors or sensor-directed mechanisms or devices that will maintain the paver screed at the proper elevation to obtain the required surface thickness and smoothness. The controls shall be capable of working in conjunction with any of the following attachments:

a. Ski-type device of not less than 9.14 meters [30 feet] in length.

b. Short ski or shoe for joint matching.]

1.9 ROLLERS

Rollers shall be in good condition and shall be operated at slow speeds to avoid displacement of the SMA mixture. The number, type, and weight of rollers shall be sufficient to compact the mixture to the required density. Rollers that cause crushing of the aggregate shall not be used.

1.10 WEATHER LIMITATIONS

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NOTE: The temperature requirements are included to avoid problems with the Contractor achieving density because the mix cools too fast. Waivers to these requirements, for isolated incidences during production, are applicable if the density requirements are still met.

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The SMA shall not be placed upon a wet surface or when the surface temperature of the underlying course is less than 7 degrees C [45 degrees F]. The temperature requirements may be waived by the Contracting Officer/Engineer, if requested; however, all other requirements, including compaction, shall be met.

PART 2 PRODUCTS

2.1 AGGREGATES

Aggregates shall consist of crushed stone, crushed gravel, screenings, and mineral filler, as required. The portion of material retained on the 4.75 mm [No. 4 sieve] is coarse aggregate. The portion of material passing the 4.75 mm [No. 4 sieve] and retained on the 0.075 mm [No. 200 sieve] is fine aggregate. The portion passing the 0.075 mm [No. 200 sieve] is defined as mineral filler. All aggregate test results and samples shall be submitted to the Contracting Officer/Engineer at least 14 days prior to start of construction.

2.1.1 Coarse Aggregate

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NOTE: The requirement for magnesium sulfate (requirement b., below) may be deleted in climates where freeze-thaw does not occur. However, in these areas where freeze-thaw does not occur, requirement b., should remain if experience has shown that this test separates good performing aggregates from bad performing aggregates.
****

Coarse aggregate shall consist of 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 shall meet the following requirements:

a. The percentage of loss shall not be greater than 30 percent after 500 revolutions when tested in accordance with ASTM C 131.

b. The percentage of loss shall not be greater than 18 percent after five cycles when tested in accordance with ASTM C 88 using magnesium sulfate.

c. One-hundred percent by weight of coarse aggregate shall have at least two fractured faces when tested in accordance with ASTM D 5821. At least 90 percent by weight of coarse aggregate shall have at least two or more fractured faces when tested in accordance with COE CRD-C 171. Fractured faces shall be produced by crushing.

d. The particle shape shall be essentially cubical and the aggregate shall not contain more than 20 percent, by weight, of flat and elongated particles (3:1 ratio of maximum to minimum) and no more than 5 percent, by weight, of flat and elongated particles (5:1 ratio of maximum to minimum) when tested in accordance with ASTM D 4791.

e. The maximum absorption shall not be greater than 2 percent when tested in accordance with ASTM C 127.

2.1.2 Fine Aggregate

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NOTE: The lower limit for uncompacted void content (requirement c., below) should be set at 45 for fine aggregate angularity unless local experiences indicate that a lower value can be used. There are some aggregates which 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.
****

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

a. The fine aggregate portion of the blended aggregate shall be 100 percent crushed manufactured fines.

b. The individual fine aggregate sources shall have a sand equivalent value greater than 45 when tested in accordance with ASTM D 2419.

c. The fine aggregate portion of the blended aggregate shall have an uncompacted void content greater than 45.0 percent when tested in accordance with ASTM C 1252 Method A.

d. Aggregate shall be non-plastic, with a Liquid Limit of 25 percent maximum when tested in accordance with ASTM 4318.

e. The maximum absorption shall not be greater than 2 percent when tested in accordance with ASTM C 128.

2.1.3 Mineral Filler

Mineral filler shall be non-plastic material meeting the requirements of ASTM D 242.

2.1.4 Aggregate Gradation

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Generally, the layer thickness should be at least 37 mm [1.5 inches].

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The combined aggregate gradation shall conform to gradations specified in Table 1, when tested in accordance with ASTM C 136 and ASTM C 117, and shall 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 1. Aggregate Gradations

Sieve Size, mm	Percent Passing by Mass
25.0	---
19.0	100
12.5	85-100
9.5	65-75
4.7	32-42
2.36	25-32
1.18	19-24
0.60	12-18
0.30	10-17
0.15	9-15
0.075	8-13

Table 1. Aggregate Gradations

Sieve Size, inch	Percent Passing by Mass
1	---
3/4	100
1/2	85-100
3/8	65-75
No. 4	32-42
No. 8	25-32
No. 16	19-24
No. 30	12-18
No. 50	10-17
No. 100	9-15
No. 200	8-13

2.1.5 Stabilizer

The stabilizer can be cellulose or mineral fibers. Requirements and test procedures are outlined in Tables 2 and 3.

2.2 ASPHALT CEMENT BINDER

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NOTE: Performance Graded (PG) asphalt binders should be specified wherever available. The same grade PG binder used by the local highway agency in the area should be considered as the base grade for the project (e.g., the grade typically specified in that specific location for dense graded mixes on highways with design ESALs less than 10 million). The exception would be that grades with a low temperature higher than PG XX-22 should not be used (e.g. PG XX-16 or PG XX-10), unless the Engineer has had successful experience with them.

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Table 2. Cellulose Fibers Quality Requirements

Properties	Requirement
Sieve Analysis	
Method A	
Alpine Sieve[1] Analysis	
Fiber length	6 mm [0.25 in.] (max.)
Passing 150 micron [No. 100] sieve	70 percent (± 10 percent)
Method B	
Mesh Screen[2] Analysis	
Fiber length	6 mm [0.25 in.] (max.)
Passing 850 micron [No. 20] sieve	85 percent (± 10 percent)
425 micron [No. 40] sieve	65 percent (± 10 percent)
106 micron [No. 140] sieve	30 percent (± 10 percent)
Ash Content[3]	18 percent (± 5 percent) non-volatiles
pH[4]	7.5 (± 1.0)
Oil Absorption[5]	5.0 (± 1.0) (times fiber weight)
Moisture Content[6]	< 5 percent (by weight)

[1]This test is performed using an Alpine Air Jet Sieve (Type 200 LS). A representative 5-gram sample of fiber is sieved for 14 minutes at a controlled vacuum of 75 kPa (11 psi). The portion remaining on the screen is weighed.

[2]This test is performed using standard 850, 425, 250, 180, 150, 106-micron (No. 20, 40, 60, 80, 100, 140) sieves, nylon brushes, and a shaker. A representative 10-gram sample of fiber is sieved using a shaker and two nylon brushes on each screen. The amount retained on each sieve is weighed and the percentage passing calculated. The repeatability of this method is suspect and needs to be verified.

[3]A representative 2-3 gram sample of fiber is placed in a tared crucible and heated between 595 degrees and 650 degrees C (1100 degrees and 1200 degrees F) for not less than 2 hours. The crucible and ash are cooled in a desiccator and reweighed.

[4]Five grams of fiber is added to 100 ml of distilled water, stirred, and let sit for 30 minutes. The pH is determined with a probe calibrated with pH 7.0 buffer.

[5]Five grams of fiber is accurately weighed and suspended in an excess of mineral spirits for not less than 5 minutes to ensure total saturation. It is then placed in a screen mesh strainer (approximately 0.5 square millimeter hole size) and shaken on a wrist–action shaker for 10 minutes (approximately 31-3/4 mm [1-1/4 inch] motion at 240 shakes/minute). The shaken mass is then transferred without touching, to a tared container and weighed. Results are reported as the amount (number of times its own weight) the fibers are able to absorb.

[6]Ten grams of fiber is weighed and placed in a 121 degree C (250 degrees F) forced-air oven for 2 hours. The sample is then reweighed immediately upon removal from the oven.

Table 3. Mineral Fibers Quality Requirements

Properties	Requirement
Sieve Analysis	
Fiber length[1]	6 mm [.25 in.] max. mean test value
Thickness[2]	5 m [0.0002 in.] max. mean test value
Shot content[3]	
250 micron [No. 60] sieve	95 percent passing (min.)
63 micron [No. 230] sieve	65 percent passing (min.)

[1]The fiber length is determined according to the Baur McNett fractionation.

[2]The fiber diameter is determined by measuring at least 200 fibers in a phase contract microscope.

[3]Shot content is a measure of non-fibrous material. The shot content is determined on vibrating sieves. Two sieves, No. 60 and No. 230, are typically utilized; for additional information see ASTM C 612.

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Note: Typically, rutting is not a problem on airport runways. However, at airports with a history of stacking on ends of runways and taxiway areas, rutting has accrued due to the slow speed of loading on the pavement. If there has been rutting on the project or it is anticipated that stacking may accrue during the design life of the project, then the following grade "bumping" should be applied for the top 125 mm [5 inches] of paving in the end of runway and taxiway areas: for aircraft tire pressure between 0.7 and 1.4 MPa [100 and 200 psi], increase the high temperature one grade; for aircraft tire pressure greater than 1.4 MPa [200 psi], increase the high temperature two grades. Each grade adjustment is 6 degrees C. Polymer modified asphalt, PMA, has been shown to perform very well in these areas. The low temperature grade should remain the same. The Engineer may lower the low temperature grade to comply with the recommendations of the FHWA's software program "LTPPBind," if it is believed to be appropriate.

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Asphalt cement binder shall conform to [ASTM D 3381 Table 2, Viscosity Grade [______]] [ASTM D 6373 Performance Grade (PG) [______]] [ASTM D 946 Penetration Grade [______]]. Test data indicating grade certification shall be provided by the supplier at the time of delivery of each load to the mix plant. Copies of these certifications shall be submitted to the Contracting Officer/Engineer. The supplier is defined as the last source of any modification to the binder. The Contractor Officer/Engineer may sample and test the binder at the mix plant at any time before or during mix production. Samples for this verification testing shall be obtained by the Contractor in accordance with ASTM D 140 and in the presence of the Contracting Officer/Engineer. These samples shall be furnished to the Contracting Officer/Engineer for the verification testing, which shall be at no cost to the Contractor.

2.3 MIX DESIGN

The Contractor shall develop the mix design. The asphalt mix shall be composed of a mixture of coarse and fine aggregate, mineral filler, a stabilizer, if required, and asphalt material. The aggregate fractions shall be sized, handled in separate size groups, and combined in such proportions that the resulting mixture meets the grading requirements of the job mix formula (JMF). No SMA for payment shall be produced until a JMF has been approved. The SMA shall be designed using procedures contained in AI MS-2 and the criteria shown in Table 4 or by procedures contained in AASHTO MP8. The aggregate quality requirements given in this specification shall be used instead of those given in AASHTO MP8. The aggregate passing on the 9.50 mm [3/8 inch] sieve and retained on the 4.75 mm [No. 4] sieve, as determined by CDT Test 303, shall have a retained surface area of 95 percent. When the retained coating area is less than 95 percent, the aggregate stripping tendencies shall be countered by the use of hydrated lime or by treating the bitumen with an approved antistripping agent as furnished by the Contractor. The hydrated lime will be considered as mineral filler and will be considered in the gradation requirements. The amount of hydrated lime or antistripping agent added to the bitumen will be determined during development of the JMF and will be sufficient to produce a retained coating area greater than 95 percent. Use of additional antistripping agent may be directed during the progress of work, if necessary. If an anti-strip agent is required, it shall be provided by the Contractor at no additional cost. Sufficient materials to produce 90 kg [200 pounds] of blended mixture shall be provided to the Contracting Officer/Engineer for verification of mix design at least 14 days prior to construction of test section.

2.3.1 JMF Requirements

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NOTE: In Table 4, use a 50-blow (compactive effort) Marshall Mix for all SMA pavements.

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Table 4. SMA Mix Design Criteria

Test Property	50 Blow Mix
Stability, newtons minimum	5400[1]
Air voids, percent	3.0-4.0
Percent Voids in mineral aggregate (minimum)	17.0[2]
Retained Coating Area, minimum percent	95
Draindown, percent (maximum)	0.3 (1 hour reading)[3]

[1]This is a minimum requirement. The average during construction shall be significantly higher than this number to ensure compliance with the specifications.

[2]Calculate VMA in accordance with AI MS-2, based on ASTM D 2726 bulk specific gravity for the aggregate.

[3] Calculate Draindown in accordance with ASTM D 6390 determination of draindown characteristics in uncompacted asphalt mixtures.

Table 4. SMA Mix Design Criteria

Test Property	50 Blow Mix
Stability, pounds minimum	1200[1]
Air voids, percent	3.0-4.0
Percent Voids in mineral aggregate (minimum)	17.0[2]
Retained Coating Area, minimum percent	95
Draindown, percent (maximum)	0.3 (1 hour reading)[3]

[1]This is a minimum requirement. The average during construction shall be significantly higher than this number to ensure compliance with the specifications.

[2]Calculate VMA in accordance with AI MS-2, based on ASTM D 2726 bulk specific gravity for the aggregate.

[3] Calculate Draindown in accordance with ASTM D 6390 determination of draindown characteristics in uncompacted asphalt mixtures.

The job mix formula shall be submitted in writing by the Contractor for approval at least 14 days prior to the start of the test section and shall include as a minimum:

****

NOTE: If the JMF is designed according to AI MS-2, delete elements, t, u, and v, as given below. If the JMF is designed according to AASHTO MP8, delete element j, as given below.

****

a. Percent passing each sieve size.

b. Percent of asphalt cement.

c. Percent of each aggregate and mineral filler to be used.

d. Asphalt viscosity grade, penetration grade, or performance grade.

e. Type and amount of stabilizer, if required.

f. Laboratory mixing temperature.

g. Lab compaction temperature.

h. Temperature-viscosity relationship of the asphalt cement.

i. Plot of the combined gradation on the 0.45 power gradation chart, stating the nominal maximum size.

j. Graphical plots of stability, flow, air voids, voids in the mineral aggregate, and unit weight versus asphalt content as shown in AI MS-2.

k. Specific gravity and absorption of each aggregate.

l. Percent natural sand.

m. Percent particles with one and two or more fractured faces (in coarse aggregate).

n. Fine aggregate angularity.

o. Percent flat or elongated particles (in coarse aggregate).

p. Retained Coating Area.

q. Antistrip agent (if required) and amount.

r. List of all modifiers and amount.

s. Percent draindown of mixture.

t. Dry-rodded-in-the coarse aggregate (VCA_{DRC}).

u. Voids-in-the coarse aggregate mixture (VCA_{Mix}).

v. Number of revolutions of SGC compactor.

2.3.2 Adjustments to JMF

The JMF for each mixture shall be in effect until a new formula is approved in writing by the Contracting Officer. Should a change in sources of any materials be made, a new mix design shall be performed and a new JMF approved before the new material is used. The Contractor will be allowed to adjust the JMF within the limits specified below in

Table 5 to optimize mix volumetric properties. If adjustments are needed that exceed these limits, a new mix design shall be developed. Tolerances given above may permit the aggregate grading to be outside the limits shown in Table 1; this is acceptable.

Table 5. Job Mix Tolerances

Material	Tolerance, Plus or Minus
Aggregate passing 4.75 mm or larger sieves	3 percent
Aggregate passing 2.36, 1.18, 0.60, 0.30, 0.15, and 0.075 mm sieves	2 percent
Asphalt cement	0.25 percent
Temperature of mixing	14 degrees C

Table 5. Job Mix Tolerances

Material	Tolerance, Plus or Minus
Aggregate passing No. 4 or larger sieves	3 percent
Aggregate passing Nos. 8, 30, 50, 100, and 200 sieves	2 percent
Asphalt cement	0.25 percent
Temperature of mixing	25 degrees F

PART 3 EXECUTION

3.1 PREPARATION OF ASPHALT BINDER MATERIAL

A continuous supply of the asphalt cement material shall be supplied to the mixer at a uniform temperature. The method of heating shall avoid local overheating of the asphalt cement material. The temperature of unmodified asphalts shall be no more than [160 degrees C][325 degrees F] when added to the aggregates. Modified asphalts shall be no more than [174 degrees C] [350 degrees F] when added to the aggregates.

3.2 PREPARATION OF MINERAL AGGREGATE

The aggregate for the mixture shall be heated and dried prior to mixing. No damage shall occur to the aggregates due to the maximum temperature and rate of heating used. The temperature of the aggregate and mineral filler shall not exceed [175 degrees C][350 degrees F] when the asphalt cement is added. The temperature shall 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.

3.3 PREPARATION OF STONE MATRIX ASPHALT MIXTURE

The aggregates, stabilizer (if used), and the asphalt cement shall be weighed or metered and introduced into the mixer in the amount specified by the JMF. The combined materials shall be mixed until the aggregate and stabilizer obtain a uniform coating of asphalt binder and are thoroughly distributed throughout the mixture. Wet mixing time shall be the shortest time that will produce a satisfactory mixture, but not less than 25 seconds for batch plants. The wet mixing time for all plants shall be established by the Contractor, based on the procedure for determining the percentage of coated particles described in ASTM D 2489, for each individual plant and for each type of aggregate used. The wet mixing time will be set to achieve a minimum of 95 percent coated particles. The moisture content of all SMA upon discharge from the plant shall not exceed 0.5 percent by total weight of mixture as measured by ASTM D 1461.

3.4 PREPARATION OF THE UNDERLYING SURFACE

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NOTE: 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 weatherproofing of the base, improving the bond between the base and SMA, 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 contact, an adjustment to the contract price should be made. Environmental laws in certain states may not allow prime coats to be applied.

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 will need to be covered in the contract documents. Guidance on the use and application of prime coats is contained in UFC 3-250-03 "Standard Practice Manual for Flexible Pavements."

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Immediately before placing the SMA, the underlying course shall be cleaned of dust and debris. A [prime coat] [and/or] [tack coat] shall be applied in accordance with the contract specifications.

3.5 TEST SECTION

Before full production, the Contractor shall place a test section for each JMF used. The contractor shall construct a minimum test section of [75 - 150 meters] [250 - 500 feet] long and two paver passes wide placed in two lanes, with a longitudinal cold joint. The test section shall be of the same depth as the course which it represents. The underlying grade or pavement structure, upon which the test section is to be constructed, shall be the same as the remainder of the course represented by the test section. The equipment used in construction of the test section shall be the same equipment to be used on the remainder of the course represented by the test section. The test section shall be placed as part of the project pavement as approved by the Contracting Officer/Engineer.

3.5.1   Sampling and Testing for Test Section

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NOTE: Select the wording according to method used for design (either AI MS-2 or AASHTO MP8) and delete the wording for the mixture design method not used.

Table 6 applies only to the test section. The limits in Tables 7, 8, and 9, apply to a number of tests run from a lot. This is why the limits listed in Table 6 are different from those listed in Tables 7, 8, and 9.

Select the appropriate VMA requirement to match the selected gradation.

****

One random sample shall be taken at the plant, triplicate specimens compacted, and tested for [density, stability, flow, and laboratory air voids]. A [portion of the same] sample shall be tested for aggregate gradation and asphalt content. Four randomly selected cores shall be taken from the finished pavement mat, and four from the longitudinal joint, and tested for density. Random sampling shall be in accordance with procedures contained in ASTM D 3665. The test results shall be within the tolerances shown in Table 6 for work to continue. If all test results meet the specified requirements, the test section shall remain as part of the project pavement. If test results exceed the tolerances shown, the test section shall be removed and replaced at no cost to the Government and another test section shall be constructed.

Table 6. Test Section Requirements for Material and Mixture Proportions

Property	Specification Limit
Aggregate Gradation-Percent Passing (Individual Test Result)	
4.75 mm and larger	JMF plus or minus 8
2.36, 0.60, and 0.30 mm	JMF plus or minus 6
0.075 mm	JMF plus of minus 2.0
Asphalt Content, Percent (Individual Test Result)	JMF plus or minus 0.5
Laboratory Air Voids, Percent (Average of 3 specimens)	JMF plus or minus 1.0
VMA, Percent (Average of 3 specimens)	17.0 minimum
Stability, newtons (Average of 3 specimens)	5400 minimum
Mat Density, Percent of Maximum Theoretical Density (Average of 4 Random Cores)	94.0 minimum
Joint Density, Percent of Maximum Theoretical Density (Average of 4 Random Cores)	92.0 minimum

Table 6. Test Section Requirements for Material and Mixture Proportions

Property	Specification Limit
Aggregate Gradation-Percent Passing (Individual Test Result)	
No. 4 and larger	JMF plus or minus 8
No. 8, No. 30, and No. 50	JMF plus or minus 6
No. 200	JMF plus of minus 2.0
Asphalt Content, Percent (Individual Test Result)	JMF plus or minus 0.5
Laboratory Air Voids, Percent (Average of 3 specimens)	JMF plus or minus 1.0
VMA, Percent (Average of 3 specimens)	17.0 minimum
Stability, pounds (Average of 3 specimens)	1200 minimum
Mat Density, Percent of Maximum Theoretical Density (Average of 4 Random Cores)	94.0 minimum
Joint Density, Percent of Maximum Theoretical Density (Average of 4 Random Cores)	92.0 minimum

3.5.2 Additional Test Sections

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

3.6 TESTING LABORATORY

The laboratory used to develop the JMF and for Government acceptance testing shall meet the requirements of ASTM D 3666. A certification stating that it meets these requirements or clearly listing all deficiencies shall be signed by the manager of the laboratory and submitted to the Contracting Officer prior to the start of construction. The certification shall contain as a minimum:

a. Qualifications of personnel: laboratory manager, supervising technician, and testing technicians.

b. A listing of equipment to be used in developing the job mix.

c. A copy of the laboratory's quality control system.

d. Evidence of participation in the AASHTO Materials Reference Laboratory (AMRL) program.

3.7 TRANSPORTING AND PLACING

3.7.1 Transporting

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NOTE: 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. Remove last sentence if material transfer vehicle is not used.

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The SMA shall be transported from the mixing plant to the site in clean, tight vehicles. Deliveries shall be scheduled so that placing and compacting of mixture is uniform with minimum stopping and starting of the paver. Adequate artificial lighting shall be provided for night placements. Hauling over freshly placed material will not be permitted until the material has been compacted as specified, and allowed to cool to 60 degrees C [140 degrees F]. To deliver mix to the paver, the Contractor shall use a material transfer vehicle which shall be operated to produce continuous forward motion of the paver.

3.7.2 Placing

The mix shall be placed and compacted at a temperature suitable for obtaining density, surface smoothness, and other specified requirements.

Upon arrival, the mixture shall be placed to the full width by an asphalt paver; it shall be struck off in a uniform layer of such depth that, when the work is completed, it shall have the required thickness and conform to the grade and contour indicated. The speed of the paver shall be regulated to eliminate pulling and tearing of the asphalt mat. Unless otherwise permitted, placement of the mixture shall begin along the centerline of a crowned section or on the high side of areas with a one-way slope. The mixture shall be placed in consecutive adjacent strips having a minimum width of 3 meters [10 feet]. The longitudinal joint of the SMA course shall be offset from the longitudinal joint in the course immediately below by at least 300 mm [1 foot]; however, the joint in the surface course shall be at the centerline of the pavement. Transverse joints in the SMA course shall be offset by at least 3 meters [10 feet] from transverse joints in the previous course. Transverse joints in adjacent lanes shall be offset a minimum of 3 meters [10 feet]. 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.

3.8 COMPACTION OF MIXTURE

After placing, the mixture shall be thoroughly and uniformly compacted by rolling with steel-wheel rollers. Pneumatic rollers will not be used to compact SMA. The surface shall be compacted as soon as possible without causing displacement, cracking or shoving. The sequence of rolling operations and the type of rollers used (with the exception noted) shall be at the discretion of the Contractor, with the exception that the Contractor shall not apply more than three passes with a vibratory roller in the vibrating mode. The speed of the roller shall, at all times, be sufficiently slow to avoid 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, shall be corrected at once. Sufficient rollers shall be furnished to handle the output of the plant. Rolling shall 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 shall be kept properly moistened, but excessive water will not be permitted. In areas not accessible to the roller, the mixture shall be thoroughly compacted with hand tampers. Any mixture that becomes loose and broken, mixed with dirt, contains check-cracking, or is in any way defective shall be removed full depth, replaced with fresh hot mixture and immediately compacted to conform to the surrounding area. This work shall be done at the Contractor’s expense. Skin patching will not be allowed.

3.9 JOINTS

The formation of joints shall be made ensuring a continuous bond between the courses and to obtain the required density. All joints shall have the same texture as other sections of the course and meet the requirements for smoothness and grade.

3.9.1 Transverse Joints

The roller shall 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 shall be made by means of placing a bulkhead or by tapering the course. The tapered edge shall 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 shall be removed from the project. In both methods, all contact surfaces shall be given a light tack coat of asphalt material before placing any fresh mixture against the joint.

3.9.2 Longitudinal Joints

Longitudinal joints that are irregular, damaged, uncompacted, cold (less than 80 degrees C [175 degrees F] at the time of placing the adjacent lane), or otherwise defective, shall be cut back a minimum of 50 mm [2 inches] from the edge with a cutting wheel to expose a clean, sound vertical surface for the full depth of the course. All cutback material shall be removed from the project. All contact surfaces shall 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.

3.10 CONTRACTOR QUALITY CONTROL

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NOTE: The Contractor may be able to meet the specified quality control requirements with in-house capability or may have to hire a material testing firm to provide the required quality control testing.

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3.10.1 General Quality Control Requirements

The Contractor shall develop an approved Quality Control Plan. SMA for payment shall not be produced until the quality control plan has been approved. The plan shall address all elements which affect the quality of the pavement including, but not limited to:

a. Mix Design.

b. Aggregate Grading.

c. Quality of Materials.

d. Stockpile Management.

e. Proportioning.

f. Mixing and Transportation.

g. Mixture Volumetric.

h. Moisture Content of Mixtures.

i. Placing and Finishing.

j. Joints.

k. Compaction.

l. Surface Smoothness.

3.10.2 Testing Laboratory

The Contractor shall provide a fully equipped asphalt laboratory located at the plant or job site. The effective working area of the laboratory shall 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 shall be adequate to illuminate all working areas. It shall be equipped with heating and air conditioning units to maintain a temperature of [24 degrees C plus or minus 2.3 degrees C] [75 degrees F plus or minus 5 degrees F]. Laboratory facilities shall be kept clean and all equipment shall be maintained in proper working condition. The Contracting Officer/ Engineer shall be permitted unrestricted access to inspect the Contractor’s laboratory facility, to witness quality control activities, and to perform any check testing desired. 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 shall be suspended immediately and will not be permitted to resume until the deficiencies are corrected.

3.10.3 Quality Control Testing

The Contractor shall perform all quality control tests applicable to these specifications as set forth in the Quality Control Program. The testing program shall include, but shall 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 Quality Control Testing Plan shall be developed as part of the Quality Control Program.

3.10.3.1 Asphalt Content

A minimum of two test to determine asphalt content will be performed per lot (a lot is defined in paragraph MATERIAL ACCEPTANCE AND PERCENT PAYMENT) by one of the following methods: extraction method in accordance with ASTM D 2172, Method A or B, the ignition method in accordance with the ASTM D 6307, or the nuclear method in accordance with ASTM D 4125, 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, shall 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 shall be used in the calculation of the asphalt content for the mixture.

3.10.3.2 Gradation

Aggregate gradations shall be determined a minimum of twice per lot from mechanical analysis of recovered aggregate in accordance with ASTM D 5444. When asphalt content is determined by the nuclear method, aggregate gradation shall be determined from hot bin samples on batch plants, or from the cold feed on drum mix plants. For batch plants, aggregates shall be tested in accordance with ASTM C 136 using actual batch weights to determine the combined aggregate gradation of the mixture. All samples will be taken in accordance with ASTM D 75.

3.10.3.3 Temperatures

Temperatures shall 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.

3.10.3.4 Aggregate Moisture

The moisture content of aggregate used for production shall be determined a minimum of once per lot in accordance with ASTM C 566.

3.10.3.5 Moisture Content of Mixture

The moisture content of the mixture shall be determined at least once per lot in accordance with ASTM D 1461 or an approved alternate procedure.

3.10.3.6 Laboratory Air Voids, Marshall Stability and Flow

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NOTE: If the JMF was designed according to AASHTO MP8, delete the requirements for stability and flow.

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Mixtures samples shall be taken at least four times per lot and compacted into specimens, using 50 blows per side with the Marshall hammer as described in UFC 3-250-03. After compaction, the laboratory air voids of each specimen shall be determined, as well as the Marshall stability and flow.

3.10.3.7 In-Place Density

The Contractor shall conduct any necessary testing to ensure the specified density is achieved. A nuclear gauge may be used to monitor pavement density in accordance with ASTM D 2950.

3.10.3.8 Grade and Smoothness

The Contractor shall conduct the necessary checks to ensure the grade and smoothness requirements are met in accordance with paragraph MATERIAL ACCEPTANCE AND PERCENT PAYMENT.

3.10.3.9 Additional Testing

Any additional testing, which the Contractor deems necessary to control the process, may be performed at the Contractor’s option.

3.10.3.10 QC Monitoring

The Contractor shall 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 quality control testing and to perform duplicate testing as a check to the Contractor’s quality control testing.

3.10.4 Sampling

When directed by the Contracting Officer, the Contractor shall sample and test any material which appears inconsistent with similar material being produced, unless such material is voluntarily removed and replaced or deficiencies corrected by the Contractor. All sampling shall be in accordance with standard procedures specified.

3.10.5 Control Charts

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NOTE: If the JMF was designed according to AASHTO MP8, delete the requirements for plotting stability and flow.

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For process control, the Contractor shall establish and maintain linear control charts on both individual samples and the running average of last four samples for the parameters listed in Table 7, as a minimum. These control charts shall be posted as directed by the Contracting Officer and shall be kept current at all times. The control charts shall identify the project number, the test parameter being plotted, the individual sample numbers, the Action and Suspension Limits listed in Table 7 applicable to the test parameter being plotted, and the Contractor’s test results. Target values from the JMF shall 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 shall take immediate steps to bring the process back in control. When the test results exceed either applicable Suspension Limit, the Contractor shall halt production until the problem is solved. The Contractor shall use the control charts as part of the process control system for identifying trends so that potential problems can be corrected before they occur. Decisions concerning mix modifications shall be made based on analysis of the results provided in the control charts. The Quality Control Plan shall indicate the appropriate action, which shall be taken to bring the process into control when certain parameters exceed their Action Limits.

Table 7. Action and Suspension Limits for the Parameters to be Plotted on Individual and Running Average Control Charts

Parameter to be Plotted	Individual Samples Action Limit	Individual Samples Suspension Limit	Running Average of Last Four Samples Action Limit	Running Average of Last Four Samples Suspension Limit
4.75 mm sieve, Cumulative Percent Passing, deviation from JMF target; plus or minus values	6	8	4	5
0.6 mm sieve, Cumulative Percent Passing, deviation from JMF target; plus or minus values	4	6	3	4
0.075 mm sieve, Cumulative Percent Passing, deviation from JMF target; plus or minus values	1.4	2.0	1.1	1.5
Stability, newtons (minimum)	5780	5340	6230	5780
Asphalt content, percent deviation from JMF target; plus or minus value	0.4	0.5	0.2	0.3
Laboratory Air Voids, percent deviation from JMF target value	No specific action and suspension limits set since this parameter is used to determine percent payment			
In-place Mat Density, percent of maximum theoretical density	No specific action and suspension limits set since this parameter is used to determine percent payment			
In-place Joint Density, percent of maximum theoretical density	No specific action and suspension limits set since this parameter is used to determine percent payment			

Table 7. Action and Suspension Limits for the Parameters to be Plotted on Individual and Running Average Control Charts

Parameter to be Plotted	Individual Samples Action Limit	Individual Samples Suspension Limit	Running Average of Last Four Samples Action Limit	Running Average of Last Four Samples Suspension Limit
No. 4 sieve, Cumulative Percent Passing, deviation from JMF target; plus or minus values	6	8	4	5
No. 30 sieve, Cumulative Percent Passing, deviation from JMF target; plus or minus values	4	6	3	4
No. 200 sieve, Cumulative Percent Passing, deviation from JMF target; plus or minus values	1.4	2.0	1.1	1.5
Stability, pounds (minimum)	1300	1200	1400	1300
Asphalt content, percent deviation from JMF target; plus or minus value	0.4	0.5	0.2	0.3
Laboratory Air Voids, percent deviation from JMF target value	No specific action and suspension limits set since this parameter is used to determine percent payment			
In-place Mat Density, percent of maximum theoretical density	No specific action and suspension limits set since this parameter is used to determine percent payment			
In-place Joint Density, percent of maximum theoretical density	No specific action and suspension limits set since this parameter is used to determine percent payment			

3.11 MATERIAL ACCEPTANCE AND PERCENT PAYMENT

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NOTE: 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 in-house testing capability to provide the QA testing required by this section will not always be available; in this case, it is recommended that an independent material testing company be hired to provide the QA testing for the project. 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 listed 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 there is no way of hiring an independent testing laboratory to perform the QA testing.

The QA testing program 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 anyway for laboratory air void determination. This additional testing, if conducted, is not included as part of this specification since the parameters are not used as a basis of pay.

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The Government's quality assurance (QA) program for this project, specified below, will be separate and distinct from the Contractor's quality control (QC) program specified above. Testing for acceptability of work will be performed by the Government or by an independent laboratory hired by the Contracting Officer/Engineer, except for smoothness testing which shall be performed by the Contractor. 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 2000 metric tons [2000 short tons]. 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. In order to evaluate laboratory air voids and in-place (field) density, each lot will be divided into four equal sublots.

3.11.1 Percent Payment

When a lot of material fails to meet the specification requirements for 100 percent pay as outlined in the following paragraphs, that lot shall be removed and replaced, or accepted at a reduced price which will be computed by multiplying the unit price by the lot 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. At the end of the project, an average of all lot pay factors will be calculated. If this average lot pay factor exceeds 95.0 percent, then the percent payment for the entire project will be 100 percent of the unit bid price. If the average lot pay factor is less than 95.0 percent, then each lot will be paid for at the unit price multiplied by that lot's pay factor. For any lots which are less than [2000 metric tons] [2000 pound tons], a weighted lot pay factor will be used to calculate the average lot pay factor.

3.11.2 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 conforming to 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 UFC 3-250-03. The specimens will be compacted within 2 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.

3.11.3 Additional Sampling and Testing

The Contracting Officer/Engineer reserves the right to direct additional samples and tests for any area which appears to deviate from the specification requirements. The cost of any additional testing will be paid for by the Government. 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.

3.11.4 Laboratory Air Voids

Laboratory air voids will be calculated in accordance with ASTM D 3203 by determining the Marshall density of each lab compacted specimen using ASTM D 2726 and determining the theoretical maximum density of every other sublot sample using ASTM D 2041. Laboratory air void calculations for each sublot will use the latest theoretical maximum density values obtained, for either that sublot or the previous sublot. 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 8. All laboratory air void tests will be completed and reported within 24 hours after completion of construction of each lot.

Table 8. Pay Factor Based on Laboratory Air Voids

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

3.11.5 Mean Absolute Deviation

An example of the computation of mean absolute deviation for laboratory air voids is as follows: Assume that the laboratory air voids are determined from 4 random samples of a lot (where 3 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. The mean absolute deviation is then:

Mean Absolute Deviation = $(|3.5 - 4.0| + |3.0 - 4.0| + |4.0 - 4.0| + |3.7 - 4.0|)/4 = (0.5 + 1.0 + 0.0 + 0.3)/4 = (1.8)/4 = 0.45$

The mean absolute deviation for laboratory air voids is determined to be 0.45. It can be seen from Table 9 that that lot’s pay factor based on laboratory air voids is 100 percent.

3.11.6 In-place Density

3.11.6.1 General Density Requirements

For determining in-place density, one random core will be taken by the Government Engineer 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 full thickness of the layer being placed. When the random core is less than 25 mm (1 inch) 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.

3.11.6.2 Mat and Joint Densities

The average in-place mat and joint densities are expressed as a percentage of the average maximum theoretical density for the lot. The maximum theoretical density for each lot will be determined as the average maximum theoretical density of the four random samples. The average in-place mat density and joint density for a lot are determined and compared with Table 9 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 9. The area associated with the joint is then determined and will be considered to be [3 meters] [10 feet] wide times the length of completed longitudinal construction joint in the lot. This area will not 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 SMA 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 example below). 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 maximum theoretical density on both sides of a longitudinal joint is different, the average of these two densities will be used as the maximum theoretical density needed to calculate the percent joint density. All density results for a lot will be completed and reported within 24 hours after the construction of that lot.

Table 9. Pay Factor Based on In-Place Density

Average Mat Density (4 Cores)	Pay Factor, Percent	Average Joint Density (4 Cores)
94.0	100.0	92.0, up 101.0
93.9	100.0	91.9
93.8 or 98.1	99.9	91.8
93.7	99.8	91.7
93.6 or 98.2	99.6	91.6
93.5	99.4	91.5
93.4 or 98.3	99.1	91.4
93.3	98.7	91.3
93.2 or 98.4	98.3	91.2
93.1	97.8	91.1
93.0 or 98.5	97.3	90.0
92.9	96.3	90.9
92.8 or 98.6	94.1	90.8
92.7	92.2	90.7
92.6 or 98.7	90.3	90.6
92.5	87.9	90.5
92.4 or 98.8	85.7	90.4
92.3	83.3	90.3
92.2 or 98.9	80.6	90.2
92.1	78.0	90.1
92.0 or 99.0	75.0	90.0
below 92.0, above 101.0	0.0 (reject)	below 90.0, above 101.0

3.11.6.3 Pay Factor Based on In-place Density

An example of the computation of a pay factor (in inch-pound units only) based on in-place density, is as follows: Assume the following test results for field density made on the lot: (1) Average mat density = 93.2 percent (of maximum theoretical density), (2) Average joint density = 91.0 percent (of maximum theoretical density), (3) Total area of lot = 30,000 square feet, (4) Length of completed longitudinal construction joint = 2000 feet.

a. Step 1: Determine pay factor based on mat density and on joint density, using Table 9:

   Mat density of 93.2 percent = 98.3 pay factor

   Joint density of 91.0 percent = 97.3 pay factor

b. Step 2: Determine ratio of joint area (length of longitudinal joint × 10 ft) to mat area (total paved area in the lot): Multiply the length of completed longitudinal construction joint by the specified 10 ft width and divide by the mat area (total paved area in the lot).

   (2000 ft × 10 ft)/30000 sq ft = 0.6667 ratio of joint area to mat area (ratio)

c. 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 percent

d. 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 percent. Weighted pay factor for joint density: 98.2 percent

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

3.11.7 Grade

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NOTE: The grade and surface smoothness requirements specified below are for the final wearing surface only. If there is a requirement to test and control the grade and smoothness for the intermediate courses, i.e., when the intermediate courses will be exposed to traffic, slight modifications to this specification will be required.

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The final wearing surface of pavement shall conform to the elevations and cross sections shown and shall vary not more than [9 mm][0.03 foot] for runways or [15 mm][0.05 foot] for taxiways and aprons from the plan grade established and approved at site of work. Finished surfaces at juncture with other pavements shall 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. The final wearing surface of the pavement will be tested for conformance with specified plan grade requirements. The grade will be determined by running lines of levels at intervals of [7.6 meters][25 feet], or less, longitudinally and transversely, to determine the elevation of the completed pavement surface. Within 5 working days after the completion of a particular lot incorporating the final wearing surface, the Contracting Officer will inform the Contractor in writing, of the results of the grade-conformance tests. When more than 5 percent of all measurements made within a lot are outside the [9 or 15 mm][0.03 or 0.05 foot] tolerance, the pay factor based on grade for that lot will be 95 percent. In areas where the grade exceeds the tolerance by more than 50 percent, the Contractor shall remove the surface lift full depth; the Contractor shall then replace the lift with SMA to meet specification requirements, at no additional cost to the Government. Diamond grinding may be used 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.

3.11.8 Surface Smoothness

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NOTE: Edit these paragraphs as appropriate to the project. It is desired to restrict surface smoothness testing and evaluation to either straightedge method or profilograph method. Retain the one and delete the other; otherwise, retain both as a Contractor's option. Generally, designer should require use of the profilograph method. If the profilograph method is allowed, and there are areas with dimensions less than 60 meters (200 feet) in any direction, part of the straightedge method must be retained for these short runs.

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The Contractor shall use [one] [both] of the following methods to test and evaluate surface smoothness of the pavement. All testing shall be performed in the presence of the Contracting Officer/Engineer. Detailed notes of the results of the testing shall be kept and a copy furnished to the Government Engineer immediately after each day's testing. The profilograph method shall be used for all longitudinal and transverse testing, except where the runs would be less than [60 meters] [200 feet] in length and the ends where the straightedge shall be used. Where drawings show required deviations from a plane surface (crowns, drainage inlets, etc.), the surface shall be finished to meet the approval of the Contracting Officer/Engineer.

3.11.8.1 Smoothness Requirements

a. Straightedge Testing: The finished surfaces of the pavements shall have no abrupt change of [3 mm] [1/8 inch] or more, and all pavements shall be within the tolerances specified in Table 10 when checked with an approved [4-meter] [12-foot] straightedge.

Table 10. Straightedge Surface Smoothness—Pavements

Pavement Category	Direction of Testing	Tolerance, mm
Runways and taxiways	Longitudinal	3
	Transverse	6
Calibration hardstands and compass swinging bases	Longitudinal	3
	Transverse	3
All other airfield and helicopter paved areas	Longitudinal	6
	Transverse	6

Table 10. Straightedge Surface Smoothness—Pavements

Pavement Category	Direction of Testing	Tolerance, inches
Runways and taxiways	Longitudinal	1/8
	Transverse	1/4
Calibration hardstands and compass swinging bases	Longitudinal	1/8
	Transverse	1/8
All other airfield and helicopter paved areas	Longitudinal	1/4
	Transverse	1/4

b. Profilograph Testing: The finished surfaces of the pavements shall have no abrupt change of [3 mm] [1/8 inch] or more, and all pavement shall have a Profile Index not greater than specified in Table 11 when testing with an approved California-type profilograph. If the extent of the pavement in either direction is less than [60 meters] [200 feet], that direction shall be tested by the straightedge method and shall meet requirements specified above.

3.11.8.2 Testing Method

After the final rolling, but not later than 24 hours after placement, the surface of the pavement in each entire lot shall be tested by the Contractor in such a manner as to reveal all surface irregularities exceeding the tolerances specified above. Separate testing of individual sub lots is not required. If any pavement areas are ground, these areas shall be retested immediately after grinding. The entire area of the pavement shall be tested in both a longitudinal and a transverse direction on parallel lines. The transverse lines shall be [4.5 meters] [15 feet] or less apart, as directed. The longitudinal lines shall be at the centerline of each paving lane for lines less than [6.1 meters] [20 feet] and at the third points for lanes [6.1 meters] [20 feet] or greater. Other areas having obvious deviations shall also be tested. Longitudinal testing lines shall be continuous across all joints.

a. Straightedge Testing. The straightedge shall be held in contact with the surface and moved ahead one-half the length of the straightedge for each successive measurement. The amount of surface irregularity shall be determined by placing the freestanding (unleveled) straightedge on the pavement surface and allowing it to rest upon the two highest spots covered by its length, and measuring the maximum gap between the straightedge and the pavement surface in the area between these two high points.

Table 11. Profilograph Surface Smoothness—Pavements

Pavement Category	Direction of Testing	Maximum Specified Profile Index (mm/km)
Runways	Longitudinal Transverse	110 140
Taxiways	Longitudinal Transverse	140 (Use Straightedge)
Calibration hardstands and compass swinging bases		(Use Straightedge)
All other airfield and helicopter paved areas	Longitudinal Transverse	140 140

Table 11. Profilograph Surface Smoothness—Pavements

Pavement Category	Direction of Testing	Maximum Specified Profile Index (inches/mile)
Runways	Longitudinal Transverse	7 9
Taxiways	Longitudinal Transverse	9 (Use Straightedge)
Calibration hardstands and compass swinging bases		(Use Straightedge)
All other airfield and helicopter paved areas	Longitudinal Transverse	9 9

b. Profilograph Testing. Profilograph testing shall be performed using approved equipment and procedures described in CDT Test 526. The equipment shall utilize electronic recording and automatic computerized reduction of data to indicate “must-grind” bumps and the Profile Index for the pavement. The “blanking band” shall be [5 mm] [0.2 inches] wide and the “bump template” shall span [25 mm] [1 inch] with an offset of [10 mm] [0.4 inch]. The profilograph shall be operated by an approved, factory-trained operator on the alignments specified above. A copy of the reduced tapes shall be furnished to the Government at the end of each day’s testing.

3.11.8.3 Payment Adjustment for Smoothness

a. Straightedge Testing. Location and deviation from straightedge for all measurements shall be recorded. When between 5.0 and 10.0 percent of all measurements made within a lot exceed the tolerance specified in paragraph Smoothness Requirements above, after any reduction of high spots or removal and replacement, the computed pay factor for that lot based on surface smoothness, will be 95 percent. When more than 10.0 percent of all measurements exceed the tolerance, the computed pay factor will be 90 percent. When between 15.0 and 20.0 percent of all measurements exceed the tolerance, the computed pay factor will be 75 percent. When 20.0 percent or more of the measurements exceed the tolerance, the lot shall be removed and replaced at no additional cost to the Government-Owner. Regardless of the above, any small individual area with surface deviation which exceeds the tolerance given above by more than 50 percent, shall be corrected by diamond grinding to meet the specification requirements above or shall be removed and replaced at no additional cost to the Government.

b. Profilograph Testing. Location and data from all profilograph measurements shall be recorded. When the Profile Index of a lot exceeds the tolerance specified in paragraph Smoothness Requirements above by [16 mm/km] [1.0 inch/mile], but less than [32 mm/km] [2.0 inches/mile], after any reduction of high spots or removal and replacement, the computed pay factor for that lot based on surface smoothness will be 95 percent. When the Profile Index exceeds the tolerance by [32 mm/km] [2.0 inches/mile], but less than [47 mm/km] [3.0 inches/mile], the computed pay factor will be 90 percent. When the Profile Index exceeds the tolerance by [47 mm/km] [3.0 inches/mile], but less than [63 mm/km] [4.0 inches/mile], the computed pay factor will be 75 percent. When the Profile Index exceeds the tolerance by [63 mm/km] [4.0 inches/mile] or more, the lot shall be removed and replaced at no additional cost to the Government-Owner. Regardless of the above, any small individual area with surface deviation which exceeds the tolerance given above by more than [79 mm/km] [5.0 inches/mile] or more, shall be corrected by grinding to meet the specification requirements above or shall be removed and replaced at no additional cost to the Government-Owner.

c. Bumps. (“Must Grind” Areas). Any bumps (“must grind” areas) shown on the profilograph trace which exceed [10 mm] [0.4 inch] in height shall be reduced by diamond grinding until they do not exceed [7.5 mm] [0.3 inch] when retested. Such grinding shall be tapered in all directions to provide smooth transitions to areas not requiring grinding. The following will not be permitted: (1) skin patching for correcting low areas, (2) planing or milling for correcting high areas. At the Contractor’s option, pavement areas, including ground areas, may be rechecked with the profilograph in order to record a lower Profile Index.

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