U.S. Department
of Transportation

**Federal Aviation
Administration**

Advisory Circular

Subject: Change 4 to STANDARDS FOR SPECIFYING CONSTRUCTION OF AIRPORTS

Date: 7/7/92
Initiated by: AAS-200

AC No: 150/5370-10A
Change: 4

1. **PURPOSE.** Item P-401, Plant Mix Bituminous Pavements, has been revised to incorporate quality assurance provisions.

2. **PRINCIPAL CHANGES.** The following principal changs have been made:

a. Paragraph 401-3.2. Marshall design criteria revised.

b. Paragraph 401-3.3. New paragraph on Recycled Asphalt Concrete.

c. Sections on Material Acceptance and Contractor Quality Control added.

d. Paragraph 401-5.2. Acceptance of material for mat density, joint density, stability, flow, and air voids based on Percent Within Limits (PWL). Pay adjustment for mat density and air voids.

e. Paragraph 401-6.2. Requires contractor to submit Quality Control Plan.

f. Paragraph 401-6.3. Requires contractor to perform quality control tests, and to maintain control charts for aggregate gradation and asphalt content.

g. Paragraph 401-8.1. Payment based on the lower PWL value of density or air voids.

PAGE CONTROL CHART

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ITEM P–401 PLANT MIX BITUMINOUS PAVEMENTS

DESCRIPTION

401–1.1 This item shall consist of a [ ] course composed of mineral aggregate and bituminous material mixed in a central mixing plant and placed on a prepared course in accordance with these specifications and shall conform to the lines, grades, thicknesses, and typical cross sections shown on the plans. Each course shall be constructed to the depth, typical section, or elevation required by the plans and shall be rolled, finished, and approved before the placement of the next course.

* *

Specify surface, base and/or leveling course(s).

This specification is intended to be used for pavements subject to aircraft loadings. State highway department specifications may be used for access roads, perimeter roads, and other pavements not subject to aircraft loading.

See note in paragraph 401–3.2 regarding pavements designed for aircraft gross weights of 12,500 pounds (5 662 kg) or less.

* *

MATERIALS

401–2.1 **AGGREGATE.** Aggregates shall consist of crushed stone, crushed gravel, or crushed slag with or without sand or other inert finely divided mineral aggregate. The portion of materials retained on the No. 8 sieve is coarse aggregate. The portion passing the No. 8 (2.36 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 [ ] percent when tested in accordance with ASTM C 131. The sodium sulfate soundness loss shall not exceed [ ] percent, or the magnesium sulfate soundness loss shall not exceed [ ] percent, after five cycles, when tested in accordance with ASTM C 88.

* *

Percentage of wear shall not exceed 40 for surface and intermediate courses and 50 for base course; sodium sulfate loss should not exceed 10 percent; magnesium sulfate soundness loss should not exceed 13 percent. Aggregates with a higher percentage loss or wear may be specified, provided a satisfactory service record under similar conditions of service and exposure shall have 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.

The aggregate shall not contain more than 8 percent, by weight, of flat or elongated pieces, when tested in accordance with ASTM D 4791.

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.

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For pavements designed for aircraft gross weights of 60,000 pounds (27 200 kg) or more the Engineer shall specify 70 percent for two fractured faces and 85 percent for one frac-

tured face. For pavements designed for aircraft gross weights less than 60,000 pounds (27 200 kg), the Engineer shall specify 50 percent for two fractured faces and 65 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.

* *

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 (non-manufactured) 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 20 percent natural sand by weight of total aggregates.]**

The aggregate shall have sand equivalent values of 35 or greater when tested in accordance with ASTM D 2419.

* *

The addition of natural sand to a mix containing all crushed coarse and fine aggregates will normally increase its workability and compactability. However, the addition of excessive amounts of natural sand tends to decrease the stability of the mixture. The requirement for a maximum of 20 percent natural sand may be included for locations where low stabilities are a chronic problem.

* *

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.

401-2.2 MINERAL FILLER. If filler, in addition to that naturally present in the aggregate, is necessary, it shall meet the requirements of ASTM D 242.

401-2.3 BITUMINOUS MATERIAL. Bituminous material shall conform to the following requirements:
[ ].

* *

The Engineer shall specify the grade and ASTM specification of bituminous material, based on geographical location and climatic conditions. Table VI-1, Selecting Asphalt Grade, contained in the Asphalt Institute's Manual Series-1 (MS-1) provides guidance on the selection of asphalt type. For cold climates, Table 2 of ASTM D 3381 may be specified to minimize the susceptibility for thermal cracking. Other specifications to minimize cracking, such as the addition of Penetration Index, Pen-Vis number, or performance based asphalts (PBA) can also be specified with approval of the Federal Aviation Administration. Grades of some materials are listed below:

	Grade	Specification
Penetration Grade	**40-50**	**ASTM D 946**
	60-70	
	85-100	
	100-120	
	120-150	
Viscosity Grade	**AC-2.5**	**ASTM D 3381**
	AC-5	
	AC-10	
	AC-15	
	AC-20	
	AC-30	
	AC-40	
Viscosity Grade (Residue)	**AR-1000**	**ASTM D 3381**
	AR-2000	
	AR-4000	
	AR-8000	

* *

The Contractor shall furnish vendor's certified test reports for each lot of bituminous material shipped to the project. The vendor's certified test report for the bituminous material can be used for acceptance or tested independently by the Engineer.

401-2.4 PRELIMINARY MATERIAL ACCEPTANCE. Prior to delivery of materials to the job site, the Contractor shall submit certified test reports to the Engineer for the following materials:

a. **Coarse Aggregate.**

(1) Percent of wear.

(2) Soundness.

(3) Unit weight of slag.

b. **Fine Aggregate.**

(1) Liquid limit.

(2) Plastic index.

(3) Sand equivalent.

c. **Mineral Filler.**

d. **Bituminous Material.**

The certification(s) shall show the appropriate ASTM test(s) for each material, the test results, and a statement that the material meets the specification requirement.

The Engineer may request samples for testing, prior to and during production, to verify the quality of the materials and to ensure conformance with the applicable specifications.

COMPOSITION

401-3.1 COMPOSITION OF MIXTURE. The bituminous plant mix shall be composed of a mixture of well-graded aggregate, filler if required, and bituminous material. The several 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).

401-3.2 JOB MIX FORMULA. No bituminous mixture for payment shall be produced until a job mix formula has been approved by the Engineer. The bituminous mixture shall be designed using procedures contained in Chapter III, MARSHALL METHOD OF MIX DESIGN, of the Asphalt Institute's Manual Series No. 2 (MS-2), Mix Design Methods for Asphalt Concrete, and shall meet the requirements of Tables 1 and 2.

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

Stability (lbs.)	= 270
Flow (0.01 inch)	= 1.5
Air Voids (%)	= 0.65

If material variability exceeds the standard deviations indicated, the job mix formula and subsequent production targets should be based on a stability greater than shown in Table 1, and the flow and air voids should be targeted close to the mid-range of the criteria in order meet the acceptance requirements.

If the Tensile Strength Ratio (TSR) of the composite mixture, as determined by ASTM D 4867, is less than 75, the aggregates shall be rejected or the asphalt treated with an approved anti-stripping agent. The amount of anti-stripping agent added to the asphalt shall be sufficient to produce a TSR of not less than 75. If an antistrip agent is required, it will be provided by the Contractor at no additional cost.

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.

b. Percent of asphalt cement.

c. Asphalt viscosity or penetration grade.

d. Number of blows of hammer compaction per side of molded specimen.

e. Mixing temperature.

f. Compaction temperature.

g. Temperature of mix when discharged from the mixer.

h. Temperature-viscosity relationship of the asphalt cement.

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

j. Graphical plots of stability, flow, air voids, voids in the mineral aggregate, and unit weight verses asphalt content.

k. Percent natural sand.

l. Percent fractured faces.

m. Percent elongated particles.

n. Tensile Strength Ratio (TSR).

o. Antistrip agent (if required).

The Contractor shall submit samples to the Engineer, upon request, for job mix formula verification testing.

The job mix formula for each mixture shall be in effect until modified in writing by the Engineer. Should a change in sources of materials be made, a new job mix formula must be approved by the Engineer before the new material is used.

* *

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

The Marshall Design Criteria applicable to a 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 Aircraft Gross Weights of 60,000 Lbs. or More or Tire Pressures of 100 Psi or More	Pavements Designed for Aircraft Gross Weight Less Than 60,000 Lbs. or Tire Pressure Less Than 100 Psi
Number of blows	75	50
Stability, pounds (newtons)	2150 (9555)	1350 (4450)
Flow, 0.01 in. (0.25 mm)	10–14	10–18
Air voids (percent)	2.8–4.2	2.8–4.2
Voids filled with asphalt (percent)	65–75	65–78
Percent Voids in mineral aggregate (minimum)	See Table 2	See Table 2

* *

TABLE 1. MARSHALL DESIGN CRITERIA

TEST PROPERTY	*
Number of blows	*
Stability, pounds (newtons) minimum	*
Flow, 0.01 in. (0.25 mm)	*
Air voids (percent)	*
Voids filled with asphalt (percent)	*
Percent voids in mineral aggregate, minimum	See Table 2

TABLE 2. MINIMUM PERCENT VOIDS IN MINERAL AGGREGATE

Nominal Maximum Aggregate Size/1/		Minimum Voids in Mineral Aggregate, percent		
		Design Air Voids		
in.	mm	3	4	5
½	12.5	13	14	15
¾	19.5	12	13	14
1	25.0	11	12	13
1¼	31.25	10	11	12

/1/The nominal maximum aggregate size is the next larger sieve size than the sieve on which at least 10 percent of the total aggregate is retained.

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

The gradations in Table 3 represent the limits which 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 one–half of the thickness of the course being constructed.

TABLE 3. AGGREGATE – BITUMINOUS PAVEMENTS

Sieve Size	Percentage by Weight Passing Sieves
	*
1¼ in. (31.25 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 gradations shown are based on aggregates of uniform specific gravity. The percentages passing the various sieves shall be corrected when aggregates of varying specific gravities are used, as indicated in the Asphalt Institute Manual Series No. 2 (MS-2), Appendix A.

* *

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.

For pavements designed to accommodate aircraft gross weights of 12,500 pounds (5 662 kg) or less, this section may be modified to permit the use of state highway department specifications for high-quality, hot-mix bituminous pavements that have a satisfactory performance record under equivalent loadings and exposure. When a density requirement is not specified by a state specification, the Engineer should specify an average of 98 percent of laboratory density based on four random tests per day.

When a state specification that specifies a density is used, paragraphs 401-5.1, 5.2, 5.3, and 8.1a should be deleted. When a state specification that does not specify a density is used, paragraph 401-5.1 should be modified to require only mat density tests and paragraphs 401-5.2. 5.3, and 8.1a should be deleted.

AGGREGATE—BITUMINOUS PAVEMENTS

Sieve Size	Percentage by Weight Passing Sieves			
	1¼"max	1" max	¾" max	½" max
1¼ in. (30.0 mm)	100	—	—	—
1 in. (24.0 mm)	86-98	100	—	—
¾ in. (19.0 mm)	68-93	76-98	100	—
½ in. (12.5 mm)	57-81	66-86	79-99	100
⅜ in. (9.5 mm)	49-69	57-77	68-88	79-99
No. 4 (4.75 mm)	34-54	40-60	48-68	58-78
No. 8 (2.36 mm)	22-42	26-46	33-53	39-59
No. 16 (1.18 mm)	13-33	17-37	20-40	26-46
No. 30 (0.600 mm)	8-24	11-27	14-30	19-35
No. 50 (0.300 mm)	6-18	7-19	9-21	12-24
No. 100 (0.150 mm)	4-12	6-16	6-16	7-17
No. 200 (0.075 mm)	3-6	3-6	3-6	3-6
Asphalt percent:				
Stone or gravel	4.5-7.0	4.5-7.0	5.0-7.5	5.5-8.0
Slag	5.0-7.5	5.0-7.5	6.5-9.5	7.0-10.5

* *

401-3.3 RECYCLED ASPHALT CONCRETE. Recycled asphalt concrete shall consist of reclaimed asphalt pavement (RAP), coarse aggregate, fine aggregate, mineral filler, asphalt cement, and recycling agent, if necessary. Reclaimed asphalt pavement may be used for all courses.

The RAP shall be of a consistent gradation and asphalt content. The Contractor may obtain the RAP from the job site or an existing source.

All new aggregates used in the recycled mix shall meet the requirements of paragraph 401-2.1. New bituminous material shall meet the requirements of paragraph 401-2.3. Recycling agents shall meet the requirements of ASTM D 4552.

The recycled asphalt concrete mix shall be designed using procedures contained in the Asphalt Institute's Manual Series Number 20 (MS-20), Asphalt Hot-Mix Recycling, in conjunction with MS-2 (MS-2). The job mix shall meet the requirements of paragraph 401-3.2. In addition to the requirements of paragraph 401-3.2, the job mix formula shall indicate the percent of reclaimed asphalt pavement, the percent and viscosity grade of new asphalt, the percent and grade of hot-mix recycling agent (if used), and the properties (including viscosity and penetration) of the asphalt blend.

The Contractor shall submit documentation to the Engineer, indicating that the mixing equipment proposed for use is adequate to mix the percent of RAP shown in the job mix formula and meet all local and national environmental regulations.

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Delete this paragraph if recycled asphalt pavement is not to be allowed and include a sentence that RAP will not be permitted to be used.

Recycling agents should be used when the desired viscosity of the asphalt blend cannot be obtained using only a soft asphalt.

* *

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 should 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. 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.

Three random samples shall be taken at the plant and tested for stability, flow, and air voids in accordance with paragraph 401-5.1a(2). Three randomly selected cores shall be taken from the finished pavement mat, and three from the longitudinal joint, and tested in accordance with paragraph 401-5.1b(4). Random sampling shall be in accordance with procedures contained in ASTM D 3665.

Stability, flow, and air voids shall be evaluated in accordance with paragraph 401-5.2b. Mat density shall be evaluated in accordance with paragraph 401-5.2c. Joint density shall be evaluated in accordance with paragraph 401-5.2d. The test section shall be considered acceptable if the percentage of material within limits (PWL) is 90 or more.

Two random samples of mixture shall be taken at the plant and tested for aggregate gradation and asphalt content in accordance with paragraphs 401-6.3a and 3b and evaluated in accordance with paragraphs 401-6.5a and 5b. The test section shall be considered acceptable if the gradation and asphalt content are within the limits specified in paragraphs 401-6.5a and 5b.

Voids in the mineral aggregate (VMA), for each plant sample, shall be computed in accordance with procedures contained in Chapter III, MARSHALL METHOD OF MIX DESIGN, of the Asphalt Institute's Manual Series No. 2 (MS-2), Mix Design Methods for Asphalt Concrete.

Voids filled with asphalt, for each plant sample, shall be computed as follows:

a. Determine asphalt content in percentage by volume using:

$$I = \frac{P_b \times G_{mb}}{G_b}$$

Where:

I = Percentage by volume of asphalt

P_b = Percentage by weight of asphalt

G_{mb} = Bulk specific gravity of compacted mixture

G_b = Specific gravity of asphalt

b. Determine percent voids filled with asphalt as follows:

$$VF = \frac{I}{I + P_a} \times 100$$

Where:

VF = Percent voids filled with asphalt

I = Percentage by volume of asphalt

P_a = Percent air voids

The test section shall be considered acceptable if the voids in the mineral aggregate and the voids filled with asphalt are within the limits of Table 1.

If the test section should prove to be unsatisfactory, 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 do not conform to specification requirements shall be removed at the Contractor's expense. Full production shall not begin until a satisfactory section has been constructed and accepted by the Engineer. The initial test section and any subsequent section that meets specification requirements shall be paid for 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. It should be recognized that the aggregates produced by the plant may not satisfy the gradation requirements or produce a mix that exactly meets the JMF. In those instances, it will be necessary to reevaluate and redesign the mix using plant-produced aggregates. Specimens should 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.

Until the plant is producing the desired mix consistency, frequent testing may be necessary.

* *

401-3.5 TESTING LABORATORY. The laboratory used to develop the job mix formula shall meet the requirements of ASTM D 3666. A certification signed by the manager of the laboratory stating that it meets these requirements shall be submitted to the Engineer 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

CONSTRUCTION METHODS

401-4.1 WEATHER LIMITATIONS. The bituminous mixture shall not be placed upon a wet surface or when the surface temperature of the underlying course is less than specified in Table 4. The temperature requirements may be waived by the Engineer, if requested; however, all other requirements including compaction shall be met.

TABLE 4. BASE TEMPERATURE LIMITATIONS

Mat Thickness	Base Temperature (Minimum)	
	Deg. F	Deg. C
3 in. (7.5 cm) or greater	40	4
Greater than 1 in. (2.5 cm) but less than 3 in. (7.5 cm)	45	7
1 in. (2.5 cm) or less	50	10

401–4.2 BITUMINOUS MIXING PLANT. Plants used for the preparation of bituminous mixtures shall conform to the requirements of ASTM D 995 with the following changes:

a. Requirements for All Plants.

(1) **Truck Scales.** The bituminous 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 as often as the Engineer deems necessary to assure their accuracy. Scales shall conform to the requirements of the General Provisions, Section 90–01.

(2) **Testing Facilities.** The Contractor shall provide laboratory facilities at the plant for the use of the Engineer's acceptance testing and the Contractor's quality control testing, in accordance with paragraph 401–6.2d.

(3) **Inspection of Plant.** The Engineer, or Engineer's authorized representative, 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; and checking the temperatures maintained in the preparation of the mixtures.

(4) **Storage Bins and Surge Bins.** Paragraph 3.9 of ASTM D 995 is deleted. Instead, the following applies. Use of surge bins or storage bins for temporary storage of hot bituminous mixtures will be permitted as follows:

(a) The bituminous mixture may be stored in surge bins for period of time not to exceed 3 hours.

(b) The bituminous mixture may be stored in insulated storage bins for a period of time not to exceed 24 hours.

The bins shall be such that mix drawn from them meets the same requirements as mix loaded directly into trucks.

If the Engineer determines that there is an excessive amount of heat loss, segregation or oxidation of the mixture due to temporary storage, no overnight storage will be allowed.

401–4.3 HAULING EQUIPMENT. Trucks used for hauling bituminous mixtures 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. 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 shall be securely fastened.

401–4.4 BITUMINOUS PAVERS. Bituminous pavers shall be self–propelled, with an activated screed, heated as necessary, and shall be capable spreading and finishing courses of bituminous plant mix material 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.

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.

If an automatic grade control device is used, the paver shall be equipped with a control system capable of automatically maintaining the specified screed 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.

The controls shall be capable of working in conjunction with any of the following attachments:

a. Ski-type device of not less than 30 feet (9.14 m) in length.

b. Taut stringline (wire) set to grade.

c. Short ski or shoe.

d. Laser control.

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For pavements serving aircraft 60,000 pounds (27 200 kg) or more gross weight and on all runways, it is recommended that the specifications require the use of automatic grade controls.

* *

401-4.5 ROLLERS. Rollers of the vibratory, steel wheel, and pneumatic-tired type shall be used. They shall be in good condition, capable of operating at slow speeds to avoid displacement of the bituminous mixture. The number, type, and weight of rollers shall be sufficient to compact the mixture to the required density while it is still in a workable condition.

The use of equipment which causes excessive crushing of the aggregate will not be permitted.

401-4.6 PREPARATION OF BITUMINOUS MATERIAL. The bituminous material shall be heated in a manner that will avoid local overheating and provide a continuous supply of the bituminous material to the mixer at a uniform temperature. The temperature of the bituminous material delivered to the mixer shall be sufficient to provide a suitable viscosity for adequate coating of the aggregate particles, but shall not exceed 325°F (160°C).

401-4.7 PREPARATION OF MINERAL AGGREGATE. The aggregate for the mixture shall be heated and dried prior to introduction into the mixer. The maximum temperature and rate of heating shall be such that no damage occurs to the aggregates. The temperature of the aggregate and mineral filler shall not exceed 350°F (175°C) when the asphalt is added. Particular care shall be taken that aggregates high in calcium or magnesium content are not damaged by overheating. 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.

401-4.8 PREPARATION OF BITUMINOUS MIXTURE. The aggregates and the bituminous material shall be weighed or metered and introduced into the mixer in the amount specified by the job mix formula.

The combined materials shall be mixed until the aggregate obtains a uniform coating of bitumen and is 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 95 percent of coated particles. For continuous mix plants, the minimum mixing time shall be determined by dividing the weight of its contents at operating level by the weight of the mixture delivered per second by the mixer. The moisture content of all bituminous mix upon discharge shall not exceed 0.5 percent.

* *

For batch plants, wet mixing time begins with the introduction of bituminous material into the mixer and ends with the opening of the mixer discharge gate. Distribution of aggregate and bituminous material as they enter the pugmill, speed of mixer shafts, and arrangement and pitch of paddles are factors governing efficiency of mixing. Prolonged exposure to air and heat in the pugmill harden the asphalt film on the aggregate. Mixing time, therefore, should be the shortest time required to obtain uniform distribution of aggregate sizes and thorough coating of aggregate particles with bituminous material.

* *

401-4.9 PREPARATION OF THE UNDERLYING SURFACE. Immediately before placing the bituminous mixture, the underlying course shall be cleaned of all dust and debris. A prime coat or tack coat shall be applied in accordance with Item P-602 or P-603, if required by the contract specifications.

401-4.10 TRANSPORTING, PLACING, AND FINISHING. The bituminous mixture shall be transported from the mixing plant to the site in vehicles conforming to the requirements of paragraph 401-3. 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 night placements. Hauling over freshly placed material shall not be permitted until the material has been compacted, as specified, and allowed to cool to atmospheric temperature.

[The Contractor may elect to use a material transfer vehicle to deliver mix to the paver.]

* *

Use of a material transfer vehicle allows the paver to be operated almost continuously without stopping between truckloads of mix, if a continuous supply of mix is available from the asphalt plant.

* *

The mix shall be placed and compacted at a temperature suitable for obtaining density, surface smoothness, and other specified requirements but not less than 250°F (107°C).

Upon arrival, the mixture shall be placed to the full width by a bituminous 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 bituminous 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 [ ] except where edge lanes require less width to complete the area. The longitudinal joint in one course shall offset the longitudinal joint in the course immediately below by at least 1 foot (30 cm); however, the joint in the surface top course shall be at the centerline of the pavement. Transverse joints in one course shall be offset by at least 10 feet (3 m) from transverse joints in the previous course.

Transverse joints in adjacent lanes shall be offset a minimum of 10 feet (3 m).

On 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.

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The Engineer should specify the widest paving lane practicable in an effort to hold the number of longitudinal joints to a minimum.

* *

401-4.11 COMPACTION OF MIXTURE. After placing, the mixture shall be thoroughly and uniformly compacted by rolling. The surface shall be compacted as soon as possible when the mixture has attained sufficient stability so that the rolling does not cause undue displacement, cracking or shoving. The sequence of rolling operations and the type of rollers used shall be at the discretion of the Contractor.

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 (and scrapers used), 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 in any way defective shall be removed and 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 shall not be allowed.

401-4.12 JOINTS. The formation of all joints shall be made in such a manner as to ensure a continuous bond between the courses and 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.

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. In both methods all contact surfaces shall be given a tack coat of bituminous material before placing any fresh mixture against the joint.

Longitudinal joints which are irregular, damaged, uncompacted, or otherwise defective shall be cut back to expose a clean, sound surface for the full depth of the course. All contact surfaces shall be given a tack coat of bituminous material prior to placing any fresh mixture against the joint.

MATERIAL ACCEPTANCE

401-5.1 ACCEPTANCE SAMPLING AND TESTING. 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. Testing organizations performing these tests shall meet the requirements of ASTM D 3666. All equipment in Contractor furnished laboratories shall be calibrated by the testing organization prior to the start of operations.

a. **Plant-Produced Material.** Plant-produced material shall be tested for stability, flow, and air voids on a lot basis. Sampling shall be from material deposited into trucks at the plant or from trucks at the job site. A lot will consist of:

- one day's production not to exceed 2,000 tons (1 814 000 kg), or
- a half day'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 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 1559, paragraph 4.5, at the number of blows 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 more than 30 minutes to maintain the heat. The compaction temperature of the specimens should be as specified in the job mix formula.

(2) **Testing.** Sample specimens shall be tested for stability and flow in accordance with ASTM D 1559, paragraph 5. Air voids will be determined by the Engineer in accordance with ASTM D 3203.

Prior to testing, the bulk specific gravity of each test specimen shall be measured by the Engineer in accordance with ASTM D 2726 or 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 lot in accordance with ASTM D 2041, Type C or D container. Samples shall be taken on a random basis in accordance with ASTM D 3665. The value used in the voids computation for each sublot shall be the average of the two maximum specific gravity measurements for the lot.

The stability, flow, and air voids for each sublot shall be computed by averaging the results of the three test specimens representing that sublot.

(3) **Acceptance.** Acceptance of plant produced material for stability, flow, and air voids 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 401-5.1.a 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.

(3) Sampling. Samples shall be neatly cut with a core drill or other approved equipment. The minimum diameter of the sample shall be three 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 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 average bulk specific gravity of all laboratory prepared specimens for the lot, as determined in paragraph 401-5.1a(2).

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

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, 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 unexpectedly halted 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.

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 less than (3) cored samples shall be obtained, i.e., n = 3.

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's Quality Control plan and test results:

(1) Stability

(2) Flow

(3) Air voids

(4) Mat density

(5) Joint density

(6) Thickness

(7) Smoothness

(8) Grade

Stability, flow, and air voids will be evaluated for acceptance in accordance with paragraph 401-5.2b. Mat density will be evaluated for acceptance in accordance with paragraph 401-5.2c. Joint density will be evaluated for acceptance in accordance with paragraph 401-5.2d.

Acceptance for mat density and air voids will be based on the criteria contained in paragraph 401-5.2f(1). Acceptance for stability and flow will be based on the criteria contained in paragraph 401-5.2f(2). Acceptance for joint

density will be based on the criteria contained in paragraph 401-5f(3). Thickness will be evaluated by the Engineer for compliance in accordance with paragraph 401-5.2.f(4). Acceptance for smoothness will be based on the criteria contained in paragraph 401-5.2f(5). Acceptance for grade will be based on the criteria contained in paragraph 401-5.2f(6).

The Engineer may at any time, not withstanding 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 he can demonstrate 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. Stability, Flow, Air Voids. Acceptance of each lot of plant produced material for stability, flow, and air voids shall be based on the percentage of material within specification limits (PWL). The PWL plan considers the variability (standard deviation) of the material and the testing procedures, as well as the average (mean) value of the test parameter. The Contractor should note that under this plan, producing at the target values contained in Table 1 and the applicable standard deviations listed in paragraph 401-3.2 will result in a PWL of 90 or more. If a material of greater variability is produced, the production target must be adjusted as outlined in paragraph 401-3.2 to achieve a PWL of 90 or more. The PWL is determined in accordance with the procedures contained in Paragraph 401-5.2.e.

c. Mat Density. Acceptance of each lot of in-place pavement for mat density shall be based on the percentage of material within specification limits (PWL). The Contractor should note that under this plan, producing at a target density of 98 percent and a standard deviation of 1.3 percent will result in a PWL of 90 percent based on the lower specification tolerance limit of 96.3 percent. If a material of greater variability is produced, then a higher target density must be maintained in order to achieve a PWL of 90 or more. The PWL is determined in accordance with the procedures contained in paragraph 401-5.2.e.

d. Joint Density. Acceptance of each lot of in-place pavement for joint density shall be based on the percentage of material within specification limits (PWL). The Contractor should note that under this plan, producing at a target density of 96 percent and a standard deviation of 2.1 percent will result in a PWL of 90 percent based on the lower specification tolerance limit of 93.3 percent. If a material of greater variability is produced, then a higher target density must be maintained in order to achieve a PWL of 90 or more. The PWL is determined in accordance with the procedures contained in paragraph 401-5.2e.

e. Method of Estimating Percentage of Material Within Specification Limits (PWL). The percentage of material within specification limits (PWL) is determined using standard statistical techniques and involves the average of the test results (X), the standard deviation (S_n) of the test results, the specification tolerance limit(s) (U for upper and L for lower), and the respective Quality Index(s) (Q_U and/or Q_L).

The computational sequence for computing the PWL is as follows:

(1) Locate n random sampling positions on the lot in accordance with paragraph 401-5.1.

(2) Make a measurement at each location, or take a test portion and make the measurement on the test portion in accordance with paragraph 401-5.1.

(3) Average all sublot values within the lot to find X.

(4) Find the standard deviation S_n by use of the following formula:

$$S_n = (d_1^2 + d_2^2 + d_3^2 + . . . d_n^2 / n-1)^{1/2}$$

Where:

S_n = standard deviation of the number of sublot values in the set

d_1, d_2 = deviations of the individual sample values X_1, X_2 . . . from the average value X

that is d_1 = $(X_1 - X)$, $d_2 = (X_2 - X)$ . . $d_n = (X_n - X)$

n = number of sublots

or use of a calculator which performs this function

(5) For **mat density, joint density, and stability**, compute the Lower Quality Index Q_L by use of the following formula:

$$Q_L = (X - L) / S_n$$

Where: L = specification tolerance limit from Table 5

Estimate the percentage of material within limits (PWL) by entering Table 6 with Q_L, using the column appropriate to the total number (n) of measurements. If the value of Q falls between values shown on the table, use the next higher value of PWL.

(6) For **air voids and flow**, compute the Quality Indexes Q_L and Q_U by use of the following formulas:

$$Q_L = (X - L) / S_n \quad \text{and} \quad Q_U = (U - X) / S_n$$

Where: L and U = specification tolerance limits from Table 5.

Estimate the percentage of material between the lower (L) and upper (U) tolerance limits (PWL) by entering Table 6 separately with Q_L and Q_U, using the column appropriate to the total number (n) of measurements, and determining the percent of material above P_L and percent of material below P_U for each tolerance limit. If the value of Q falls between values shown on the table, use the next higher value of P_L or P_U. Determine the PWL by use of the following formula:

$$PWL = (P_U + P_L) - 100$$

Where: P_L = percent within upper specification limit
P_U = percent within lower specification limit

f. Acceptance Criteria.

(1) **Mat Density and Air Voids.** If the PWL of the lot equals or exceeds 90 percent, the lot shall be acceptable. If the PWL is less than 90 percent, payment shall be made in accordance with paragraph 401-8.1a.

(2) **Stability and Flow.** 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.

(3) **Joint Density.** 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 evaluate the method of compacting joints. If the PWL is below 80 percent, the Contractor shall stop production until the reason for poor compaction can be determined.

(4) **Thickness.** Thickness shall be evaluated for compliance by the Engineer 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.

(5) **Smoothness.** The finished surfaces of the pavement shall not vary more than [ ] for the **[surface] [base]** course. Each lot shall be evaluated with a 12-foot (3.6 m) straightedge. The lot size shall be [ ] square yards (square meters). Measurements will be made perpendicular and parallel to the centerline at distances not to exceed 50 feet (15.2 m). When more than 15 percent of all measurements within a lot exceed the specified tolerance, the Contractor shall remove the deficient area and replace with new material. Sufficient material shall be removed to allow at least one inch of asphalt concrete to be placed. Skin patching shall not be permitted. High points may be ground off.

* *

Specify 3/8 inch (9.5 mm) for base course and 1/4 inch (6.2 mm) for surface course.

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

* *

(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 1/2 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 transversely to determine the elevation of the completed pavement. 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, the Contractor shall remove the deficient area and replace with new material. Sufficient material shall be removed to allow at least one inch of asphalt concrete to be placed. Skin patching for correcting low areas shall not be permitted. High points may be ground off.

* *

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

* *

TABLE 5. ACCEPTANCE LIMITS STABILITY, FLOW, AIR VOIDS, DENSITY

Test Property	Pavements Designed for Aircraft Gross Weights of 60,000 Lbs. or More or Tire Pressure Greater Than 100 Psi		Pavements Designed for Aircraft Gross Weight Less Than 60,000 Lbs. or Tire Pressure Less Than 100 Psi	
Number of Blows	75		50	
	Specification Tolerance		Specification Tolerance	
	L	U	L	U
Stability, minimum pounds	1800	-	1000	-
Flow, 0.01-inch	8	16	8	20
Air voids total mix (percent)	2.0	5.0	2.0	5.0
Density, percent	96.3	-	96.3	-
Joint density (percent)	93.3	-	93.3	-

TABLE 6. TABLE FOR ESTIMATING PERCENT OF LOT WITHIN LIMITS (PWL)

Percent Within Limits (PWL), P_L, and P_u	Positive Values of Q					
	n=3	n=4	n=5	n=6	n=7	n=8
99	1.1541	1.4700	1.6714	1.8008	1.8888	1.9520
98	1.1524	1.4400	1.6016	1.6982	1.7612	1.8053
97	1.1496	1.4100	1.5427	1.6181	1.6661	1.6993
96	1.1456	1.3800	1.4897	1.5497	1.5871	1.6127
95	1.1405	1.3500	1.4407	1.4887	1.5181	1.5381
94	1.1342	1.3200	1.3946	1.4329	1.4561	1.4716
93	1.1269	1.2900	1.3508	1.3810	1.3991	1.4112
92	1.1184	1.2600	1.3088	1.3323	1.3461	1.3554
91	1.1089	1.2300	1.2683	1.2860	1.2964	1.3032
90	1.0982	1.2000	1.2290	1.2419	1.2492	1.2541
89	1.0864	1.1700	1.1909	1.1995	1.2043	1.2075
88	1.0736	1.1400	1.1537	1.1587	1.1613	1.1630
87	1.0597	1.1100	1.1173	1.1191	1.1199	1.1204
86	1.0448	1.0800	1.0817	1.0808	1.0800	1.0794
85	1.0288	1.0500	1.0467	1.0435	1.0413	1.0399
84	1.0119	1.0200	1.0124	1.0071	1.0037	1.0015
83	0.9939	0.9900	0.9785	0.9715	0.9672	0.9643
82	0.9749	0.9600	0.9452	0.9367	0.9325	0.9281
81	0.9550	0.9300	0.9123	0.9025	0.8966	0.8928
80	0.9342	0.9000	0.8799	0.8690	0.8625	0.8583
79	0.9124	0.8700	0.8478	0.8360	0.8291	0.8245
78	0.8897	0.8400	0.8160	0.8036	0.7962	0.7915
77	0.8662	0.8100	0.7846	0.7716	0.7640	0.7590
76	0.8417	0.7800	0.7535	0.7401	0.7322	0.7271
75	0.8165	0.7500	0.7226	0.7089	0.7009	0.6958
74	0.7904	0.7200	0.6921	0.6781	0.6701	0.6649
73	0.7636	0.6900	0.6617	0.6477	0.6396	0.6344
72	0.7360	0.6600	0.6316	0.6176	0.6095	0.6044
71	0.7077	0.6300	0.6016	0.5878	0.5798	0.5747
70	0.6787	0.6000	0.5719	0.5583	0.5504	0.5454
69	0.6490	0.5700	0.5423	0.5290	0.5213	0.5164
68	0.6187	0.5400	0.5129	0.4999	0.4924	0.4877
67	0.5878	0.5100	0.4836	0.4710	0.4638	0.4592
66	0.5563	0.4800	0.4545	0.4424	0.4354	0.4310
65	0.5242	0.4500	0.4255	0.4139	0.4073	0.4031
64	0.4916	0.4200	0.3967	0.3856	0.3793	0.3753
63	0.4586	0.3900	0.3679	0.3575	0.3515	0.3477
62	0.4251	0.3600	0.3392	0.3295	0.3239	0.3203
61	0.3911	0.3300	0.3107	0.3016	0.2964	0.2931
60	0.3568	0.3000	0.2822	0.2738	0.2691	0.2660
59	0.3222	0.2700	0.2537	0.2461	0.2418	0.2391
58	0.2872	0.2400	0.2254	0.2186	0.2147	0.2122
57	0.2519	0.2100	0.1971	0.1911	0.1877	0.1855
56	0.2164	0.1800	0.1688	0.1636	0.1613	0.1592
55	0.1806	0.1500	0.1408	0.1363	0.1338	0.1322
54	0.1447	0.1200	0.1125	0.1090	0.1070	0.1057
53	0.1087	0.0900	0.0843	0.0817	0.0802	0.0792
52	0.0725	0.0600	0.0562	0.0544	0.0534	0.0528
51	0.0363	0.0300	0.0281	0.0272	0.0267	0.0264
50	0.0	0.0	0.0	0.0	0.0	0.0

* *

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 401-5q.1.

* *

401-5.3 RESAMPLING PAVEMENT.

a. **General.** Resampling of a lot of pavement for mat density will be allowed if the Contractor requests, in writing, within 48 hours after receiving the written test results from the Engineer. A retest will consist of all the sampling and testing procedures contained in paragraphs 401-5.1b and 401-5.2c. Only one resampling per lot will be permitted.

(1) A redefined PWL shall be calculated for the resampled lot. The number of tests used to calculate the redefined PWL shall include the initial tests made for that lot plus the retests.

(2) The cost for resampling and retesting shall be borne by the Contractor.

b. **Payment for Resampled Lots.** The redefined PWL for a resampled lot shall be used to calculate the payment for that lot in accordance with Table 7.

c. **Outliers.** If the tests within a lot include a very large or a very small value which appears to be outside the normal limits of variation, check for an outlier in accordance with ASTM E 178, at a significance level of 5 percent, to determine if this value should be discarded when computing the PWL.

[401-5.4 LEVELING COURSE. Any course used for truing and leveling shall meet the requirements of paragraph 401-3.2 and 5.2b, but shall not be subject to the density requirements of paragraph 401-5.2c and d. The leveling course shall be compacted with the same effort used to achieve density of the test section. The truing and leveling course shall not exceed a nominal thickness of 12 inches (37.5 mm).]

* *

Use this paragraph only when there is a need to restore proper cross-section prior to overlaying. Areas of the pavement requiring a leveling course shall be shown on the plans.

* *

CONTRACTOR QUALITY CONTROL

401-6.1 GENERAL. The Contractor shall establish, provide, and maintain a quality control system which will provide reasonable assurance that all materials and completed construction submitted for acceptance conform to contract requirements whether manufactured or processed by the Contractor or procured from sub-contractors or vendors. Although guidelines are established and certain requirements are specified, they are minimum and the Contractor shall assume full responsibility for meeting all requirements.

The Contractor shall be prepared to discuss and present, at the preconstruction conference, his/her understanding of the quality control responsibilities for specific items as included in these specifications.

The Contractor shall provide the Engineer a certification stating that all of the testing equipment to be used is properly calibrated and will meet the specifications applicable for the specified test procedures. As a part of the process for approving the Contractor's Plan, the Engineer may require the Contractor's technician to perform testing of samples to demonstrate an acceptable level of performance.

The Contractor shall perform quality control sampling, testing, and inspection during all phases of the work and shall perform them at a rate sufficient to ensure that the work conforms to the contract requirements, and at minimum test frequencies required by paragraph 401-6.3.

401-6.2 QUALITY CONTROL PLAN. The Contractor shall provide and maintain a Quality Control Plan (Plan) along with all the personnel, equipment, supplies, and facilities necessary to obtain samples, perform and document tests, and otherwise ensure the quality of the product.

The Contractor shall describe the Plan in a written document which shall be approved by the Engineer prior to the start of any production or construction. The written Plan shall be submitted to the Engineer for approval at least [ ] days prior to the start of operations.

* *

A minimum of 5 days is recommended.

For projects with gross tonnage of 10,000 tons (9 100 000 kg) or less, the requirement for a Quality Control Plan may be deleted.

* *

No partial payment will be made for materials which are subject to specific quality control requirements without an approved Plan.

The Plan may be operated wholly or in part by the Contractor or an independent organization; however, the Plan's administration, including compliance with the Plan and its modification, shall remain the responsibility of the Contractor.

a. **Plan Contents.** The Plan shall be organized to address the following minimum items:

(1) Quality control organization chart.

(2) Area of responsibility and authority of each individual.

(3) Names and qualifications of personnel as required by paragagraphs 401-6.2c(1)and (2).

(4) A listing of any outside organizations such as testing laboratories that will be employed by the contractor and a description of the services they will provide.

(5) A testing plan which lists the tests required to be performed by the Contractor, the frequency of testing, sampling locations, and the location of the testing facilities.

(6) Procedures for ensuring that tests are taken in accordance with the testing plan, that they are documented, and that proper corrective actions are taken when necessary.

(7) Procedures for ensuring that testing equipment is available, complies with specified standards, and has been calibrated against certified standards.

(8) Procedures for verifying that tests are taken in accordance with the appropriate ASTM standards.

(9) Procedures for submittal of test results to the Engineer on a daily basis.

b. **Plan Elements.** The Plan shall address all elements which affect the quality of the asphalt concrete including:

(1) Mix Design

(2) Aggregate Grading

(3) Quality of Materials

(4) Stockpile Management

(5) Proportioning

(6) Mixing

(7) Placing and Finishing

(8) Joints

(9) Compaction

(10) Surface smoothness

c. **Quality Control Organization.** The Plan shall be implemented by the establishment of a separate Quality Control Organization. An organization chart shall be developed to show all quality control personnel and how these personnel integrate with other management, production, and construction functions and personnel.

The organization chart shall identify all quality control staff by name and function, and shall indicate the total staff required to implement all elements of the quality control program, including inspection and testing functions for different items of work.

If an outside organization or independent testing laboratory is used for implementation of all or part of the Plan, the personnel assigned shall be subject to the qualification requirements of this paragraph. The organization chart shall indicate which personnel are contractor employees and which are provided by an outside organization.

The Quality Control Organization shall consist of the following minimum personnel:

(1) **Plan Administrator.** The Plan Administrator shall be an employee of the Contractor, or a consultant engaged by the Contractor. The Plan Administrator shall have prior quality control experience on a project of comparable size and scope.

In addition, the Plan Administrator shall meet one of the following requirements:

(a) Professional Engineer with one year of airport paving experience acceptable to the Engineer.

(b) Engineer–in–Training with two years of airport paving experience acceptable to the Engineer.

(c) An individual with three years of highway and/or airport paving experience acceptable to the Engineer and with a Bachelor of Science Degree in Civil Engineering, Civil Engineering Technology or Construction.

(d) Construction Materials Technician certified at Level III by the National Institute for Certification in Engineering Technologies (NICET).

(e) Highway Materials Technician certified at Level III by NICET.

(f) Highway Construction Technician certified at Level III by NICET.

(g) A NICET certified Engineering Technician in Civil Engineering Technology with 5 years of highway and/or airport paving experience acceptable to the Engineer.

Certification at an equivalent level, by a State or nationally recognized organization will be acceptable in lieu of NICET certification.

The Plan Administrator shall have full authority to institute any and all actions necessary for the successful operation of the Plan to ensure compliance with the specifications. The Plan Administrator shall report directly to a responsible officer in the Contractor's organization. The Administrator may supervise the Plan on more than one project provided that they can be at the job site within one hour after being notified of a problem.

(2) **Quality Control Technicians.** The Contractor shall provide a sufficient number of Quality Control Technicians to adequately implement the Plan. These personnel shall be either engineers, engineering technicians, or experienced craftsmen with qualifications equivalent to NICET Level II or higher in their appropriate field and shall have a minimum of 2 years experience in their area of expertise.

The Quality Control Technicians shall report directly to the Plan Administrator and shall perform the following functions:

(a) Inspection of all plant equipment used in proportioning and mixing to ensure proper calibration and operating condition.

(b) Performance of quality control tests necessary to adjust and control mix proportioning in accordance with the job mix formula.

(c) Inspection of all equipment used in placing, finishing, and compacting material to ensure proper operating condition.

(d) Inspection during construction to ensure placing, joint construction, and compaction is in conformance with the specifications and will produce a finished product that meets specification requirements.

(e) Performance of all quality control testing as required by paragraph 401–6.3, including density monitoring.

The Plan shall detail the criteria to be utilized to correct unsatisfactory production processes and construction practices.

Certification at an equivalent level, by a State or nationally recognized organization will be acceptable in lieu of NICET certification.

d. Testing Laboratory. The Plan must provide for a fully equipped asphalt laboratory located at the plant or job site. It shall be available for joint use by the Contractor for quality control testing and by the Engineer for acceptance testing and must have adequate equipment for the performance of the tests required by these specifications. The Engineer shall have priority in use of the equipment necessary for acceptance testing.

The effective working area of the laboratory shall be a minimum of 150 square feet (14 square meters) with a ceiling height of not less than 7.5 feet (2.3 meters). Lighting shall be adequate to illuminate all working areas. It shall be equipped with heating and air conditioning units to maintain a temperature of 70°F + 5°F (21°C + 2.3°C).

Laboratory facilities shall be kept clean and all equipment shall be maintained in proper working condition. The Engineer shall be permitted unrestricted access to inspect the Contractor's laboratory facility and witness quality control activities. The Engineer 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 be adversely affecting 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 satisfactorily corrected.

e. Sampling. The Plan shall contain a statistically based procedure of random sampling which provides that all materials being produced have an equal chance of being selected for sampling and testing. The Engineer shall be provided the opportunity to witness all sampling.

f. Noncompliance. In cases where quality control activities do not comply with either the Contractor's Quality Control Program or the contract provisions, or where the Contractor fails to properly operate and maintain an effective Quality Control Program, the Engineer may:

(1) Order the Contractor to replace ineffective or unqualified quality control personnel.

(2) Carry out the functions and operations of the Contractor's approved Quality Control Program. Costs incurred by the Owner to operate the Quality Control Program or to otherwise remedy the Contractor's non-compliance with quality related provisions of the Contract shall be deducted from the total amount due the Contractor.

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 Plan. The testing program shall include, but not necessarily limited to, tests for the control of asphalt content, aggregate gradation, temperatures, aggregate moisture, field compaction, and surface smoothness. The Contractor shall employ random sampling procedures for obtaining test samples.

a. Asphalt Content. A minimum of two extraction tests shall be performed per lot in accordance with 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 plant production. The last weight of ash value obtained shall be used in the calculation of the asphalt content for the mixture.

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.

b. Gradation. Aggregate gradations shall be determined a minimum of twice per lot from mechanical analysis of extracted aggregate in accordance with AASHTO T 30 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.

c. 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.

d. Moisture Content of Mixture. The moisture content of the mixture shall be determined once per lot in accordance with ASTM D 1461.

e. 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.

f. 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.

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

h. 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 which 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.

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 and asphalt content. 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%

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

d. Corrective Action. The Quality Control Plan shall indicate that appropriate action shall be taken when the process is believed to be out of control. 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 3/4 inch (19.0 mm) maximum size aggregate gradation. When 1-inch (25.0 mm) or 1-1/4 inch (31.2 mm) maximum size aggregate is specified, the Individual Measurements Chart requirements should be amended as follows:

Sieve	Action Limit	Suspension Limit
1 or 1-¼ inch	**0%**	**0%**
¾ inch sieve	**6%**	**11%**

When 1/2-inch (12.5 mm) maximum size aggregate is specified, the 3/4-inch (19.0 mm) and 1-inch (25.0 mm) sieves should be deleted from the Individual Measurements Chart and the 1/2-inch (12.5 mm) sieve Action and Suspension Limits should be changed to 0%. For the 1/2-inch (12.5 mm) gradation, the 1/2-inch sieve should be deleted from the Range Chart.

* *

410-6.6 QUALITY CONTROL REPORTS. The Contractor shall maintain records and shall submit reports of quality control activities daily, in accordance with the Quality Control Plan.

METHOD OF MEASUREMENT

401-7.1 MEASUREMENT. Plant mix bituminous concrete pavement shall be measured by the number of tons (kg) of bituminous mixture **[and the number of tons (kg) of bituminous material]** used in the accepted work. Recorded batch weights or truck scale weights will be used to determine the basis for the tonnage. **[The weight of bituminous material shall be adjusted in accordance with the percentage of bitumen as determined in paragraph 401-6.3a.]**

BASIS OF PAYMENT

401-8.1 PAYMENT. Payment for an accepted bituminous concrete pavement shall be made at the adjusted contract unit price per ton (kg) for bituminous mixture **[and bituminous material]**. The price shall be compensation for furnishing all materials, for all preparation, mixing, and placing of these materials, and for all labor, equipment, tools, and incidentals necessary to complete the item.

a. Basis of Adjusted Payment. Table 7 shall be used to determine the adjusted contract price for a lot of material when the results of the mat density and/or air voids tests for that lot indicate that the percentage of material within the specification limit is less than 90 percent. The percent payment shall be calculated for both mat density and air voids, and payment shall be based on the lower of the two values. **[The price adjustment shall apply to both the bituminous course and the bituminous material.]**

TABLE 7. PRICE ADJUSTMENT SCHEDULE

Percentage of Material Within the Specification Limit (PWL)	Percent of Contract Unit Price to be Paid
90–100	100
80–90	0.5 PWL + 55.0
65–80	2.0 PWL – 65.0
Below 65	[1]

[1] The lot shall be removed and replaced. However, the Engineer may decide to accept the deficient lot. In that case, if the Engineer and Contractor agree in writing, that lot shall not be removed, and it will be paid for at 50 percent of the contract price.

b. Payment. Payment will be made under:

Item P–401–8.1a	Bituminous [Surface] [Base] Course—per ton (kg)
[Item P–401–8.1b	**Bituminous Material—per ton (kg)]**

TESTING REQUIREMENTS

ASTM C 29	Unit Weight of Aggregate
ASTM C 88	Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
ASTM C 117	Test Method for Materials Finer than 75–um (No.200) Sieve in Mineral Aggregates by Washing
ASTM C 131	Resistance to Abrasion of Small Size Coarse Aggregate by Use of the Los Angeles Machine
ASTM C 136	Sieve or Screen Analysis of Fine and Coarse Aggregates
ASTM C 183	Sampling Hydraulic Cement
ASTM C 566	Total Moisture Content of Aggregate by Drying
ASTM D 75	Sampling Aggregates
ASTM D 995	Requirements for Mixing Plants for Hot–Mixed Hot–Laid Bituminous Paving Mixtures
ASTM D 118	Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin–Coated Specimens
ASTM D 1461	Moisture or Volatile Distillates in Bituminous Paving Mixtures
ASTM D 1559	Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus
ASTM D 2041	Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
ASTM D 2172	Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
ASTM D 2419	Sand Equivalent Value of Soils and Fine Aggregate
ASTM D 2489	Degree of Particle Coating of Bituminous–Aggregate Mixtures
ASTM D 2726	Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface–Dry Specimens

ASTM D 3203	Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
ASTM D 2950	Density of Bituminous Concrete in Place by Nuclear Method
ASTM D 3665	Random Sampling of Paving Materials
ASTM D 3666	Inspection and Testing Agencies for Bituminous Paving Materials
ASTM D 4125	Asphalt Content of Bituminous Mixtures by the Nuclear Method
ASTM D 4318	Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D 4791	Flat or Elongated Particles in Coarse Aggregate
ASTM D 4867	Effect of Moisture on Asphalt Concrete Paving Mixtures
ASTM E 178	Practice for Dealing With Outlying Observations
AASHTO T 30	Mechanical Analysis of Extracted Aggregate
The Asphalt Institute's Manual No. 2 (MS-2)	Mix Design Methods for Asphalt Concrete
The Asphalt Institute's Manual No. 20 (MS-20)	Hot-Mix Recycling

MATERIAL REQUIREMENTS

ASTM D 242	Mineral Filler for Bituminous Paving Mixtures
ASTM D 946	Asphalt Cement for Use in Pavement Construction
ASTM D 3381	Viscosity-Graded Asphalt Cement for Use in Pavement Construction
ASTM D 4552	Classifying Hot-Mix Recycling Agents

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