Burns Cooley Dennis, Inc.

Geotechnical, Pavements and Materials Consultants

IMPLEMENTATION OF SUPERPAVE MIX DESIGN FOR AIRFIELD PAVEMENTS

Volume III – Proposed Changes to Item P-401 Specification

for

AAPTP PROJECT 04-03

Submitted to

Airfield Asphalt Pavement Technology Program

By

Burns Cooley Dennis, Inc.
551 Sunnybrook Road
Ridgeland, Mississippi 39157

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INTRODUCTION

Approximately ninety percent of America's paved runways are paved with hot mix asphalt (HMA). However, only a small percentage of the total HMA placed in the United States is used for airfields. Historically, HMA for airfield pavements have been designed using the Marshall mix design method. Conversely, the vast majority of non-airfield HMA designed during the last 5 to 7 years has been designed using the Superpave mix design system. The percentage of HMA that is being designed using the Superpave mix design system is increasing every year. Therefore, mix design experience is being gained by HMA contractors, commercial labs, and industry personnel in the area of Superpave. Since the Marshall mix design procedure is becoming the exception to the rule, industry personnel are becoming increasingly unfamiliar with the Marshall mix design method. The airfield industry needs to implement the Superpave mix design system in airfield pavements in order to benefit from the industry's experience with Superpave.

Objective

The objectives of this study were to adapt the Superpave mix design system for designing airfields HMA mixes.

Organization

The final report for AAPTP 04-03 is divided into three volumes. Volume I of the Final Report provides documentation of all research results. Detailed discussions are provided on the research approach, test results, analyses, conclusions and recommendations for adapting Superpave for designing airfield HMA. The second volume of the final report provides guidance on the selection of mixes for airfield uses. Volume III presents revised sections of the Item P-401 specification to be placed in a guide specification for designing HMA mixes using the recommended mix design method.

This volume of the report, Volume III, includes the proposed changes/additions to the Item P-401 guide specification for the design of HMA mixes using the Superpave gyratory compactor. Sections from Item P-401 that do not contain recommended changes are not included in this document.

Section 401-2.1 AGGREGATE –This section presents changes to the coarse and fine aggregate requirements, simplifies the Flat and Elongated particle requirement and introduces a new fine aggregate test, the Uncompacted Void Content of Fine Aggregate.

401-2.1 AGGREGATE. Aggregates shall consist of crushed stone, crushed gravel, or crushed slag with or without natural sand or other inert finely divided mineral aggregate. The portion of materials retained on the No. 4 (4.75 mm) sieve is coarse aggregate. The portion passing the No. 4 (4.75 mm) sieve and retained on the No. 200 (0.075 mm) sieve is fine aggregate, and the portion passing the No. 200 (0.075 mm) sieve is mineral filler.

a. Coarse Aggregate. Coarse aggregate shall consist of sound, tough, durable particles, free from adherent films of matter that would prevent thorough coating and bonding with the bituminous material and be free from organic matter and other deleterious substances. The percentage of wear shall not be greater than 40 percent when tested in accordance with ASTM C 131. The sodium sulfate soundness loss shall not exceed 10 percent, or the magnesium sulfate soundness loss shall not exceed 13 percent, after five cycles, when tested in accordance with ASTM C 88.

* *

Aggregates with a higher percentage loss of wear or soundness may be specified in lieu of those above, provided a satisfactory service record under similar conditions of service and exposure has been demonstrated.

* *

Aggregate shall contain at least [ ] percent by weight of individual pieces having two or more fractured faces and [ ] percent by weight having at least one fractured face. The area of each face shall be equal to at least 75 percent of the smallest midsectional area of the piece. When two fractured faces are contiguous, the angle between the planes of fractures shall be at least 30 degrees to count as two fractured faces. Fractured faces shall be obtained by crushing.

* *

For pavements designed for aircraft tire pressures less than 100 psi, the Engineer shall specify 80 percent for two or more fractured faces and 85 percent for one fractured face. For pavements designed for aircraft tire pressures from 100 psi to 200 psi, the Engineer shall specify 90 percent for two or more fractured faces and 90 percent for one fractured face. For pavements designed for aircraft tire pressures more than 200 psi, the Engineer shall specify 95 percent for two or more fractured faces and 95 percent for one fractured face.

In areas where slag is not available or desired, the references to it should be deleted from all aggregate paragraphs.

* *

The aggregate shall not contain more than a total of 10 percent, by weight, of flat and elongated particles, when tested in accordance with ASTM D 4791 with a maximum to minimum diameter ratio of 5:1.

* *

The Engineer may specify ASTM D 4791 with a ratio of 3:1. If so, replace the above paragraph as follows: "The aggregate shall not contain more than a total of 20

percent by weight of flat and elongated particles when tested in accordance with ASTM D4791 with a value of 3:1."

* *

Slag shall be air-cooled, blast furnace slag, and shall have a compacted weight of not less than 70 pounds per cubic foot (1.12 mg/cubic meter) when tested in accordance with ASTM C 29.

b. Fine Aggregate. Fine aggregate shall consist of clean, sound, durable, angular shaped particles produced by crushing stone, slag, or gravel that meets the requirements for wear and soundness specified for coarse aggregate. The aggregate particles shall be free from coatings of clay, silt, or other objectionable matter and shall contain no clay balls. The fine aggregate, including any blended material for the fine aggregate, shall have a plasticity index of not more than 6 and a liquid limit of not more than 25 when tested in accordance with ASTM D 4318.

Natural (nonmanufactured) sand may be used to obtain the gradation of the aggregate blend or to improve the workability of the mix. The amount of sand to be added will be adjusted to produce mixtures conforming to requirements of this specification. The fine aggregate shall not contain more than [ ] percent natural sand by weight of total aggregates. If used, the natural sand shall meet the requirements of ASTM D 1073 and shall have a plasticity index of not more than 6 and a liquid limit of not more than 25 when tested in accordance with ASTM D 4318.

The aggregate blend shall have sand equivalent values of [ ] or greater when tested in accordance with ASTM D 2419.

The fine aggregate blend shall have a minimum percent uncompacted voids of fine aggregate of [ ] when tested by ASTM C 1252 Method A.

* *

The addition of natural sand to a mix containing all crushed coarse and fine aggregates will normally increase its workability and compactibility. However, the addition of excessive amounts of natural sand tends to decrease the stability of the mixture. For pavements designed for aircraft tire pressures less than 100 psi, a maximum of 20 percent natural sand may be included as long as all other requirements are met. For pavements designed for aircraft tire pressures 100 psi or more 15 percent natural sand may be included as long as all other requirements are met.

For pavements designed for aircraft tire pressures less than or equal to 200 psi, the Engineer shall specify a minimum sand equivalent value of 40. For pavements designed for aircraft tire pressures more than 200 psi, the Engineer shall specify a sand equivalent value of 50.

For pavements designed for aircraft tire pressures less than 100 psi, the Engineer shall specify a minimum percent uncompacted voids of fine aggregate of 40. For pavements designed for aircraft tire pressures of 100 psi or more, the Engineer shall specify a minimum percent uncompacted voids of fine aggregate of 45.

* *

c. Sampling. ASTM D 75 shall be used in sampling coarse and fine aggregate, and ASTM C 183 shall be used in sampling mineral filler.

Section 401-3.2 JOB MIX FORMULA – In this section, the Asphalt Institute reference was changed, the TSR requirement was increased, and the requirements for the Job Mix Formula submittal were changed. Criteria is also given for the mix design volumetrics and aggregate gradations.

401-3.2 JOB MIX FORMULA. No bituminous mixture for payment shall be produced until a job mix formula has been approved in writing by the Engineer. The bituminous mixture shall be designed using procedures contained in Chapter 5, SUPERPAVE MIX DESIGN, of the Asphalt Institute's Superpave Series No. 2 (SP-2), Superpave Mix Design, 3rd edition.

The design criteria in Table 1 are target values necessary to meet the acceptance requirements contained in paragraph 401-5.2b. The criteria are based on a production process which has a material variability with the following standard deviations:

Air Voids (%) = 0.65

If material variability exceeds the standard deviations indicated, the job mix formula and subsequent production targets for air voids shall be targeted close to the mid-range of the criteria in order to meet the acceptance requirements.

Tensile Strength Ratio (TSR) of the composite mixture, as determined by ASTM D 4867, shall not be less than 80, nor shall the dry strength be less than 200 psi as determined by ASTM D 1074. Anti-stripping agent shall be added to the asphalt, as necessary, to produce a TSR of not less than 80 while maintaining a minimum dry strength of 200 psi. If an antistrip agent is required, it will be provided by the Contractor at no additional cost to the Owner.

The job mix formula shall be submitted in writing by the Contractor to the Engineer at least [ ] days prior to the start of paving operations and shall include as a minimum:

a. Percent passing each sieve size for total combined gradation, individual gradation of all aggregate stockpiles and percent by weight of each stockpile used in the job mix formula.

b. Percent of asphalt binder.

c. Asphalt binder performance grade.

d. Number of gyrations from the Superpave Gyratory Compactor.

e. Mixing temperature.

f. Compaction temperature.

g. Temperature of mix when discharged from the mixer.

h. Temperature-viscosity relationship of the asphalt binder.

i. Plot of the combined gradation on the Federal Highway Administration (FHWA) 45 power gradation curve.

j. Graphical plots of $\%G_{mm}@N_{ini}$, air voids, voids in the mineral aggregate, voids filled with asphalt and dust-to-binder ratio versus asphalt content.

k. Percent natural sand.

l. Percent uncompacted voids of fine aggregate

m. Percent fractured faces.

n. Percent by weight of flat and elongated particles (and criteria).

o. Tensile Strength Ratio (TSR).

p. Dry strength.

q. Antistrip agent (if required).

The Contractor shall submit to the Engineer the results of verification testing of three (3) asphalt samples prepared at the optimum asphalt content. The average of the results of this testing shall indicate conformance with the job mix formula requirements specified in Tables 1, 2 and 3.

When the project requires asphalt mixtures of differing aggregate gradations, a separate job mix formula and the results of job mix formula verification testing must be submitted for each mix.

The job mix formula for each mixture shall be in effect until a modification is approved in writing by the Engineer. Should a change in sources of materials be made, a new job mix formula must be submitted within [ ] days and approved by the Engineer in writing before the new material is used. After the initial production job mix formula(s) has/have been approved by the Engineer and a new or modified job mix formula is required for whatever reason, the subsequent cost of the Engineer's approval of the new or modified job mix formula will be borne by the Contractor. There will be no time extension given or considerations for extra costs associated with the stoppage of production paving or restart of production paving due to the time needed for the Engineer to approve the initial, new or modified job mix formula.

* *

The Engineer shall specify the number of days. A minimum of 10 days is recommended.

The Superpave Design Criteria applicable to the project shall be specified by the Engineer from the information shown below and inserted into Table 1. Asterisks denote insert points.

Test Property		Pavements Designed for Design Aircrafts with Tire Pressures of		
		<100 psi	100 psi - 200 psi	> 200 psi
Initial Gyration Level		6	7	7
Design Gyration Level		50	65	80
Required Relative Density, Percent of Theoretical Maximum Specific Gravity	$N_{initial}$	≤90.5	≤90.5	≤90.0
	N_{design}	96.0	96.0	96.0
Voids in Mineral Aggregate (VMA), Percent Minimum		See Table 2		
Voids Filled with Asphalt (VFA) Range, Percent		70-80	65-78	65-75
Dust-to-Binder Ratio Range		0.6-1.4	0.6-1.4	0.6-1.4

* *

TABLE 1. SUPERPAVE DESIGN CRITERIA

TEST PROPERTY		
Initial Gyration Level		*
Design Gyration Level		*
Required Relative Density, Percent of Theoretical Maximum Specific Gravity	$N_{initial}$	*
	N_{design}	*
Voids in Mineral Aggregate (VMA), Percent Minimum		See Table 2
Voids Filled with Asphalt (VFA) Range, Percent		*
Dust-to-Binder Ratio Range		*

TABLE 2. MINIMUM PERCENT VOIDS IN MINERAL AGGREGATE

Maximum Aggregate Size		Minimum VMA
in.	**mm**	**Percent**
½	12.5	15.0
¾	19.0	14.0
1	25.0	13.0
1-½	37.5	12.0

* *

Modifications to the minimum Voids in Mineral Aggregate (VMA) as found in Table 2 may be made depending on the definition of maximum particle size and/or local conditions.

* *

The mineral aggregate shall be of such size that the percentage composition by weight, as determined by laboratory sieves, will conform to the gradation or gradations specified in Table 3 when tested in accordance with ASTM C 136 and C 117.

The gradations in Table 3 represent the limits that shall determine the suitability of aggregate for use from the sources of supply. The aggregate, as selected (and used in the JMF), shall have a gradation within the limits designated in Table 3 and shall not vary from the low limit on one sieve to the high limit on the adjacent sieve, or vice versa, but shall be well graded from coarse to fine.

Deviations from the final approved mix design for bitumen content and gradation of aggregates shall be within the action limits for individual measurements as specified in paragraph 401-6.5a. The limits still will apply if they fall outside the master grading band in Table 3.

The maximum size aggregate used shall not be more than 0.4 of the thickness of the course being constructed except where otherwise shown on the plans or ordered by the Engineer.

TABLE 3. AGGREGATE - BITUMINOUS PAVEMENTS

Sieve Size	Percentage by Weight Passing Sieve
1-½ in. (37.50 mm)	*
1 in. (25.0 mm)	*
¾ in. (19.0 mm)	*
½ in. (12.5 mm)	*
⅜ in. (9.5 mm)	*
No. 4 (4.75 mm)	*
No. 8 (2.36 mm)	*
No. 16 (1.18 mm)	*
No. 30 (0.60 mm)	*
No. 50 (0.30 mm)	*
No. 100 (0.15 mm)	*
No. 200 (0.075 mm)	*
Asphalt percent	
Stone or gravel	*
Slag	*

* *

The aggregate gradation shall be specified by the Engineer from the gradations shown in this note. The gradation shall be inserted into Table 3. Asterisks denote insert points. Where locally-available aggregates cannot be economically blended to meet the grading requirements of the gradations shown, the gradations may be modified to fit the characteristics of such local aggregates with approval of the FAA. The modified gradation must produce a paving mixture that satisfies the mix design requirements.

AGGREGATE - BITUMINOUS PAVEMENTS				
Sieve Size	**Percentage by Weight Passing Sieves**			
	1-½" max	**1" max**	**¾ " max**	**½" max**
1-½ in. (37.5 mm)	100	--	--	--
1 in. (24.0 mm)	86-98	100	--	--
¾ in. (19.0 mm)	68-93	76-97	100	--
½ in. (12.5 mm)	57-81	67-87	77-98	100
⅜ in. (9.5 mm)	49-69	58-80	68-89	77-98
No. 4 (4.75 mm)	34-54	42-62	50-70	58-78
No. 8 (2.36 mm)	22-42	29-48	35-55	40-60
No. 16 (1.18 mm)	13-33	19-40	23-34	27-47
No. 30 (0.600 mm)	8-24	12-30	16-34	18-36
No. 50 (0.300 mm)	6-18	8-22	12-28	11-25
No. 100 (0.150 mm)	4-12	6-17	7-20	6-18
No. 200 (0.075 mm)	3-6	3-6	3-6	3-6

* *

Section 401-3.4 TEST SECTION – In this section, %G_{mm}@N_{ini} and the volume of effective asphalt were added to the requirements for an acceptable test section.

401-3.4 TEST SECTION. Prior to full production, the Contractor shall prepare and place a quantity of bituminous mixture according to the job mix formula. The amount of mixture shall be sufficient to construct a test section [ ] long and [ ] wide, placed in two lanes, with a longitudinal cold joint, and shall be of the same depth specified for the construction of the course which it represents. A cold joint is an exposed construction joint at least 4 hours old or whose mat has cooled to less than 160° F. 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 type and weight to be used on the remainder of the course represented by the test section.

The test section shall be evaluated for acceptance as a single lot in accordance with the acceptance criteria in paragraph 401-5.1 and 401-6.3. The test section shall be divided into equal sublots. As a minimum the test section shall consist of 3 sublots.

The test section shall be considered acceptable if; 1) mat density, air voids, $\%G_{mm}@N_{ini}$, volume of effective asphalt (VEA), and joint density are 90 percent or more within limits, 2) gradation and asphalt binder content are within the action limits specified in paragraphs 401-6.5a and 5b, and 3) the voids in mineral aggregate are within the limits of Table 2.

If the initial test section should prove to be unacceptable, the necessary adjustments to the job mix formula, plant operation, placing procedures, and/or rolling procedures shall be made. A second test section shall then be placed. If the second test section also does not meet specification requirements, both sections shall be removed at the Contractor's expense. Additional test sections, as required, shall be constructed and evaluated for conformance to the specifications. Any additional sections that are not acceptable shall be removed at the Contractor's expense. Full production shall not begin until an acceptable section has been constructed and accepted in writing by the Engineer. Once an acceptable test section has been placed, payment for the initial test section and the section that meets specification requirements shall be made in accordance with paragraph 401-8.1.

Job mix control testing shall be performed by the Contractor at the start of plant production and in conjunction with the calibration of the plant for the job mix formula. If aggregates produced by the plant do not satisfy the gradation requirements or produce a mix that meets the JMF. It will be necessary to reevaluate and redesign the mix using plant-produced aggregates. Specimens shall be prepared and the optimum bitumen content determined in the same manner as for the original design tests.

* *

> **The test section should be a minimum of 300 feet (90 m) long and 20 to 30 feet (6 to 9 m) wide. The test section affords the Contractor and the Engineer an opportunity to determine the quality of the mixture in place, as well as performance of the plant and laydown equipment.**

* *

Contractor will not be allowed to place the test section until the Contractor Quality Control Program, showing conformance with the requirements of Paragraph 401-6.1, has been approved, in writing, by the Engineer.

Section 401-5.1 ACCEPTANCE SAMPLING AND TESTING – In this section, the volume of effective asphalt was added as a testing requirement for plant produced material.

401-5.1 ACCEPTANCE SAMPLING AND TESTING. Unless otherwise specified, all acceptance sampling and testing necessary to determine conformance with the requirements specified in this section will be performed by the Engineer at no cost to the Contractor except that coring [and profilograph testing]

as required in this section shall be completed and paid for by the Contractor. Testing organizations performing these tests [except profilograph] shall meet the requirements of ASTM D 3666. All equipment in Contractor furnished laboratories shall be calibrated by an independent testing organization prior to the start of operations at the Contractor's expense.

* *

See note to Engineer in section 401-5.2b(5) regarding the use of profilograph testing.
If this testing is specified, it is performed and paid for by the Contractor.

* *

a. Plant-Produced Material. Plant-produced material shall be tested for air voids and VEA on a lot basis. Sampling shall be from material deposited into trucks at the plant or from trucks at the job site. Samples shall be taken in accordance with ASTM D 979. A lot will consist of:

• one day or shift's production not to exceed 2,000 tons (1 814 000 kg), or

• a half day or shift's production where a day's production is expected to consist of between 2,000 and 4,000 tons (1 814 000 and 3 628 000 kg), or

• similar subdivisions for tonnages over 4,000 tons (3 628 000 kg).

Where more than one plant is simultaneously producing material for the job, the lot sizes shall apply separately for each plant.

(1) Sampling. Each lot will consist of four equal sublots. Sufficient material for preparation of test specimens for all testing will be sampled by the Engineer on a random basis, in accordance with the procedures contained in ASTM D 3665. One set of laboratory compacted specimens will be prepared for each sublot in accordance with ASTM D 6926, at the number of gyrations required by paragraph 401-3.2, Table 1. Each set of laboratory compacted specimens will consist of three test portions prepared from the same sample increment.

The sample of bituminous mixture may be put in a covered metal tin and placed in an oven for not less than 30 minutes nor more than 60 minutes to stabilize to compaction temperature. The compaction temperature of the specimens shall be as specified in the job mix formula.

(2) Testing. Air voids will be determined by the Engineer in accordance with ASTM D 3203. Volume of effective asphalt will be determined by calculating the VMA and subtracting the air voids from the VMA.

Prior to testing, the bulk specific gravity of each test specimen shall be measured by the Engineer in accordance with ASTM D 2726 using the procedure for laboratory prepared thoroughly dry specimens, or ASTM D 1188, whichever is applicable, for use in computing air voids and pavement density.

For air voids determination, the theoretical maximum specific gravity of the mixture shall be measured twice for each sublot in accordance with ASTM D 2041, Type C, D or E container. The value used in the air voids computation for each sublot shall be based on the average of the two maximum specific gravity measurements for the sublot.

(3) Acceptance. Acceptance of plant produced material for air voids and volume of effective asphalt shall be determined by the Engineer in accordance with the requirements of paragraph 401-5.2b.

b. Field Placed Material. Material placed in the field shall be tested for mat and joint density on a lot basis.

(1) Mat Density. The lot size shall be the same as that indicated in paragraph 401-5.1a and shall be divided into four equal sublots. One core of finished, compacted materials shall be taken by the Contractor from each sublot. Core locations will be determined by the Engineer on a random basis in accordance with procedures contained in ASTM D 3665. Cores shall not be taken closer than one foot from a transverse or longitudinal joint.

(2) Joint Density. The lot size shall be the total length of longitudinal joints constructed by a lot of material as defined in paragraph 401-5.1a. The lot shall be divided into four equal sublots. One core of finished, compacted materials shall be taken by the Contractor from each sublot. Core locations will be determined by the Engineer on a random basis in accordance with procedures contained in ASTM D 3665. ALL CORING SHALL BE CENTERED ON THE JOINT. THE MINIMUM CORE DIAMETER FOR JOINT DENSITY DETERMINATION SHALL BE 5 INCHES.

(3) Sampling. Samples shall be neatly cut with a core drill. The cutting edge of the core drill bit shall be of hardened steel or other suitable material with diamond chips embedded in the metal cutting edge. The minimum diameter of the sample shall be five inches. Samples that are clearly defective as a result of sampling shall be discarded and another sample taken. The Contractor shall furnish all tools, labor, and materials for cutting samples and filling the cored pavement. Cored holes shall be filled in a manner acceptable to the Engineer and within one day after sampling.

(4) Testing. The bulk specific gravity of each cored sample will be measured by the Engineer in accordance with ASTM D 2726 or ASTM D 1188, whichever is applicable. The percent compaction (density) of each sample will be determined by dividing the bulk specific gravity of each sublot sample by the theoretical maximum specific gravity for the sublot, as determined in paragraph 401-5.1a(2). The bulk specific gravity used to determine the joint density at joints formed between different lots shall be the lowest of the bulk specific gravity values from the two different lots.

(5) Acceptance. Acceptance of field placed material for mat density will be determined by the Engineer in accordance with the requirements of paragraph 401 5.2b(1). Acceptance for joint density will be determined in accordance with the requirements of paragraph 401-5.2b(3).

c. Partial Lots — Plant-Produced Material. When operational conditions cause a lot to be terminated before the specified number of tests have been made for the lot, or when the Contractor and Engineer agree in writing to allow overages or other minor tonnage placements to be considered as partial lots, the following procedure will be used to adjust the lot size and the number of tests for the lot.

The last batch produced where production is halted will be sampled, and its properties shall be considered as representative of the particular sublot from which it was taken. In addition, an agreed to minor placement will be sampled, and its properties shall be considered as representative of the particular sublot from which it was taken. Where three sublots are produced, they shall constitute a lot. Where one or two sublots are produced, they shall be incorporated into the next lot, and the total number of sublots shall be used in the acceptance plan calculation, i.e., n = 5 or n = 6, for example. Partial lots at the end of asphalt production on the project shall be included with the previous lot.

d. Partial Lots — Field Placed Material. The lot size for field placed material shall correspond to that of the plant material, except that, in no cases, shall less than three (3) cored samples be obtained, i.e., n = 3.

Section 401-5.2 ACCEPTANCE CRITERIA – The volume of effective asphalt was added to the acceptance criteria. Acceptance limits for VEA were added to Table 5.

401-5.2 ACCEPTANCE CRITERIA.

a. General. Acceptance will be based on the following characteristics of the bituminous mixture and completed pavement as well as the implementation of the Contractor Quality Control Program and test results:

(1) Air Voids
(2) Volume of effective asphalt
(3) Mat density
(4) Joint density
(5) Thickness
(6) Smoothness
(7) Grade

Mat density and air voids will be evaluated for acceptance in accordance with paragraph 401-5.2b(1). (SHOULD NOW BE A VEA SENTENCE) will be evaluated for acceptance in accordance with paragraph 401-5.2b(2). Joint density will be evaluated for acceptance in accordance with paragraph 401-5.2b(3).

Thickness will be evaluated by the Engineer for compliance in accordance with paragraph 401-5.2b(4). Acceptance for smoothness will be based on the criteria contained in paragraph 401-5.2b(5). Acceptance for grade will be based on the criteria contained in paragraph 401-5.2b(6).

The Engineer may at any time, notwithstanding previous plant acceptance, reject and require the Contractor to dispose of any batch of bituminous mixture which is rendered unfit for use due to contamination, segregation, incomplete coating of aggregate, or improper mix temperature. Such rejection may be based on only visual inspection or temperature measurements. In the event of such rejection, the Contractor may take a representative sample of the rejected material in the presence of the Engineer, and if it can be demonstrated in the laboratory, in the presence of the Engineer, that such material was erroneously rejected, payment will be made for the material at the contract unit price.

b. Acceptance Criteria.

(1) Mat Density and Air Voids. Acceptance of each lot of plant produced material for mat density and air voids shall be based on the percentage of material within specification limits (PWL). If the PWL of the lot equals or exceeds 90 percent, the lot shall be acceptable. Acceptance and payment shall be determined in accordance with paragraph 401-8.1.

(2) Volume of Effective Asphalt. Acceptance of each lot of plant produced material for volume of effective asphalt shall be based on the percentage of material within specification limits (PWL). If the PWL of the lot equals or exceeds 90 percent, the lot shall be acceptable. If the PWL is less than 90 percent, the Contractor shall determine the reason and take corrective action. If the PWL is below 80 percent, the Contractor must stop production and make adjustments to the mix. Lots with PWL below 80 percent for volume of effective asphalt shall be removed and replaced at the expense of the Contractor.

(3) Joint Density. Acceptance of each lot of plant produced material for joint density shall be based on the percentage of material within specification limits (PWL). If the PWL of the lot is equal to or exceeds 90 percent, the lot shall be considered acceptable. If the PWL is less than 90 percent, the Contractor shall evaluate the reason and act accordingly. If the PWL is less than 80 percent, the Contractor shall cease operations and until the reason for poor compaction has been determined. IF THE PWL IS LESS THAN 71 PERCENT, THE PAY FACTOR FOR THE LOT USED TO COMPLETE THE JOINT SHALL BE REDUCED BY 5 PERCENTAGE POINTS. This lot pay factor reduction shall be incorporated and evaluated in accordance with paragraph 401-8.1.

(4) Thickness. Thickness of each lift of surface course shall be evaluated by the Engineer for compliance to the requirements shown on the plans. Measurements of thickness shall be made by the Engineer using the cores extracted for each sublot for density measurement. The maximum allowable

deficiency at any point shall not be more than ¼ inch less than the thickness indicated for the lift. Average thickness of lift, or combined lifts, shall not be less than the indicated thickness. Where the thickness tolerances are not met, the lot or sublot shall be corrected by the Contractor at his expense by removing the deficient area and replacing with new pavement. The Contractor, at his expense, may take additional cores as approved by the Engineer to circumscribe the deficient area.

(5) Smoothness. The final surface shall be free from roller marks. The finished surfaces of each course of the pavement, except the finished surface of the final course, shall not vary more than ⅜ inch when evaluated with a 16 foot straightedge. The finished surface of the final course of pavement shall not vary more than ¼ inch when evaluated with a 16 foot straightedge. The lot size shall be [ ] square yards (square meters). Smoothness measurements shall be made at 50 foot intervals and as determined by the Engineer. In the longitudinal direction, a smoothness reading shall be made at the center of each paving lane. In the transverse direction, smoothness readings shall be made continuously across the full width of the pavement. However, transverse smoothness readings shall not be made across designed grade changes. At warped transition areas, straightedge position shall be adjusted to measure surface smoothness and not design grade transitions. When more than 15 percent of all measurements within a lot exceed the specified tolerance, the Contractor shall remove the deficient area to the depth of the final course of pavement and replace with new material. Skin patching shall not be permitted. Isolated high points may be ground off providing the course thickness complies with the thickness specified on the plans. High point grinding will be limited to 15 square yards. Areas in excess of 15 square yards will require removal and replacement of the pavement in accordance with the limitations noted above.

* *

The Engineer shall specify the lot size. A minimum of 2,000 square yards (1 650 square meters) is recommended.

Use of a profilograph can be included in the specifications for surface smoothness for runways and taxiways on a case by case basis provided it is approved by the FAA. Use of a profilograph may not be practical for all asphalt construction. Thin lift overlays and other minimum resurfacing may not allow for removal of existing pavement roughness. However, the use of the profilograph is recommended for new construction or overlays designed to correct grade and smoothness deficiencies. If the profilograph is to be included, straightedge requirements need only apply to the perpendicular direction. To include profilograph requirements, add ASTM E 1274 to the referenced testing list and add the following:

(a) Profilograph. The Contractor shall furnish a 25 foot wheel base California type profilograph and competent operator to measure pavement surface deviations. The profilograph shall be operated in accordance with the manufacturer's instructions and at a speed no greater than 3 mph. Original profilograms for the appropriate locations interpreted in accordance with ASTM E 1274 shall be furnished to the Engineer. The profilograms shall be recorded on a scale of one inch equal to 25 feet longitudinally and one inch equal to one inch (or full scale) vertically. Profilographs shall be calibrated prior to testing.

The surface of the runway and/or taxiway pavements of continuous placement of 50 feet or more shall be tested and evaluated as described herein. One pass along the centerline shall be required for each paving lane. Runs shall be continuous through a day's production. Each trace shall be completely labeled to show paving lane and stationing.

The Contractor shall furnish paving equipment and employ methods that produce a riding surface for each section of pavement having an average profile

index meeting the requirements of Table 7. A typical section will be considered to be the width of the paving lane and 1/10 of a mile long. The profile index will be determined in accordance with ASTM E 1274. A blanking band of 0.2 inches shall be used. Within each 1/10 mile section, all areas represented by high points having a deviation in excess of 0.4 inches in 25 feet or less shall be removed by the Contractor using an approved method. After removing all individual deviations in excess of 0.4 inches, additional corrective work shall be performed if necessary to achieve the required ride quality. All corrective work shall be completed prior to determination of pavement thickness.

On pavement sections where corrections were necessary, second profilograph runs shall be performed to verify that the corrections have produced an average profile index of 15 inches per mile or less. If the initial average profile index was less than 15, only those areas representing greater than 0.4 inch deviation will be re-profiled for correction verification.

Individual sections shorter than 50 feet and the last 15 feet of any section where the Contractor is not responsible for the adjoining section shall be straightedged in accordance with paragraph 401-5.2b(5).

If there is a section of 250 feet or less, the profilogram for the section shall be included in the evaluation of the previous section. If there is an independently placed section of 50 to 250 feet in length, a profilogram shall be made for that section and the pay adjustment factors for short section of Table 7 shall apply.

All costs necessary to provide the profilograph and related to furnishing the appropriate profilograms as required in this provision are incidental to pavement construction and no direct compensation will be made therefore.

* *

(6) Grade. The finished surface of the pavement shall not vary from the gradeline elevations and cross sections shown on the plans by more than ½ inch (12.70 mm). The finished grade of each lot will be determined by running levels at intervals of 50 feet (15.2 m) or less longitudinally and all breaks in grade transversely (not to exceed 50 feet) to determine the elevation of the completed pavement. The Contractor shall pay the cost of surveying of the level runs that shall be performed by a licensed surveyor. The documentation, stamped and signed by a licensed surveyor, shall be provided by the Contractor to the Engineer. The lot size shall be [ ] square yards (square meters). When more than 15 percent of all the measurements within a lot are outside the specified tolerance, or if any one shot within the lot deviates ¾ inch or more from planned grade, the Contractor shall remove the deficient area to the depth of the final course of pavement and replace with new material. Skin patching shall not be permitted. Isolated high points may be ground off providing the course thickness complies with the thickness specified on the plans. High point grinding will be limited to 15 square yards. Areas in excess of 15 square yards will require removal and replacement of the pavement in accordance with the limitations noted above.

* *

A minimum of 2,000 square yards (1 650 square meters) is recommended.

* *

c. Percentage of Material Within Specification Limits (PWL). The percentage of material within specification limits (PWL) shall be determined in accordance with procedures specified in Section 110 of the General Provisions. The specification tolerance limits (L) for lower and (U) for upper are contained in Table 5.

d. Outliers. All individual tests for mat density and air voids shall be checked for outliers (test criterion) in accordance with ASTM E 178, at a significance level of 5 percent. Outliers shall be discarded, and the PWL shall be determined using the remaining test values.

* *

The specification tolerance limits applicable to the project, based on design criteria specified in Table 1, shall be specified by the Engineer from the information shown below and inserted into Table 5. Asterisks denote insert points.

* *

TABLE 5. SUPERPAVE ACCEPTANCE LIMITS FOR AIR VOIDS, VEA AND DENSITY

TEST PROPERTY	Pavements Designed for Aircrafts with Tire Pressures of					
	less than 100 psi		100 psi to 199 psi		200 psi or more	
Number of Gyrations	50		65		80	
	Specification Tolerance Limits		Specification Tolerance Limits		Specification Tolerance Limits	
	L	U	L	U	L	U
Air Voids, percent	3	5	3	5	3	5
Volume of Effective Asphalt, percent	*	--	*	--	*	--
Surface Course Mat Density, percent	92.5	98	92.5	98	92.5	98
Base Course Mat Density, percent	92	98	92	98	92	98
Joint Density, percent	90	98	90	98	90	98

* The minimum volume of Effective Asphalt will be calculated as the minimum design VMA minus 4.0 percent.

* *

TABLE 5. SUPERPAVE ACCEPTANCE LIMITS FOR AIR VOIDS, VMA AND DENSITY

TEST PROPERTY	*	
Number of Gyrations	*	
	Specification Tolerance Limits	
	L	U
Air Voids, percent	*	*
Volume of Effective Asphalt, percent	*	*
Mat Density*, percent	*	*
Joint Density*, percent	*	*

*Mat and joint density percents are the percent of the theoretical maximum specific gravity determined for the lot.

The criteria in Table 5 are based on production processes which have variability with the following standard deviations:

Surface Course Mat Density (%), 1.30
Base Course Mat Density (%), 1.55
Joint Density (%), 2.1

The Contractor should note that (1) 90 PWL is achieved when consistently producing a surface course with an average mat density of at least 98 percent with 1.30% or less variability, (2) 90 PWL is achieved when consistently producing a base course with an average mat density of at least 97.5 percent with 1.55% or less variability, and (3) 90 PWL is achieved when consistently producing joints with an average joint density of at least 96 percent with 2.1% or less variability.

* *

> **A lot is the quantity of material to be controlled and may represent a specified tonnage or a specified number of truckloads. The lot size, to be determined by the Engineer, should, for the most part, depend on the operational capacity of the plant, but shall in no case exceed 2,000 tons (1 814 000 kg) in accordance with paragraph 401-5.1a.**

* *

Section 401-6.3 QUALITY CONTROL TESTING – In this section, air voids and volume of effective asphalt testing was added to the quality control testing requirements.

401-6.3 QUALITY CONTROL TESTING. The Contractor shall perform all quality control tests necessary to control the production and construction processes applicable to these specifications and as set forth in the approved Quality Control Program. The testing program shall include, but not necessarily be limited to, tests for the control of air voids, volume of effective asphalt, asphalt content, aggregate gradation, temperatures, aggregate moisture, field compaction, and surface smoothness. A Quality Control Testing Plan shall be developed as part of the Quality Control Program.

a. Air Voids. Air voids testing will be performed at least four times per lot in accordance with ASTM D 3203. Prior to testing, the bulk specific gravity of each test specimen shall be measured in accordance with ASTM D 2726 using the procedure for laboratory prepared thoroughly dry specimens, or ASTM D 1188, whichever is applicable, for use in computing air voids and pavement density.

For air voids determination, the theoretical maximum specific gravity of the mixture shall be measured in accordance with ASTM D 2041, Type C, D or E container.

b. Volume of Effective Asphalt. Volume of effective asphalt should be calculated when the air voids are calculated. Volume of effective asphalt will be determined by calculating the VMA and subtracting the air voids from the VMA.

c. Asphalt Content. A minimum of two extraction tests shall be performed per lot in accordance with ASTM D 6307 or ASTM D 2172 for determination of asphalt content. The weight of ash portion of the extraction test, 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 plan production. The last weight of ash value obtained shall be used in the calculation of the asphalt content for the mixture. The asphalt content for the lot will be determined by averaging the test results.

The use of the nuclear method for determining asphalt content in accordance with ASTM D 4125 is permitted, provided that it is calibrated for the specific mix being used.

d. Gradation. Aggregate gradations shall be determined a minimum of twice per lot from mechanical analysis of extracted aggregate in accordance with ASTM D 5444 and ASTM C 136 (Dry Sieve). 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 or continuous mix plants, and tested in accordance with ASTM C 136 (dry sieve) using actual batch weights to determine the combined aggregate gradation of the mixture.

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

f. Moisture Content of Mixture. The moisture content of the mixture shall be determined once per lot in accordance with ASTM D 1461 [or AASHTO T110].

* *

ASTM D 1461 may be replaced with AASHTO T110 moisture content testing procedure using a conventional oven or microwave.

* *

g. Temperatures. Temperatures shall be checked, at least four times per lot, at necessary locations to determine the temperatures of the dryer, the bitumen in the storage tank, the mixture at the plant, and the mixture at the job site.

h. In-Place Density Monitoring. The Contractor shall conduct any necessary testing to ensure that the specified density is being achieved. A nuclear gauge may be used to monitor the pavement density in accordance with ASTM D 2950.

i. Additional Testing. Any additional testing that the Contractor deems necessary to control the process may be performed at the Contractor's option.

j. Monitoring. The Engineer reserves the right to monitor any or all of the above testing. 401-6.4 SAMPLING. When directed by the Engineer, the Contractor shall 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 shall be in accordance with standard procedures specified.

Section 401-6.5 Control Charts – In this section, control chart requirements were expanded to include air voids and volume of effective asphalt. Action and Suspension limits were also listed for air voids and the volume of effective asphalt.

401-6.5 CONTROL CHARTS. The Contractor shall maintain linear control charts both for individual measurements and range (i.e., difference between highest and lowest measurements) for aggregate gradation and asphalt content.

Control charts shall be posted in a location satisfactory to the Engineer and shall be kept current. As a minimum, the control charts shall identify the project number, the contract item number, the test number, each test parameter, the Action and Suspension Limits applicable to each test parameter, and the Contractor's test results. The Contractor shall use the control charts as part of a process control system for identifying potential problems and assignable causes before they occur. If the Contractor's projected data during production indicates a problem and the Contractor is not taking satisfactory corrective action, the Engineer may suspend production or acceptance of the material.

a. Individual Measurements. Control charts for individual measurements shall be established to maintain process control within tolerance for aggregate gradation, asphalt content, air voids and volume of effective asphalt. The control charts shall use the job mix formula target values as indicators of central tendency for the following test parameters with associated Action and Suspension Limits:

CONTROL CHART LIMITS FOR INDIVIDUAL

MEASUREMENTS		
Sieve	Action Limit	Suspension Limit
¾ inch (19.0 mm)	0%	0%
½ inch (12.5 mm)	+/-6%	+/-9%
⅜ inch (9.5 mm)	+/-6%	+/-9%
No. 4 (4.75 mm)	+/-6%	+/-9%
No. 16 (1.18 mm)	+/-5%	+/-7.5%
No. 50 (0.30 mm)	+/-3%	+/-4.5%
No. 200 (0.075 mm)	+/-2%	+/-3%
Asphalt Content	+/-0.45%	+/-0.70%
Air Voids	+/-%	+/-%
Volume of Effective Asphalt	+/-%	+/-%

b. Range. Control charts for range shall be established to control process variability for the test parameters and Suspension Limits listed below. The range shall be computed for each lot as the difference between the two test results for each control parameter. The Suspension Limits specified below are based on a sample size of n = 2. Should the Contractor elect to perform more than two tests per lot, the Suspension Limits shall be adjusted by multiplying the Suspension Limit by 1.18 for n = 3 and by 1.27 for n = 4.

CONTROL CHART LIMITS BASED ON RANGE (Based on n = 2)	
Sieve	Suspension Limit
½ inch (12.5 mm)	11 percent
⅜ inch (9.5 mm)	11 percent
No. 4 (4.75 mm)	11 percent
No. 16 (1.18 mm)	9 percent
No. 50 (0.30 mm)	6 percent
No. 200 (0.075 mm)	3.5 percent
Asphalt Content	0.8 percent
Air Voids	percent
Volume of Effective Asphalt	percent

c. Corrective Action. The Contractor Quality Control Program shall indicate that appropriate action shall be taken when the process is believed to be out of tolerance. The Plan shall contain sets of rules to gauge when a process is out of control and detail what action will be taken to bring the process into control. As a minimum, a process shall be deemed out of control and production stopped and corrective action taken, if:

(1) One point falls outside the Suspension Limit line for individual measurements or range; or

(2) Two points in a row fall outside the Action Limit line for individual measurements.

* *

The aggregate control chart parameters and Suspension and Action Limits contained in the above paragraphs are based on ¾ inch (19.0 mm) maximum size aggregate gradation. When 1-inch (25.0 mm) or 1-½ inch (37.5 mm) maximum size aggregate is specified, the Individual Measurements Chart requirements should be amended as follows:

Sieve	**Action Limit**	**Suspension Limit**
1 inch or 1-½ inch	**0%**	**0%**

¾ inch	**6%**	**11%**

When ½-inch (12.5 mm) maximum size aggregate is specified, the ¾-inch (19.0 mm) and 1-inch (25.0 mm) sieves should be deleted from the Individual Measurements Chart and the ½-inch (12.5 mm) sieve Action and Suspension Limits should be changed to 0%. For the ½-inch (12.5 mm) gradation, the ½-inch sieve should be deleted from the Range Chart.

* *