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

JUN 12 2001

FROM: HQ AFCESA/CESC
139 Barnes Drive, Suite 1
Tyndall AFB FL 32403-5319

SUBJECT: **Engineering Technical Letter (ETL) 01-6: Contingency Airfield Pavement Specifications**

1. Purpose. This ETL provides specifications for construction of contingency airfields.

2. Application. Requirements of this ETL are voluntary, but highly recommended to improve quality of construction.

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

2.2. Effective Date: Immediately.

2.3. Ultimate Recipients:

- Base civil engineers (BCE) and other units responsible for design of contingency airfield pavements.
- Air Force major command (MAJCOM) engineers.
- Rapid Engineers Deployable - Heavy Operations Repair Squadron Engineers (RED HORSE) units responsible for design and construction of contingency airfields.

2.4. Coordination: MAJCOM pavement engineers.

3. Referenced Publications.

3.1. Air Force:

- AFJMAN 32-1019, *Soil Stabilization for Pavements*
- ETL 97-2, *Maintenance and Repair of Rigid Airfield Pavement Surfaces, Joints, and Cracks*
- ETL 97-5, *Proportioning Concrete Mixtures with Graded Aggregates for Rigid Airfield Pavements*

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

- AASHTO M 182, *Burlap Cloth Made From Jute or Kenaf*
- AASHTO M 20, *Penetration Graded Asphalt Cement*
- AASHTO M 226, *Viscosity Graded Asphalt Cement*
- AASHTO M 81, *Rapid Curing Cutback Asphalt*
- AASHTO M 82, *Medium Curing Cutback Asphalt*

- AASHTO MP1, *Standard Specification for Performance Graded Asphalt Binder*
- AASHTO T 102, *Spot Test of Asphaltic Materials*
- AASHTO T 134, *Moisture Density of Soil Cement*
- AASHTO T 135, *Wetting-and-Drying Testing of Compacted Soil-Cement Mixtures*
- AASHTO T 136, *Freezing-and-Thawing Tests of Compacted Soil-Cement Mixtures*
- AASHTO T 40, *Sampling Bituminous Materials*
- AASHTO T 89, *Liquid Limit*
- AASHTO T 90, *Plastic Limit and Plasticity Index*

3.3. American Concrete Institute:

- ACI 211.1, *Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete*
- ACI 301, *Standard Specifications for Structural Concrete*
- ACI 305R, *Hot Weather Contracting*

3.4. Asphalt Institute (AI):

- AI MS-2, *Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types*

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

- ASTM A 184/A 184M, *Standard Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement*
- ASTM A 615/A 615M, *Standard Specification for Deformed or Plain Billet-Steel for Concrete Reinforcement*
- ASTM C 25, *Standard Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime*
- ASTM C 29/C 29M, *Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate*
- ASTM C 31/C 31M, *Standard Practice for Making and Curing Concrete Test Specimens in the Field*
- ASTM C 33, *Standard Specification for Concrete Aggregates*
- ASTM C 39/C 39M, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*
- ASTM C 50, *Standard Practice for Sampling, Sample Preparation, and Marking of Lime and Limestone Products*
- ASTM C 88, *Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate*
- ASTM C 117, *Materials Finer Than 75 pm (No. 200) Sieve in Mineral Aggregates by Washing*
- ASTM C 123, *Standard Test Method for Lightweight Particles in Aggregate*
- ASTM C 127, *Specific Gravity and Absorption of Coarse Aggregate*
- ASTM C 128, *Specific Gravity and Absorption of Fine Aggregate*
- ASTM C 131, *Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine*

- ASTM C 136, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*
- ASTM C 142, *Standard Test Method for Clay Lumps and Friable Particles in Aggregates*
- ASTM C 143/C 143M, *Standard Test Method for Slump of Hydraulic-Cement Concrete*
- ASTM C 150, *Standard Specification for Portland Cement*
- ASTM C 171, *Standard Specification for Sheet Materials for Curing Concrete*
- ASTM C 172, *Standard Practice for Sampling Freshly Mixed Concrete*
- ASTM C 173, *Test for Air Content of Freshly Mixed Concrete by the Volumetric Method*
- ASTM C 174/C 174M, *Measuring Length of Drilled Concrete Cores*
- ASTM C 183, *Sampling and the Amount of Testing of Hydraulic Cement*
- ASTM C 192/C 192M, *Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory*
- ASTM C 231, *Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method*
- ASTM C 260, *Standard Specification for Air-Entraining Admixtures for Concrete*
- ASTM C 494/C 494M, *Standard Specification for Chemical Admixtures for Concrete*
- ASTM C 566, *Standard Test Method for Total Moisture Content of Aggregate by Drying*
- ASTM C 595, *Standard Specification for Blended Hydraulic Cements*
- ASTM C 881, *Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete*
- ASTM D 5, *Standard Test Method for Penetration of Bituminous Materials*
- ASTM D 75, *Standard Practice for Sampling Aggregates*
- ASTM D 92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup*
- ASTM D 140, *Standard Practice for Sampling Bituminous Materials*
- ASTM D 242, *Mineral Filler for Bituminous Paving Mixtures*
- ASTM D 422, *Standard Test Method for Particle-Size Analysis of Soils*
- ASTM D 490, *Specification for Road Tar*
- ASTM D 558, *Standard Test Methods for Moisture-Density Relations of Soil-Cement Mixtures*
- ASTM D 559, *Standard Test Methods for Wetting and Drying Compacted Soil Cement Mixtures*
- ASTM D 560, *Standard Test Methods for Freezing and Thawing Compacted Soil-Cement Mixtures*
- ASTM D 633, *Volume Correction Table for Road Tar*
- ASTM D 698, *Tests for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures, Using 5.5-pound (2.5 kg) Rammer and 12-inch (300 mm) Drop*
- ASTM D 946, *Standard Specification for Penetration-Graded Asphalt Cement for Use in Pavement Construction*

- ASTM D 977, *Standard Specification for Emulsified Asphalt*
- ASTM D 1250, *Petroleum Measurement Tables*
- ASTM C 1252, *Test Methods for Uncompacted Void Content of Fine Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading*
- ASTM D 1461, *Standard Test Method for Moisture or Volatile Distillates in Bituminous Paving Mixtures*
- ASTM D 1556, *Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Core Method*
- ASTM D 1557, *Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft –lbf/f[2,700 kN – m/m])*
- ASTM D 1559, *Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus*
- ASTM D 1632, *Making and Curing Soil-Cement Compression and Flexure Test Specimens in the Laboratory*
- ASTM D 1633, *Compressive Strength of Molded Soil-Cement*
- ASTM D 1751, *Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)*
- ASTM D 1752, *Preformed Sponge Rubber and Cork Expansion Joint*
- ASTM D 1754, *Standard Test Method for Effects of Heat and Air on Asphaltic Materials (Thin-Film Oven Test)*
- ASTM D 1856, *Recovery of Asphalt by Abson Method*
- ASTM D 2026, *Cutback Asphalt (Slow Curing Type)*
- ASTM D 2027, *Specification for Cutback Asphalt (Medium-Curing Type)*
- ASTM D 2028, *Specification for Cutback Asphalt (Rapid-Curing Type)*
- ASTM D 2041, *Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures*
- ASTM D 2167, *Standard Test Method for Density and Unit of Soil in Place by Rubber-Balloon Method*
- ASTM D 2170, *Standard Test Method for Kinematic Viscosity of Asphalts (Bitumens)*
- ASTM D 2171, *Standard Test Method for Viscosity of Asphalts by Vacuum Capillary Viscometer*
- ASTM D 2172, *Standard Test Method for Quantitative Extraction of Bitumen form Bituminous Paving Mixtures*
- ASTM D 2216, *Laboratory Determination of Water (Moisture) Content of Soil and Rock*
- ASTM D 2397, *Standard Specification for Cationic Emulsified Asphalt*
- ASTM D 2419, *Sand Equivalent Value of Soils and Fine Aggregate*
- ASTM D 2487, *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*
- ASTM D 2726, *Standard Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures*
- ASTM D 2872, *Standard Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)*

- ASTM D 2922, *Standard Test Method for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)*
- ASTM D 2995, *Standard Practice for Determining Application Rate of Bituminous Distributors*
- ASTM D 3017, *Standard Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth)*
- ASTM D 3381, *Standard Specification for Viscosity-Graded Asphalt Cement for Use in Pavement Construction*
- ASTM D 3405, *Standard Specification for Joint Sealants, Hot-Applied, for Concrete and Asphalt Pavements*
- ASTM D 3569, *Standard Specification for Joint Sealant, Hot-Applied, Elastomeric Jet-Fuel-Resistant-Type for Portland Cement Concrete Pavements*
- ASTM D 3665, *Practice for Random Sampling of Construction Materials*
- ASTM D 4125, *Standard Test Methods for Asphalt Content of Bituminous Mixtures by the Nuclear Method*
- ASTM D 4318, *Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*
- ASTM D 4791, *Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate*
- ASTM D 4867/D 4867M, *Standard Test Method for Effect of Moisture on Asphalt Paving Mixtures*
- ASTM D 5444, *Test Method for Mechanical Size Analysis of Extracted Aggregate*
- ASTM D 6307*, Standard Test Method for Asphalt Content of Hot-Mix Asphalt by Ignition Method*
- ASTM E 11, *Wire-Cloth Sieves for Testing Purposes Y 17 R*

3.6. California Department of Transportation (CDT):

- CDT 01, *Standard Method of Test for Centrifuge Kerosene Equivalent and Approximate Bitumen Ratio*

3.7. U.S. Army Corps of Engineers (COE):

- COE CRD-C 130, *Standard Recommended Practice for Estimating Scratch Hardness of Coarse Aggregate Particles*
- COE CRD-C 300, *Corps of Engineers Specifications for Membrane-Forming Compounds for Curing Concrete*
- COE CRD-C 525, *Corps of Engineers Test Method for Evaluation of Hot-Applied Joint Sealants for Bubbling due to Heating*
- COE CRD-C 71, *Test for Ultimate Tensile Strain Capacity of Concrete*

3.8. Federal Specifications (FS):

- FS SS-S-200, *Sealing Compounds, Two-Component Elastomeric, Polymer Type, Jet-Fuel-Resistant, Cold Applied*
- FS TT-B-1325, *Beads (Glass Sphere) Retroreflective*

- FS TT-B-1952, *Paint, Traffic and Airfield Marking, Water Emulsion Base*

3.9. National Ready-Mixed Concrete Association – Concrete Plant Manufacturers Bureau (NRMCA CPMB)

- NRMCA CPMB 100, *Concrete Plant Standards of the Concrete Plant Manufacturers Bureau*

3.10. Unified Facilities Criteria (UFC):

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

3.11. U.S. Army Technical Manual (TM):

- TM 5-822-14, *Soil Stabilization for Pavements*

3.12. Other:

- *Proportioning Concrete Mixtures with Graded Aggregates, A Handbook for Rigid Airfield Pavements*, Jim Lafrenz, AFCESA

4. Acronyms and Terms.

AASHTO	- American Association of State Highway and Transportation Officials
ACI	- American Concrete Institute
AFCESA	- Air Force Civil Engineer Support Agency
ASTM	- American Society for Testing and Materials
BCE	- base civil engineer
C	- Celsius
CBR	- California bearing ratio
CDT	- California Department of Transportation
CF	- coarseness factor
C.O.C.	- Cleveland open cup
COE	- Corps of Engineers
CPMB	- Concrete Plant Manufacturer's Bureau
CU	- coefficient of uniformity
DCP	- Dynamic cone penetrometer
ETL	- Engineering Technical Letter
F	- Fahrenheit
FOD	- foreign object debris
FS	- Federal Specification
HMA	- hot-mix asphalt
JMF	- job-mix formula
kN	- kilonewton
lb ft	- pound foot
LL	- liquid limit
PI	- plasticity index
MAJCOM	- major command

N•m	- newton meter
NRMCA	- National Ready-Mixed Concrete Association
OGM	- open graded materials
PFC	- porous friction course
psi	- pounds per square inch
QA	- quality assurance
QC	- quality control
RDM	- rapid draining materials
RED HORSE	- Rapid Engineers Deployable - Heavy Operations Repair Squadron Engineers
SSD	- saturated surface dry
TM	- Technical Manual
TSR	- tensile strength ratio
USACE	- U.S. Army Corps of Engineers
VMA	- voids in mineral aggregate
VTM	- voids in total mix
W	- workability factor
w/(c+p)	- water/cement plus pozzolan

5. Background. Existing U.S. Army Corps of Engineers (USACE) specifications are intended primarily for contract work. Generally, they are too complicated and complex for contingency construction. The need to develop simple specifications that can be readily adopted by RED HORSE and other units became apparent when a team composed of MAJCOM, Army, RED HORSE, and Air Force Civil Engineer Support Agency (AFCESA) engineers jointly designed a C-17 airfield during the Kosovo conflict. The specifications developed for that airfield have been revised and now include quality control (QC)/quality assurance (QA) procedures and checklists for identifying and correcting construction problems**.**

6. Specifications. Attached are specifications for earthwork, lime stabilization, Portland cement stabilization, base course, drainage, reclamation, concrete, asphalt, prime and tack coat, porous friction course, joint sealants, seal coat, and pavement marking.

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

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

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ASPHALT PRIME AND TACK COAT REQUIREMENTS

A1.1. General. This specification covers the requirements for asphalt prime and tack coats.

A1.2. Materials. The selection of a prime or tack coat material will be based on material availability. The following paragraphs give guidance on material selection:

A1.2.1. Tack Coat Material:

A1.2.1.1. Cutback asphalt should be supplied in accordance with ASTM D 2028, *Specification for Cutback Asphalt (Rapid-Curing Type)*, cutback grades RC-70 or RC-250. These materials perform better than emulsions in cool weather construction.

A1.2.1.2. Paving grade asphalt should be supplied in accordance with Table A1. The harder grades, penetration 85-100, viscosity grades AC 10 or AR 4000, are recommended for airfield pavements.

Table A1. Paving Grade Asphalt Standards

ASTM Standard	Grade
ASTM D 946	Penetration grade 200-300, 120-150, or 85-100
ASTM D 3381	Viscosity grade AC 2.5, AC 5, or AC 10
ASTM D 3381	Aged residue viscosity grades AR 1000, AR 2000, or AR 4000

A1.2.1.3. Emulsions, either anionic or cationic, can be used for tack coats. Anionic emulsion should meet the requirements of ASTM D 977*, Standard Specification for Emulsified Asphalt*, grades RS-1, MS-1, HFMS-1, SS-1 or SS-1h. Cationic emulsions should meet the requirements of ASTM D 2397*, Standard Specification for Cationic Emulsified Asphalt*, grades, CRS-1, CSS-1, and CSS-1h. Grades SS-1 and CSS-1h are made with harder base asphalt and are recommended for airfield pavements. Grades RS-1, SS-1, and SS-1h are widely used as tack coat materials.

A1.2.2. Prime Coat Material:

A1.2.2.1. Cutback asphalt should be supplied in accordance with Table A2.

Table A2. Cutback Asphalt Standards

ASTM Standard	Cure	Type
ASTM D 2026	Slow cure	Type SC-70 or SC-250
ASTM D 2027	Medium cure	Type MC-30, MC-70, or MC-250
ASTM D 2028	Rapid cure	Type RC-70 or RC-250

A1.2.2.2. Selection of a particular type and grade should consider the nature or the surface to be treated. An open base course material will be penetrated readily, and all of the above types and grades can be considered except for the low-viscosity MC-30. A tight surface is not going to be penetrated as readily; therefore, the less viscous materials are recommended such as RC-70, MC-30, MC-70, and SC-70. Some caution is urged in using the RC-70 and the RC-250 because the solvent may separate or be absorbed by the base course fines, and leave the asphalt deposited on the surface. These materials perform better than emulsions in cool weather construction.

A1.2.2.3. Emulsions, either anionic or cationic, can be used. Anionic emulsion should meet the requirements of ASTM D 977, Grades SS-1 or SS-1h. Cationic emulsions should meet the requirements of ASTM D 2397, Grades CSS-1 and CSS-1h. Penetration and coating will be most efficient with the base course at about optimum moisture content. Water dilution of the emulsion is also required to reduce the viscosity.

A1.3. Construction:

A1.3.1. Preparation of Surface. Immediately prior to applying the asphalt material, the surface will be clean, dry, and free of all loose or objectionable material. If emulsions are used for prime coat material, the base course should be damp.

A1.3.2. Use of Prime Coats. Prime coats will be used if it will take at least 7 days before a surface layer is constructed on the prepared base. If the surfacing is placed within 7 days of completion of the prepared base, the contractor/construction unit will have the option of using protective measures, such as prime coat. If a prime coat is not applied, the contractor/construction unit will be responsible for protecting the prepared surface from damage (water or traffic) until the surfacing is completed. If damage occurs, it will be repaired by the contractor/construction unit by approved methods (if repaired by contractor, then repairs will be carried out at no additional cost to the Government).

A1.3.3. Application Rate. The application rates specified below are the rates for the asphalt residue content and do not account for the water or solvent if an emulsion or cutback is used. Tack coats should be applied at the rate of 1.8 liters (0.05 gallon) per square yard. Prime coats should be applied at the rate of 0.9 liter (0.25 gallon) per square yard. If at the prescribed application rate the material flows off the surface, the application rate should be reduced to one-half the total amount and applied in two separate applications, 24 hours apart.

A1.3.4. Application Equipment. A calibrated bituminous distributor capable of the required application rates will apply prime and tack coats. The equipment will include a self-powered pressure bituminous material distributor and equipment for heating bituminous material. The distributor will be designed, equipped, maintained, and operated so that bituminous material at even heat may be applied uniformly on variable widths of surface at the specified rate. The allowable variation from the specified rate will not exceed 10%. Distributor equipment will include a tachometer, pressure gages, volume-measuring devices or a calibrated tank, and a thermometer for measuring temperatures of tank contents. The distributor will be self-powered and will be equipped with a power unit for the pump and full circulation spray bars adjustable laterally and vertically.

A1.3.5. Application Temperature. Application temperature will provide an application viscosity between 10 and 60 seconds, Saybolt Furol, or between 20 and 120 square millimeters per second (20 and 120 centistokes), kinematic. Table A3 shows the normal application temperatures for each material type.

Table A3. Application Temperatures.

Liquid Asphalt	
SC-7	48.9-107.2 °C (120-225 °F)
SC-250	73.9-132.2 °C (165-270 °F)
MC-30	29.4-87.8 °C (85-190 °F)
MC-70	48.9-107.2 °C (120-225 °F)
MC-250	73.9-132.2 °C (165-270 °F)
RC-70	48.9-93.3 °C (120-200 °F)
RC-250	73.9-121.1 °C (165-250 °F)
Penetration Grade Asphalt	
200-300	+129.4 °C (+265 °F)
120-150	+132.2 °C (+270 °F)
85-100	+137.8 °C (+280 °F)
Viscosity Grade Asphalt	
AC 2.5	+132.2 °C (+270 °F)
AC 5	+137.8 °C (+280 °F)
AC 10	+137.8 °C (+280 °F)
AR 1000	+135 °C (+275 °F)

AR 2000	+140.6 °C (+285 °F)
AR 4000	+143.3 °C (+290 °F)
Emulsions	
RS-1	21.1-60 °C (70-140 °F)
MS-1	21.1-71.1 °C (70-160 °F)
HFMS-1	21.1-71.1 °C (70-160 °F)
SS-1	21.1-71.1 °C (70-160 °F)
SS-1h	21.1-71.1 °C (70-160 °F)
CRS-1	51.7-85 °C (125-185 °F)
CSS-1	21.1-71.1 °C (70-160 °F)
CSS-1h	21.1-71.1 °C (70-160 °F)

A1.3.6. Application. Asphalt material will be applied at the specified rate with uniform distribution over the surface to be treated. All areas and spots missed by the distributor will be properly treated by hand spray. If required, clean dry sand will be used to blot up excess bituminous material.

A1.3.7. Curing Period. Following application of the asphalt material and prior to application of the succeeding layer of pavement, the asphalt coat will be allowed 24 hours to cure and to obtain evaporation of any volatiles or moisture. Prime coats with emulsions require 48 hours to obtain proper penetration.

A1.4. QC Testing:

A1.4.1. The application rate and application temperature should be checked periodically to ensure the proper rate is being applied. The application rate can be accomplished by placing paper of a known weight on the surface to be treated and applying the asphalt material to the surface and the paper. Change in weight of the paper will indicate the amount of asphalt on the paper, thus the amount per square yard can be calculated. Another method to check application rate is by comparing weigh bills to amount of area covered.

A1.4.2. QA should consist of checking computations on calibration and observing surfaces to see that uniform applications are being obtained.

BASE COURSE REQUIREMENTS

A2.1 General. This specification covers the requirements for base and subbase course materials. Material selection will be based on meeting minimum California bearing ratio (CBR) values. See paragraph A2.2. for guidance on selecting materials suitable to meet a given minimum CBR base on gradation and particle shape.

A2.2. Material. The Table A4 should be used as guidance for selecting materials to meet given minimum CBR requirements. Materials meeting the requirements given in Table A4 can be assumed to provide the minimum CBR stated. For materials that do not meet all requirements, expedient field tests (dynamic core penetrometer [DCP] or field CBR on compacted test fills) should be performed on the material to determine the CBR of the material in question. All base and subbase materials should be comprised of sound, durable, and unweathered materials. Materials that are soft (break down under compaction of handling) should not be used.

Table A4. Base Course Requirements

CBR Type	Sieve Size (Gradations Shown in Percentage Passing Square-Mesh Sieve)							
	50 mm (2 in)	37.5 mm (1.5 in)	25 mm (1 in)	12.5 mm (0.5 in)	4.75 mm (No. 4)	2 mm (No. 10)	0.425 mm (No. 40)*	0.075 mm (No. 200)
No. 1 CBR 100/80**	100%	70-100%	45-80%	30-60%	20-50%	15-40%	5-25%	0-10%
No. 2 CBR 100/80**		100%	60-100%	30-65%	20-50%	15-40%	5-25%	0-10%
No. 3 CBR 100/80**			100%	40-70%	20-50%	15-40%	5-25%	0-10%
No. 4 CBR 50	100%					50%		15%
No. 5 CBR 40	100%					80%		15%
No. 6 CBR 30	100%							15%
No. 7 CBR PCC Base***	100%					85%		15%

Notes:
*For all materials, the portion of the material passing the No. 40 sieve will either be

nonplastic or have a liquid limit (LL) not greater than 25 and a plastic index (PI) of not greater than 5.

**The CBR value for these gradations depends on the percentage of crushed particles. If the material is developed from a quarry operation where all the material is crushed, the CBR value is 100. If the material is from a crushed pit run gravel where only a percentage of the material is crushed, the following should apply: Crushed particles must be a minimum of 40% to a maximum of 79% - 80 CBR. For material with 80% or more crushed - 100 CBR. Below 40% crushed particles, CBR must be tested.

***This material gradation is provided for a base course under rigid pavement. The key point on rigid base material is to have at least 15% coarser than the No. 10 sieve to prevent pumping through rigid pavement joints. All other gradations will work for rigid base if it meets this criterion.

A2.3. Construction.

A2.3.1. Stockpiling Material. Material should be stockpiled on a cleared and leveled area. Different materials should be stockpiled separately. The material at the base of the stockpile should be considered as sacrificial and not incorporated into the work.

A2.3.2. Preparation of Underlying Material. Prior to base or subbase placement, the underlying material will be cleaned of all foreign substances. The surface of the underlying course will meet the specified compaction requirements for that material. Ruts or soft yielding spots in the underlying course will be corrected by removing, replacing, and recompacting the unsatisfactory material. Do not place material in snow or on a soft, muddy, or frozen underlying course.

A2.3.3. Placement. The material will be placed in layers not to exceed a compacted lift thickness of 152 millimeters (6 inches). When more than one lift is required to meet the layer thickness the layers should be placed in no more than 152 millimeters and no less than 76 millimeters (3 inches) of compacted lift thickness. If the base course is to be a mixture of different gradations, the gradations will be blended prior to placement with no in-place proportioning.

A2.3.3.1. Deposit and spread the material in lanes, in a uniform layer, and without segregation of size to such loose depth that, when compacted, the layer will have the required thickness. Spread the base aggregate by spreader boxes or other devices having positive thickness controls to minimize the need for hand manipulation. Do not dump materials from vehicles in piles since this requires rehandling and may permit segregation of material.

A2.3.3.2. Do not spread and place the aggregate more than 1700 square meters (2000 square yards) in advance of the roller. Keep any necessary sprinkling within these limits.

A2.3.4. Moisture Content. The moisture content should be adjusted to ±3% of optimum to facilitate compaction.

A2.3.5. Density. Each layer will be compacted to 100% maximum density using the modified effort or ASTM D 1557, *Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft –lbf/f [2,700 kN – m/m])*.

A2.3.6. Surface Smoothness. The surface layer will not show deviations in excess of 9.5 millimeters (0.375 inch) when tested with a 3.6-meter (12-foot) straightedge applied with and at right angles to the centerline of the area. Deviations will be corrected by removing material and replacing it with new material. Skin patches will not be used. An area may be reworked if the surface is scarified, material added to the surface, and the surface recompacted.

A2.3.7. Maintenance. The base or subbase material will be maintained in a satisfactory condition until the next layer is placed.

A2.4. QC Testing. A lot normally consists of either one day's production where it is not expected to exceed 2000 square meters (2400 square yards), or one-half day's production where a day's production is expected to consist of between 2000 and 4000 square meters (2400 and 4800 square yards). Take one test for each sublot, where a sublot is half of a lot. Determine sampling locations on a random basis in accordance with statistical procedures contained in ASTM D 3665, *Practice for Random Sampling of Construction Materials*.

A2.4.1. Density. Take one density test from each sublot. Density will be at least 100% of the maximum density of laboratory specimens prepared from samples of the material delivered to the jobsite. The specimens will be compacted and tested in accordance with ASTM D 1557. The in-place field density will be determined in accordance with ASTM D 1556, *Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Core Method*, or ASTM D 2167*, Standard Test Method for Density and Unit of Soil in Place by Rubber-Balloon Method*. ASTM D 2922, *Standard Test Method for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)*, may be used if the tests are calibrated with one of the other two methods. If the specified density is not attained, the entire lot will be reworked and/or recompacted and two additional random tests made for each lot. This procedure will be followed until the specified density is reached.

A2.4.2. Surface Smoothness. Tests for surface smoothness will be a 3.6-meter straightedge applied with and at right angles to the centerline of the area to ensure the surface layer will not show deviations in excess of 9.5 millimeters. Tests will be taken randomly, at least one test for each sublot.

A2.4.3. Thickness Control. The compacted layer thickness will be measured in test holes taken every 4180 square meters (5000 square yards). The layer thickness will be acceptable if it is within ±25 millimeters (±1 inch) of plan thickness. Any area greater than 25 millimeters' deficient will be reworked by scarifying the surface, adding material to the surface, and recompacting. Areas greater than 25 millimeters in required layer thickness will be considered acceptable as long as surface smoothness requirements are met.

A2.4.4. Gradation. Gradation tests will be taken every 4180 square meters of base or subbase placement.

A2.5. QA. Testing requirements stated above are for QC. QA testing should be accomplished at the rate of one QA test for every ten QC tests.

CONCRETE SPECIFICATIONS

A3.1. General. This specification is intended to stand alone for construction of concrete (rigid) pavement; however, where the construction covered herein interfaces with other specifications, the construction at each interface should conform to the requirements of both this specification and the other specification, including tolerances for both.

A3.2. Material.

A3.2.1. Cementitious Materials. Cementitious materials should be Portland cement and conform to ASTM C 150, *Standard Specification for Portland Cement*, either Type II, low-alkali or Type V, low-alkali. If the material must be high-early-strength Portland cement, it should conform to ASTM C 150, Type III, with C3A limited to 5% (low-alkali).

A3.2.2. Aggregates. Aggregates should consist of clean, hard, uncoated particles meeting the requirements of ASTM C 33*, Standard Specification for Concrete Aggregates*, including deleterious materials, abrasion loss, and soundness requirements of ASTM C 33, and other requirements specified herein.

A3.2.2.1. In addition to the grading requirements specified for coarse aggregate and for fine aggregate, the following are more requirements for combined aggregate grading:

A3.2.2.1.1. If necessary, use a blending aggregate to meet the required combined grading. Batch this blending aggregate separately. Compute the combined grading of all aggregates used, in the proportions selected, on the basis of cumulative percent retained on each sieve specified for fine and coarse aggregate.

A3.2.2.1.2. The materials selected and the proportions used should be such that when the coarseness factor (CF) and the workability factor (W) are plotted on a diagram as described in paragraph A3.2.2.1.4, the point thus determined should fall within the parallelogram described therein.

A3.2.2.1.3. CF is determined from the following equation:

$$CF = \frac{\text{(cumulative percent retained on the 9.5-mm [0.375-in] sieve) x (100)}}{\text{(cumulative percent retained on the 2.36-mm [No. 8] sieve)}}$$

W is defined as the cumulative percent passing the 2.36 mm (No. 8) sieve. However, adjust W upwards only, by 2.5 percentage points for each 42 kilograms (94 pounds) of cementitious material per cubic meter (cubic yard) greater than 335 kilograms per cubic meter (564 pounds per cubic yard).

A3.2.2.1.4. Plot a diagram using a rectangular scale with W on the Y-axis with units from 20 (bottom) to 45 (top), and with CF on the X-axis with units from 80 (left side) to

30 (right side). On this diagram, plot a parallelogram with corners at the following coordinates (CF-75, W-28), (CF-75, W-40), (CF-45, W-32.5), and (CF-45, W-41). If the point determined by the intersection of the computed CF and W does not fall within the above parallelogram, change as necessary the grading of each size of aggregate used and the proportions selected.

A3.2.2.1.5. Plot the individual percent retained on each sieve for the combined aggregate grading, on either rectangular or semi-log graph paper. The graph should show a relative smooth transition between coarse and fine aggregate and should have no major valleys or peaks in the area smaller than the 23.6 mm (No. 8 sieve). If this plot does not meet the above criteria, change as necessary the grading of each size aggregate used and the proportions selected.

A3.2.2.2. Coarse Aggregate. Coarse aggregate should consist of crushed gravel, crushed stone, or a combination thereof. The nominal maximum size of the coarse aggregate should be 19 millimeters (0.75 inch), 25 millimeters, or 38 millimeters (1.5 inches), depending on the thickness of the Portland cement concrete slab and the reinforcement. In general, the maximum size of the coarse aggregate should be such that there are no areas too small for a mixture of stone and cement to reside in the finished Portland cement concrete product. When the nominal maximum size is greater than 25 millimeters, the aggregates should be furnished in two ASTM C 33 size groups, No. 67 and No. 4. The amount of deleterious material in each size of coarse aggregate should not exceed the limits shown in ASTM C 33 Class 1N, 4M, or 4S, depending on the weathering region, and the following limits:

A3.2.2.2.1. Lightweight particles: 1% maximum by mass (ASTM C 123*, Standard Test Method for Lightweight Particles in Aggregate*).

A3.2.2.2.2. Other soft particles: 2% maximum by mass (Corps of Engineers [COE] CRD-C 130, *Standard Recommended Practice for Estimating Scratch Hardness of Coarse Aggregate Particles*).

A3.2.2.2.3. Total of all deleterious particles: 5% maximum by mass (substances listed in ASTM C 33 and paragraphs A3.2.2.2 through A3.2.2.2.2, exclusive of material finer than a 0.075-millimeter [No. 200] sieve).

A3.2.2.2.4. The separation medium for lightweight particles should have a density of 2 milligrams per cubic meter (specific gravity of 2.0).

A3.2.2.3. Fine Aggregate. Fine aggregate should consist of natural sand, manufactured sand, or a combination of the two, and should be composed of clean, hard, durable particles, meeting the requirements of ASTM C 33 and the requirements herein. The amount of deleterious material in the fine aggregate should not exceed the limits in ASTM C 33, and should not exceed the following limits:

A3.2.2.3.1. Lightweight particles (ASTM C 123): 1% maximum by mass using a medium with a density of 2 milligrams per cubic meter (specific gravity of 2.0).

A3.2.2.3.2. The total of all deleterious material types, listed in ASTM C 33 and paragraphs A3.2.2.3 and A3.2.2.3.1, should not exceed 3% of the mass of the fine aggregate.

A3.2.3. Chemical Admixtures. Air-entraining admixture should conform to ASTM C 260, *Standard Specification for Air-Entraining Admixtures for Concrete*. Do not use an accelerator when specified in paragraph A3.3.5, nor to reduce the amount of cementitious material used. Accelerator should conform to ASTM C 494/C 494M, *Standard Specification for Chemical Admixtures for Concrete*, Type C. Calcium chloride and admixtures containing calcium chloride should not be used. A water-reducing or retarding admixture should meet the requirements of ASTM C 494/C 494M. Type G or Type H admixtures are not allowed.

A3.2.4. Curing Materials. Membrane-forming curing compound should be a white pigment compound conforming to COE CRD-C 300, *Corps of Engineers Specifications for Membrane-Forming Compounds for Curing Concrete*. Burlap should be new or clean material never used for anything other than curing concrete.

A3.2.5. Water. Water for mixing and curing should be clean, potable, and free of injurious amounts of oil, acid, salt, or alkali.

A3.2.6. Joint Materials:

A3.2.6.1. Expansion Joint Material. Expansion joint filler should be a preformed material conforming to ASTM D 1751, *Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)*, or ASTM D 1752, *Preformed Sponge Rubber and Cork Expansion Joint* (Types I, II, or III). Expansion joint filler should be 20 millimeters thick.

A3.2.6.2. Slip Joint Material. Slip joint material should be 6-millimeter-thick expansion joint filler conforming to ASTM D 1751 or ASTM D 1752.

A3.3. Reinforcing.

A3.3.1. General. Reinforcing bars should conform to ASTM A 615/A 615M, *Standard Specification for Deformed or Plain Billet-Steel for Concrete Reinforcement*, for the specified yield strength of steel. Bar mats should conform to ASTM A 184/A 184M, *Standard Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement*. Reinforcement should be free from loose, flaky rust, loose scale, oil, grease, mud, or other coatings that might reduce the bond with concrete.

A3.3.2. Dowels. Dowels should be single-piece, plain (non-deformed) steel bars conforming to ASTM A 615/A 615M Grade 60 or higher. Dowels should be free of loose, flaky rust and loose scale and should be clean and straight.

A3.3.3. Tie Bars. Tie bars should be deformed steel bars conforming to ASTM A 615/A 615M for the specified yield strength of steel. Do not use Grade 60 or higher for bars that are bent and straightened during construction.

A3.3.4. Epoxy Resin. All epoxy-resin materials should be two-component materials conforming to ASTM C 881*, Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete* (class as appropriate for each application temperature to be encountered); except that, in addition, the materials should meet the following requirements:

A3.3.4.1. Material for use for embedding dowels and anchor bolts should be Type IV, Grade 3.

A3.3.4.2. Material for use as patching for complete filling of spalls, wide cracks, and other voids, and for use in preparing epoxy resin mortar should be Type III, grade as approved.

A3.3.4.3. Material for injecting cracks should be Type IV, Grade 1.

A3.3.4.4. Material for bonding freshly mixed Portland cement concrete, mortar, or freshly mixed epoxy resin concrete to hardened concrete should be Type V, Grade as approved.

A3.3.5. Specified Concrete Strength And Other Properties. Specified compressive strength (f'c), for concrete is 34.4 megapascals (4.4 megapascals flexural strength) (5000 pounds per square inch [psi] [650 psi flexural strength]) at 28 days. Maximum allowable water-cementitious material ratio is 0.45. The water-cementitious material ratio is based on absolute volume equivalency, where the ratio is determined using the weight of cement for a cement-only mix, or using the total volume of cement plus pozzolan converted to an equivalent weight of cement by the absolute volume equivalency method described in ACI 211.1, *Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete*. The concrete should be air-entrained with a total air content of 6±1%. The maximum allowable slump of the concrete should be 75 millimeters for pavement constructed with fixed forms.

A3.3.6. Mixture Proportions.

A3.3.6.1. Composition Concrete. Composition concrete should be composed of cementitious material, water, fine and coarse aggregates, and admixtures. Admixtures should consist of air-entraining admixture. Do not substitute the materials used in the mixture proportions without performing additional tests to show that the quality of the concrete is satisfactory.

A3.3.6.2. Concrete Mixture Proportioning Studies. All materials used in mixture proportioning studies should be representative of those proposed for use on the project. If there is a change in materials, perform additional mixture design studies using the new materials. Trial mixtures having proportions, slumps, and air content suitable for the work should be based on methodology described in ACI 211.1. Use at least three different water-cement ratios, which will produce a range of strength encompassing that required on the project. Proportion laboratory trial mixtures for maximum permitted slump and air content. Maximum sand content should be 40% of the total aggregate saturated surface dry (SSD) weight. Aggregate quantities should be based on the mass in a saturated surface dry condition.

A3.3.6.3. Mixture Proportioning Procedure. The procedure should consist of the following:

A3.3.6.3.1. Fabricate, cure and test 6 test cylinders per age for each mixture at 7 and 28 days.

A3.3.6.3.2. Using the average strength for each water/cement plus pozzolan ratio (w/(c+p)), plot the results from each of the three mixtures on separate graphs for w/(c+p) versus 28-day strength.

A3.3.6.3.3. From the graphs select a w/(c+p) which will produce a mixture giving a 28-day strength equal to the required strength determined in accordance with the following paragraph.

A3.3.6.4. Average Strength Required for Mixtures. In order to ensure meeting the strength requirements during production, the mixture proportions selected should produce a required average compressive strength (f'cr) exceeding the specified compressive strength (f'c), in accordance with procedures in Chapter 3 of ACI 301, *Standard Specifications for Structural Concrete*.

A3.3.7. Equipment.

Note: Disregard the equipment portion of this specification for RED HORSE or other military unit construction.

A3.3.7.1. Batching and Mixing. The batching plant should conform to National Ready-Mixed Concrete Association – Concrete Plant Manufacturers Bureau (NRMCA CPMB) 100, *Concrete Plant Standards of the Concrete Plant Manufacturers Bureau*, the equipment requirements in ASTM C 94/C 94M, *Standard Specification For Ready-Mixed Concrete*, and as specified. Water should not be weighed or measured cumulatively with another ingredient. All concrete materials batching should meet ASTM C 94/C 94M requirements. Mixers should be stationary mixers or truck mixers. Batching, mixers, mixing time, permitted reduction of mixing time, and concrete uniformity should meet the requirements of ASTM C 94/C 94M.

A3.3.7.2. Transporting Equipment. Transporting equipment should be in conformance with ASTM C 94/C 94M, and as specified herein. Concrete should be transported to the paving site in rear-dump trucks, in truck mixers designed with extra-large blading and rear opening specifically for low slump concrete, or in agitators. Bottom-dump trucks should not be used for delivery of concrete.

A3.3.7.3. Delivery Equipment. When concrete transport equipment cannot operate on the paving lane, side-delivery transport equipment consisting of self-propelled moving conveyors should be used to deliver concrete from the transport equipment and discharge it in front of the paver. Front-end loaders, dozers, or similar equipment should not be used to distribute the concrete.

A3.3.7.4. Paver-finisher. The paver-finisher should be a heavy-duty, self-propelled machine designed specifically for paving and finishing high-quality pavement. The paver-finisher should weigh at least 3280 kilograms per meter (2200 pounds per foot) of lane width, and should be powered by an engine having at least 15,000 watts per meter (6 horsepower per foot) of lane width. The paver-finisher should spread, consolidate, and shape the plastic concrete to the desired cross section in one pass. The paver-finisher should be equipped with a full width "knock-down" auger, capable of operating in both directions, which will evenly spread the fresh concrete in front of the screed or extrusion plate. Immersion vibrators should be gang-mounted at the front of the paver on a frame equipped with suitable controls so that all vibrators can be operated at any desired depth within the slab or completely withdrawn from the concrete. The vibrators should be automatically controlled so that they will be immediately stopped as forward motion of the paver ceases. The spacing of the immersion vibrators across the paving lane should be as necessary to properly consolidate the concrete, but the clear distance between vibrators should not exceed 750 millimeters (30 inches), and the outside vibrators should not exceed 300 millimeters (12 inches) from the edge of the lane. The paver-finisher should be equipped with a transversely oscillating screed or an extrusion plate to shape, compact, and smooth the surface.

A3.3.7.5. Paver-finisher with Fixed Forms. The paver-finisher should be equipped with wheels designed to ride the forms, keep it aligned with the forms, and to spread the preventing deformation of the forms.

A3.3.7.6. Other Types of Finishing Equipment. Bridge deck finishers should be used for pavements 250 millimeters (10 inches) or less in thickness, where longitudinal and transverse surface smoothness tolerances are 6.5 millimeters or greater. Clary screeds or other rotating tube floats will not be allowed on the project.

A3.3.7.7. Texturing Equipment.

A3.3.7.7.21. Fabric Drag. A fabric drag should consist of a piece of fabric material as wide as the lane width, securely attached to a separate wheel-mounted frame spanning the paving lane or to one of the other similar pieces of equipment. The material should be wide enough to provide 300 to 450 millimeters (12 to 18 inches) dragging flat on the pavement surface. The fabric material should be clean, reasonably new burlap, kept clean and saturated during use.

A3.3.7.7.2. Deep Texturing Equipment. Texturing equipment should consist of a stiff-bristle broom forming a drag at least 1.2 meters (4 feet) long.

A3.3.7.7.3. Sawing Equipment. Equipment for sawing joints and for other similar sawing of concrete should be standard diamond-tip-bladed concrete saws mounted on a wheeled chassis.

A3.4. Execution.

A3.4.1. Conditioning of Underlying Material. Ensure underlying material, subgrade, base course, or subbase course, upon which concrete is to be placed, is clean, damp, and free from debris, waste concrete or cement, frost, ice, and standing or running water. After the underlying material has been prepared for concrete placement, do not allow the movement of any equipment.

A3.4.2. Weather Limitations.

A3.4.2.1. Hot Weather Paving. The temperature of concrete should not exceed 32 °C (90 °F). Cool steel forms, dowels, and reinforcing prior to concrete placement when steel temperatures are greater than 49 °C (120 °F).

A3.4.2.2. Cold Weather Paving. The ambient temperature of the air at the placing site and the temperature of surfaces to receive concrete should be not less 5 °C (40 °F). The temperature of the concrete when placed should be not less than 10 °C (50 °F). Materials entering the mixer should be free from ice, snow, or frozen lumps. Do not use salt, chemicals, or other materials in the concrete to prevent freezing. Do not use calcium chloride at any time. Cover and provide other means for maintaining the concrete at a temperature of at least 10 °C for not less than 72 hours after placing, and at a temperature above freezing for the remainder of the curing period. Completely remove and replace pavement damaged by freezing as specified in paragraph A3.4.8.

A3.4.3. Concrete Production.

A3.4.3.1. General Requirements. Concrete should be deposited in front of the paver within 45 minutes from the time cement has been charged into the mixing drum, except that if the ambient temperature is above 32 °C, the time should be reduced to 30 minutes.

A3.4.3.2. Transporting and Transfer-Spreading Operations. Use non-agitating equipment only on smooth roads and for haul time less than 15 minutes. Equipment may be allowed to operate on the underlying material only if no damage is done to the underlying material and its degree of compaction.

A3.4.4. Paving. Construct pavement with paving and finishing equipment utilizing fixed forms.

A3.4.4.1. Consolidation. Insert the paver vibrators into the concrete not closer to the underlying material than 50 millimeters (2 inches). The vibrators or any tamping units in front of the paver should be automatically controlled so that they may be stopped immediately as forward motion ceases. Do not allow excessive vibration. Vibrate concrete in small, odd-shaped slabs or in locations inaccessible to the paver-mounted vibration equipment with a hand-operated immersion vibrator. Vibrators should not be used to transport or spread the concrete.

A3.4.4.2. Operation. When the paver is operated between or adjacent to previously constructed pavement (fill-in lanes), make provisions to prevent damage to the previously constructed pavement, including keeping the existing pavement surface free of any debris, and placing rubber mats beneath the paver tracks. Transversely oscillating screeds and extrusion plates should overlap the existing pavement the minimum possible, but in no case more than 200 millimeters (8 inches).

A3.4.4.3. Required Results. The paver-finisher should be operated to produce a thoroughly consolidated slab throughout, true to line and grade within specified tolerances. The paver-finishing operation should produce a surface finish free of irregularities, tears, voids of any kind, and any other discontinuities. It should produce only a very minimum of paste at the surface. Do not permit multiple passes of the paver-finisher. The equipment and its operation should produce a finished surface requiring no hand finishing, other than the use of cutting straightedges, except in very infrequent instances. Do not apply water, other than true fog sprays (mist), to the concrete surface during paving and finishing.

A3.4.4.4. Fixed Form Paving. Forms should be steel, except that wood forms may be used for curves having a radius of 45 meters (150 feet) or less, and for fillets. Forms may be built up with metal or wood, added only to the base, to provide an increase in depth of not more than 25%. The base width of the form should be not less than eight-tenths of the vertical height of the form, except that forms 200 millimeters or less in vertical height should have a base width not less than the vertical height of the form. Wood forms for curves and fillets should be adequate in strength and rigidly braced. Set forms on firm material cut true to grade so that each form section when placed will be firmly in contact with the underlying layer for its entire base. Do not set forms on blocks or on built-up spots of underlying material. Keep forms in place at least 12 hours after the concrete has been placed. Remove forms without injuring the concrete.

A3.4.4.5. Placing Reinforcing Steel. Position reinforcement on suitable chairs securely fastened to the subgrade prior to concrete placement, or place on an initial layer of consolidated concrete, with the subsequent layer placed within 30 minutes of the first layer placement.

A3.4.4.6. Placing Dowels and Tie Bars. Install dowels with alignment not greater than 1 millimeter per 100 millimeters (0.125 inch per foot). Location of dowels should be within a horizontal tolerance of ±15 millimeters (±0.625 inch) and a vertical tolerance of ±5 millimeters (±0.1875 inch). Paint the portion of each dowel intended to move within the concrete or expansion cap with one coat of rust-inhibiting primer paint, and then oil just prior to placement. Omit dowels and tie bars in joints when the center of the dowel or tie bar is located within a horizontal distance from an intersecting joint equal to or less than one-fourth of the slab thickness.

A3.4.4.6.1. Contraction Joints. Dowels and tie bars in longitudinal and transverse contraction joints within the paving lane should be held securely in place by means of rigid metal basket assemblies. The dowels and tie bars should be welded to the assembly or held firmly by mechanical locking arrangements that will prevent them from becoming distorted during paving operations. The basket assemblies should be held securely in the proper location by means of suitable anchors.

A3.4.4.6.2. Construction Joints – Fixed-form Paving. Installation of dowels and tie bars should be by the bonded-in-place method, supported by means of devices fastened to the forms. Installation by removing and replacing in preformed holes is not permitted.

A3.4.4.6.3. Dowels Installed in Hardened Concrete. Installation should be by bonding the dowels into holes drilled into the hardened concrete. Holes approximately 3 millimeters (0.125 inch) greater in diameter than the dowels should be drilled into the hardened concrete. Bond dowels in the drilled holes using epoxy resin injected at the back of the hole before installing the dowel and extrude to the collar during insertion of the dowel so as to completely fill the void around the dowel. Do not apply by buttering the dowel. Hold the dowels in alignment at the collar of the hole, after insertion, and before the grout hardens, by means of a suitable metal or plastic collar fitted around the dowel. Check the vertical alignment of the dowels by placing the straightedge on the surface of the pavement over the top of the dowel and measuring the vertical distance between the straightedge and the beginning and ending point of the exposed part of the dowel.

A3.4.4.6.4. Expansion Joints. Dowels in expansion joints should be installed by the bonded-in-place method or by bonding into holes drilled in hardened concrete, using procedures specified in paragraph A3.4.4.6.3.

A3.4.5. Finishing. Do not use clary screeds, "bridge deck" finishers, or other rotating pipe or tube type equipment. The sequence of machine operations should be transverse finishing, longitudinal machine floating (if used), straightedge finishing, texturing, and then edging of joints. Hand finishing should be used only infrequently and only on isolated areas of odd slab shapes and in the event of a breakdown of the mechanical finishing equipment. Supplemental hand finishing for machine-finished pavement should be kept to an absolute minimum. Use, primarily, 3- to 4-meter (10- to 12-foot) cutting straightedges for supplemental hand finishing; use bull floats sparingly.

Do not at any time add water to the surface of the slab in any way, except for fog (mist) sprays to prevent plastic shrinkage cracking.

A3.4.5.1. Machine Finishing with Fixed Forms. The machine should be designed to ride the forms. Do not use machines that cause displacement of the forms. The machine should make only one pass over each area of pavement. If the equipment and procedures do not produce a surface of uniform texture, true to grade, in one pass, stop the operation immediately and adjust as necessary the equipment, mixture, and procedures.

A3.4.5.2. Surface Correction. While the concrete is still plastic, eliminate irregularities and marks in the pavement surface by means of cutting straightedges, 3 to 4 meters in length. Fill depressions with freshly mixed concrete, strike off, consolidate, and refinish. Strike off projections above the required elevation and refinish. Use long-handled, flat bull floats sparingly and only as necessary to correct minor, scattered surface defects. Hold to the absolute minimum necessary finishing with hand floats and trowels. Do not overfinish joints and edges.

A3.4.5.3. Hand Finishing. Hand-finishing operations should be used only for those unusual slabs as specified in paragraph A3.4.5. Do not use grate tampers (jitterbugs). As soon as placed and vibrated, strike off the concrete and screed. Tamp the surface with a strike-off and tamping screed, or vibratory screed. Immediately following the final tamping of the surface, float the pavement longitudinally. Use long-handled, flat bull floats sparingly and only as necessary to correct surface defects. Hold to the absolute minimum necessary finishing with hand floats and trowels. Do not overfinish joints and edges. Do not add water to the pavement during finishing operations.

A3.4.5.4. Texturing. Before the surface sheen has disappeared and before the concrete hardens, the surface of the pavement should be given a texture as described herein. After curing is complete, all textured surfaces should be thoroughly power-broomed to remove all debris. The concrete in areas of recesses for tie-down anchors, lighting fixtures, and other outlets in the pavement should be finished to provide a surface of the same texture as the surrounding area.

A3.4.5.4.1. Fabric-Drag Surface Finish. Apply surface texture by dragging the surface of the pavement, in the direction of the concrete placement, with a moist fabric drag. The dragging should produce a uniform finished surface having a fine sandy texture without disfiguring marks.

A3.4.5.4.2. Broom Texturing. Surface texture should be applied using a mechanical stiff-bristle broom drag of a type that will uniformly score the surface transverse to the pavement center line. The broom should be capable of traversing the full width of the pavement in a single pass at a uniform speed and pressure. Successive passes of the broom should be overlapped the minimum necessary to obtain a uniformly textured surface. The scores should be uniform in appearance and approximately 1.5 millimeters (0.0625 inch) in depth, but not more than 3 millimeters in depth. Hand brooming will be permitted only on isolated odd shaped slabs or slabs where hand finishing is permitted.

A3.4.5.5. Edging. After texturing has been completed, the edge of the slabs along the forms should be carefully finished with an edging tool to form a smooth rounded surface with a 3-millimeter radius. Do not add water to the surface during edging.

A3.4.6. Curing. Continuously protect the concrete against loss of moisture and rapid temperature changes for at least 7 days from the completion of finishing operations. Protect unhardened concrete from rain and flowing water. During hot weather with low humidity and/or wind, institute measures to prevent plastic shrinkage cracks from developing. ACI 305R, *Hot Weather Contracting*, contains means of predicting plastic shrinkage cracking and preventative measures. Plastic shrinkage cracks that occur should be filled by injection of epoxy resin after the concrete hardens. Plastic shrinkage cracks should never be troweled over or filled with slurry. Accomplish curing by one of the following methods:

A3.4.6.1. Membrane Curing. Apply a uniform coating of white-pigment membrane-forming curing compound to the entire exposed surface of the concrete, including pavement edges, as soon as the free water has disappeared from the surface after finishing. If evaporation is high and no moisture is present on the surface even though bleeding has not stopped, use fog sprays to keep the surface moist until setting of the cement occurs, then immediately apply curing compound. Curing compound should be applied to the finished surfaces by means of a self-propelled automatic spraying machine, equipped with multiple spraying nozzles with wind shields, spanning the newly paved lane. The curing compound should be applied at a maximum application rate of 5 square meters per liter (200 square feet per gallon). Applying the curing compound by hand-operated, mechanical powered pressure sprayers will be permitted only on odd widths or shapes of slabs and on concrete surfaces exposed by the removal of forms. The compound should form a uniform, continuous, cohesive film that will not check, crack, or peel, and is free from pinholes and other discontinuities. Immediately respray areas where the curing compound develops these defects or is damaged by heavy rainfall, sawing, or other construction operations within the curing period.

A3.4.6.2. Moist Curing. Concrete to be moist-cured should be maintained continuously wet for the entire curing period, commencing immediately after finishing. Surfaces should be cured by ponding, by continuous sprinkling, by continuously saturated burlap or cotton mats, or by continuously saturated plastic-coated burlap. Do not use impervious sheet curing.

A3.4.7. Joints. All joints should be straight, perpendicular to the finished grade of the pavement, and continuous from edge to edge or end to end of the pavement with no abrupt offset and no gradual deviation greater than 13 millimeters (0.5 inch).

A3.4.7.1. Longitudinal Construction Joints. Dowels should be installed in the longitudinal construction joints.

A3.4.7.2. Transverse Construction Joints. Transverse construction joints should be installed at a planned transverse joint at the end of each day's placing operations and when concrete placement is interrupted. Transverse construction joints should be constructed either by utilizing headers and hand placement and finishing techniques, or by placing concrete beyond the transverse construction joint location and then saw cutting full depth and removing concrete back to the transverse construction joint location. For the latter case, dowels should be installed using methods for dowels installed in hardened concrete described in paragraph A3.4.4.6.3. All transverse construction joints should be dowelled.

A3.4.7.3. Expansion Joints. Expansion joints should be formed where required by the pavement design, and around any structures and features that project through or into the pavement, using preformed joint filler of the type, thickness, and width indicated on plans, and should extend the full slab depth. Edges of the concrete at the joint face should be edged. Install the joint filler strips to form a recess at the pavement surface to be filled with joint sealant. Construct expansion joints with dowels for load transfer.

A3.4.7.4. Slip Joints. Install slip joints the full depth of the slab using expansion joint preformed joint filler material attached to the face of the original concrete placement. Construct a reservoir for joint sealant at the top of the joint. Edges of the joint face should be edged.

A3.4.7.5. Contraction Joints. Transverse and longitudinal contraction joints should be of the weakened-plane or dummy type. Longitudinal contraction joints should be constructed by sawing a groove in the hardened concrete with a power-driven saw. Construct transverse contraction joints in conformance with requirements for sawed joints.

A3.4.7.6. Sawed Joints. Construct sawed contraction joints by sawing a groove in the concrete with a 3-millimeter blade to the indicated depth. The time of initial sawing will vary depending on existing and anticipated weather conditions and will be such as to prevent uncontrolled cracking of the pavement. Commence sawing of the joints as soon as the concrete has hardened sufficiently to permit cutting the concrete without chipping, spalling, or tearing. Saw the joints at the required spacing consecutively in the sequence of the concrete placement. Discontinue sawing at a given joint location when a crack develops ahead of the saw cut. Immediately after the joint is sawed, thoroughly flush the saw cut and adjacent concrete surface with water until all waste from sawing is removed from the joint. Respray the surface with curing compound as soon as free water disappears. The top of the joint opening and the joint groove at exposed edges should be tightly sealed with cord or backer rod before the concrete in the region of the joint is resprayed with curing compound.

A3.4.8. Repair, Removal, and Replacement of Slabs. Remove and replace new pavement slabs that contain full-depth cracks. To determine whether cracks extend the full depth of the pavement may require minimum 150-millimeter-diameter cores to be drilled. Drill cores and fill the hole later with a well consolidated concrete mixture bonded to the walls of the hole with epoxy resin. Cracks that do not extend the full depth of the slab may be cleaned and then pressure injected with epoxy resin, Type IV, Grade 1. Ensure that the crack is not widened during epoxy resin injection. Where a full depth crack intersects the original transverse joint, remove and replace the slab(s) containing the crack, with dowels installed, as specified in paragraph A3.4.8.1. Spalls along joints should be repaired as specified in paragraph A34.8.2.

A3.4.8.1. Removal and Replacement of Full Slabs. Unless there are keys or dowels present, all edges of the slab should be sawcut full depth. If keys, dowels, or tie bars are present along any edges, these edges should be sawed full depth 150 millimeters from the edge if only keys are present, or just beyond the end of dowels or tie bars if they are present. These joints should then be carefully sawed on the joint line to within 25 millimeters of the depth of the dowel or key. The main slab should be further divided by sawing full depth, at appropriate locations, and each piece lifted out and removed. The narrow strips along keyed or doweled edges should be carefully broken up and removed. Take care to prevent damage to the dowels, tie bars, or keys, or to concrete that will remain in place. Paint or lightly oil protruding portions of dowels. Trim the joint face below keys or dowels so that there is no abrupt offset. If underbreak occurs at any point along any edge, hand-fill the area with concrete to produce an even joint face from top to bottom before replacing the removed slab. If underbreak over 100 millimeters deep occurs, remove and replace the entire slab containing the underbreak. Where there are no dowels, tie bars, or keys on an edge, or where they have been damaged, install by epoxy grouting dowels (of the size and spacing as specified for other joints in similar pavement) into holes drilled into the existing concrete. Cut off original damaged dowels or tie flush with the joint face. All four edges of the new slab should contain dowels or original keys or original tie bars. Prior to placement of new concrete, grade and recompact the underlying material, clean all loose material and contaminants from the surfaces of all four joint faces, and coat with a double application of membrane-forming curing compound as bond breaker. Place concrete as specified for original construction. Prepare and seal the resulting joints around the new slab.

A3.4.8.2. Repairing Spalls Along Joints. Repair spalls along joints and cracks by first making a vertical saw cut at least 25 millimeters outside the spalled area and to a depth of at least 50 millimeters. Saw cuts should be straight lines forming rectangular areas. The concrete between the saw cut and the joint, or crack, should be chipped out to remove all unsound concrete. The cavity should be thoroughly cleaned with high-pressure water jets supplemented with compressed air to remove all loose material. Immediately before filling the cavity, a prime coat should be applied to the dry cleaned surface of all sides and bottom of the cavity, except any joint face. The prime coat should be applied in a thin coating and scrubbed into the surface with a stiff-bristle brush. Prime coat for Portland cement repairs should be a neat cement grout and for epoxy resin repairs should be epoxy resin, Type III, Grade 1. The cavity should be filled with low slump Portland cement concrete or mortar, or with epoxy-resin concrete or mortar. Portland cement concrete should be used for larger spalls, those more than 0.009 cubic meter (0.33 cubic foot) in size after removal operations; Portland cement mortar should be used for spalls between 0.00085 and 0.009 cubic meter (0.03 and 0.33 cubic foot); and epoxy resin mortar or Type III, Grade 3 epoxy resin for those spalls less than 0.00085 cubic meter in size after removal operations. Portland cement concretes and mortars should be very low slump mixtures, proportioned, mixed, placed, tamped, and cured. Epoxy resin mortars should be made with Type III, Grade 1 epoxy resin, using proportions, mixing, placing, tamping and curing procedures as recommended by the manufacturer. Any repair material on the surrounding surfaces of the existing concrete should be removed before it hardens. Where the spalled area abuts a joint, use an insert or other bond-breaking medium to prevent bond at the joint face. Saw a reservoir for the joint sealant to the dimensions required for other joints. In lieu of sawing, spalls not adjacent to joints and popouts, both less than 150 millimeters in maximum dimension, may be prepared by drilling a core 50 millimeters in diameter greater than the size of the defect, centered over the defect, and 50 millimeters deep or 13 millimeters into sound concrete, whichever is greater. Repair the core hole as specified above for other spalls.

A3.4.8.3. Areas Defective in Plan Grade or Smoothness. In areas not meeting the specified limits for surface smoothness and plan grade, high areas should be reduced to attain the required smoothness and grade, except as depth is limited below. High areas should be reduced by grinding the hardened concrete with a surface grinding machine after the concrete is at least 14 days old. The depth of grinding should not exceed 6 millimeters. All pavement areas requiring plan grade or surface smoothness corrections in excess of the specified limits should be removed and replaced. In pavement areas given a wire comb or tined texture, areas exceeding 2 square meters (25 square feet) that have been corrected by rubbing or grinding should be retextured by grooving machine sawn grooves meeting the requirements for the wire comb or tined texture.

A3.4.9. Existing Concrete Pavement Removal and Repair. Remove existing concrete pavement as indicated and as specified in paragraph A3.4.8.

A3.4.10. Pavement Protection. Protect the pavement against all damage prior to final acceptance of the work. Exclude traffic from the new pavement. As a construction expedient in paving intermediate lanes between newly paved pilot lanes, operation of the hauling equipment may be permitted on the new pavement after the pavement has been cured for 7 days and the joints have been sealed or otherwise protected. Keep all new and existing pavement carrying construction traffic or equipment completely clean, continuously. Use special cleaning and care where traffic uses or crosses active airfield pavement.

A3.5. QC Testing. QA testing and inspection guidance for concrete pavements is based on the requirements of ETL 97-5, *Proportioning Concrete Mixtures with Graded Aggregates for Rigid Airfield Pavements,* and ETL 97-2, *Maintenance and Repair of Rigid Airfield Pavement Surfaces, Joints, and Cracks*. Major QA responsibilities include approval of mixture material quality, approval of mixture proportions, approval of the test strip, daily monitoring of operations and QC testing procedures and results, and determining acceptability of the project. Acceptability requirements include strength, grade and surface smoothness.

A3.5.1. Acceptability of Work. Take concrete samples at the placement to determine the slump, air content, and strength of the concrete. Make test cylinders for determining conformance with the strength requirements of these specifications and, when required, for determining the time at which pavements may be placed into service. All air content measurements should be determined in accordance with ASTM C 231, *Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method*. All slump tests should be made in accordance with ASTM C 143/C 143 M, *Standard Test Method for Slump of Hydraulic-Cement Concrete*. All test cylinders should be 150-millimeter by 300-millimeter cylinders and should be fabricated in accordance with ASTM C 192/C 192M, *Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory*, using only steel molds, cured in accordance with ASTM C 31/C 31M*, Standard Practice for Making and Curing Concrete Test Specimens in the Field*, and tested in accordance with ASTM C 39/C 39M*, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*. A strength test should be the average of the strengths of two cylinders made from the same sample of concrete and tested at 28 days.

A3.5.2. Material Quality. Aggregate tests include specific gravity, absorption, Los Angeles abrasion, sulfate soundness, alkali or carbonate reaction, particle shape, fineness modulus, and deleterious materials. The materials supplier will provide a certification that the cement and curing compound meets specifications requirements. Materials that do not meet the material quality requirements of the specification will not be used on the project.

A3.5.3. Mixture Proportions. Proportioning should be accomplished in accordance with the specifications. Guidance and examples for the Air Force specification are contained in *Proportioning Concrete Mixtures with Graded Aggregates, A Handbook for Rigid Airfield Pavements.* Construct a test section using the approved mixture proportions and ensure the test section meets requirements, including strength, grade, smoothness, and texture before recommending approval. If the test section is not acceptable, adjustments should be made to the mixture proportions and/or construction equipment or techniques, and construct another test section. A test section must be approved before production begins.

A3.5.4. Strength Testing. QA responsibilities include monitoring flexural strength or compressive strength tests, water/cement ratio and air content tests conducted for QC.

A3.5.4.1. Flexural Strength. Four cylinders from the same batch should be fabricated, cured and tested for compressive strength, testing two cylinders at 7-day and two cylinders at 28-day age. A minimum of one set of four cylinders should be fabricated, cured and tested for each shift of concrete placement. Keep control charts for strength, showing the 7-day and 28-day compressive strengths, and the 28-day required compressive strength. Prepare a strength gain curve with the proposed design mix that meets the specified compressive strength at 90 days. The curve is based on compressive strength tests at 7, 14, 28 and 90 days. During production, prepare test cylinders (three test cylinders each at 7, 14, 28, and 90 days) for each 400 cubic meters (14,125 cubic feet). Compare the plot of the average strength of the three test cylinders to the design strength curve. The compressive strength is acceptable when the average compressive strength at any of the four ages meets or exceeds the design strength gain curve. Specified compressive strength (f'c), for concrete is 27.5 megapascals (4000 psi) (4.4 megapascals flexural strength) at 28 days. Additionally, the strength of the concrete will be considered satisfactory so long as the average of all sets of three consecutive test results equals or exceeds the specified compressive strength (f'c) and no individual test result falls below the specified compressive strength (f'c) by more than 3.4 megapascals (500 psi). Additional analysis or testing, including taking cores and/or load tests may be required when the strength of the concrete in the structure is considered potentially deficient.

A3.5.4.2. Water/Cement Ratio. Maximum allowable water-cementitious material ratio is 0.45. The water-cementitious material ratio is based on absolute volume equivalency, where the ratio is determined using the weight of cement for a cement-only mix, or using the total volume of cement plus pozzolan converted to an equivalent weight of cement by the absolute volume equivalency method described in ACI 211.1. Higher ratios than 0.45 result in weaker pavements and possible cracking due to excessive shrinkage. Ratios below about 0.4 may be stiff and harder to place Suspend operations when the ratio exceeds two standard deviations higher than the design ratio for two consecutive batches.

A3.5.4.3. Air Content. The concrete should be air-entrained with a total air content of 6$\pm$1%. Perform air content tests when test specimens are fabricated. In addition, make at least two other tests for air content on randomly selected batches of each separate concrete mixture produced during each 8-hour period of paving. Whenever air content reaches specified limits, make an immediate confirmatory test. If the second test also shows air content at or exceeding specified limits, immediately adjust the amount of air-entraining admixture batched to bring air content within specified limits. If the next adjusted batch of concrete is not within specified limits, halt concrete placement until concrete air content is within specified limits. For QA, determine air content for each 400 cubic meters of concrete and plot results on a control chart with the upper limit at 2% above the specified value and the lower limit at 1% below the specified value. Monitor the results. Suspend production when 2 consecutive points are outside the limits.

A3.5.5. Smoothness Requirements. Use a 3.6-meter straight edge to determine if the finished surface meets the specified smoothness requirements. The straightedge should be constructed of aluminum or magnesium alloy and should have blades of box or box-girder cross section with flat bottom, adequately reinforced to insure rigidity and accuracy. Straightedges should have handles for operation on the pavement. Two criteria are used for smoothness: a specified deviation from the straight edge for the surface; and, for slip form paving, allowed edge slump. The procedure for measuring both criteria and the allowable deviations are contained in the specifications. Observe measurements and ensure the measurement procedure is correct and that all deviations are marked for repair/replacement as outlined in the specifications.

A3.5.5.1. Surface Smoothness Requirements. The finished surfaces of the pavements should have no abrupt change of 3 millimeters or more, and all pavements should be within the tolerances specified in Table A5 when checked with the straightedge.

Table A5. Straightedge Surface Smoothness for Pavements

Pavement Category	Direction of Testing	Tolerance
Runways and taxiways	Longitudinal	3 mm (0.125 in)
	Transverse	6.5 mm (0.25 in)
All other airfield and helicopter paved areas	Longitudinal	6.5 mm (0.25 in)
	Transverse	6.5 mm (0.25 in)

A3.5.5.2. Surface Smoothness Testing Method. Test the surface of the pavement with the straightedge to identify all surface irregularities exceeding the tolerances specified in Table A5. Test the entire area of the pavement in both a longitudinal and a transverse direction on parallel lines approximately 4.5 meters (15 feet) apart. Hold the straightedge in contact with the surface and move ahead one-half the length of the straightedge for each successive measurement. Determine the amount of surface irregularity by placing the straightedge on the pavement surface and allowing it to rest upon the two highest spots covered by its length and measuring the maximum gap between the straightedge and the pavement surface, in the area between these two high points.

A3.5.6. Plan Grade Testing and Conformance. The finished surface of the pavements should conform, within the tolerances shown in Table A5, to the lines, grades, and cross sections shown. The finished surface of new abutting pavements should coincide at their juncture. The finished surface of airfield runway, taxiway, and apron pavements should vary not more than 12 millimeters (0.472 inch) above or below the plan grade line or elevation indicated. The surfaces of other pavements should vary not more than 18 millimeters (0.7 inch) above or below the plan grade line or elevation indicated. Each pavement category should be checked for conformance with plan grade requirements by running lines of levels at intervals to determine the elevation at each joint intersection.

A3.5.7. Slump. The maximum allowable slump of the concrete should be 75 millimeters for pavement constructed with fixed forms. Perform slump tests when test specimens are fabricated. Perform additional tests when excessive variation in workability is observed. Whenever slump approaches the maximum limit, immediately adjust the batch masses of water and fine aggregate, without exceeding the maximum w/(c+p). When a slump result exceeds the specification limit, do not deliver concrete to the paving site until adjustments have been made and slump is again within the limit.

A3.5.8. Temperature. Measure the temperature of the concrete when strength specimens are fabricated.

Table A6. Checklist for Portland Cement Concrete Pavement

Task	Yes	No
Preconstruction		
Plans and specifications thoroughly reviewed?		
Has plant been checked, calibrated, approved?		
Is the proposed cement appropriate?		
Have cement, pozzolans, admixtures been tested and approved?		
Are aggregates from an approved source or have they been tested?		
Is water from an approved source?		
Has the proposed mix proportion been approved and meets the specification?		
Preconstruction and Periodically	**Yes**	**No**
Are cements and pozzolans stored properly and protected from dampness?		
Are admixtures protected against freezing?		
Visually check aggregates for:		
• Contamination (e.g., soil, mud from equipment, wind blown dust, clay balls)		
• Segregation (watch storage and handling procedures)		
• Flat and elongated particles		
• Moisture (is sand allowed to drain before use or is it fluctuating in moisture content?)		
Is base properly placed, graded, and at proper elevation?		
Are all forms, reinforcing steel, tie bars, and/or dowel bars of the proper size, properly placed, and adequately secured?		
Are all floats and screeds straight?		
Are paving vibrators operating, vibrating at specified frequency, properly spaced, and capable of being inserted to adequate depth in concrete?		
Is there an automatic cutoff for the vibrators if the paver stops?		

Are there adequate backup equipment and materials to handle problems (e.g., forms and dowels for transverse construction joints, backup saws for sawing contraction joints, method of applying curing compound)?		
Mixing and Placing	**Yes**	**No**
Are proportions the same as approved mix design?		
Are adjustments being made for moisture content of the aggregates (particularly the sand)? Moisture content of the aggregate is being checked?		
Any sign of segregation, hardened balls of cement, or contaminates in the concrete?		
Is supply of concrete continuous and uniform? (If too slow, the paver advances too slowly and/or forms low spots under the screed. If excessive, the paver may ride over material leaving high spots.)		
Are QC tests being run properly?		
Are fresh concrete tests within specification? (temperature, air content, slump)		
Are strength specimens prepared, cured, and handled properly?		
Ensure water is not added to the concrete after testing and strength specimens are taken.		
Behind the Paver	**Yes**	**No**
Is hand finishing and spot repair minimal?		
Is smoothness being checked?		
Are dowels correctly installed and aligned?		
Is edge slump within specification?		
Ensure water is not sprayed on the fresh surface for finishing.		
Is texture as specified?		
Is curing as specified? Continuous and uniform? Curing protection maintained?		
Keep unnecessary traffic off pavement.		
Sawing started as soon as possible and continued without stopping until finished?		

Table A7. Troubleshooting Guide for PCC

Problem	Cause or Definition	Action
False set	Unusual stiffening of concrete far ahead of initial set with little evolution of heat (rare)	• Do not add water • Plasticity can be restored with additional mixing • Notify cement supplier
Premature hardening	• Improper use of accelerator • High concrete temperature	• Use retarders • Avoid Type III, lower concrete temperature • Use pozzolans
Slump out of specification or varying	• Change in water content or aggregate gradation • Concrete temperature too high (stiffens with temperature increase)	• Check aggregate moisture contents and gradations • Check water being added at the plant • Check to see if water added onsite • Lower concrete temperature
Fluctuating air content	• Pozzolan varying • Cement brand changed • Sand gradation changed • Worn mixer blades • Overloading mixer • Excessive/variable mixing • Organic contamination • Interaction with admixtures such as calcium chloride • Improper air entraining agent or change in brand.	Check materials and construction procedures

Excessive concrete temperature	• High ambient temperatures • Hot cement	Lower concrete temperature by chilling water, cooling aggregate, paving at night
Failure to set	• Organic contamination • Retarder not dispersed	• Check water, aggregates, equipment for contamination • Better mixing to disperse retarder
Sticky mix	• Sand too fine • Using wood float on air-entrained concrete.	• Change sand gradation • Use magnesium or aluminum floats
Honeycombing	• Inoperative vibrators • Inadequate vibration • Excessive vibrator spacing • Concrete segregation	• Check vibrators • Improve material handling, mixing and placing procedures to avoid segregation
Excessive edge slump	• Poor and/or nonuniform concrete • Improper equipment operation, and/or unskilled labor	Adjust mix design and construction procedures
Smoothness problems	• Nonuniform concrete • “Stop-and-go” paver operation • Too much or too little concrete in front of paver	Improve mixing and construction procedures
Popouts	• Unsound aggregates • Clay balls	Check aggregates
Scaling	• Overfinishing • Premature freezing of concrete	• Improve finishing technique • Protect concrete from freezing

Contraction cracking	• Sawing too late • Slab size too large	• Saw sooner • Check slab dimensions
Raveling of saw cut	Sawing too soon	Wait longer to saw
Plastic shrinkage cracking	Excessive loss of moisture due to temperature, humidity, wind, and or curing procedures	• Lower concrete temperature • Use wind breaks and sun screens • Pave at night • Improve curing procedure
Low strength concrete	• Improper sample preparation, curing, testing • Excessive water/cement ratio • Contamination • Batching errors • Improper mixing • Inadequate consolidation • Inadequate curing	Check sampling, materials, batching, mixing, construction, and curing procedures
Joint spalls	• Excessive hand finishing • Adding concrete to fix low spots • Nonuniform concrete • Damage from equipment	Improve construction practices

A3.6. Additional References:

- ASTM C 172, *Standard Practice for Sampling Freshly Mixed Concrete*
- ASTM C 173, *Test for Air Content of Freshly Mixed Concrete by the Volumetric Method*

DRAINAGE LAYER

A4.1. General. This specification covers the requirements for a drainage layer under roads, streets and airfield pavements. The following are various types of drainage layers:

A4.1.1. Aggregate Drainage Layer. A drainage layer consisting of rapid draining materials (RDM) or a combination of open graded materials (OGM) stabilized with choke stone meeting the gradations of Table A8.

A4.1.2. Bituminous-stabilized Drainage Layer. A drainage layer consisting of OGM stabilized with asphalt cement.

A4.1.3. Cement-stabilized Drainage Layer. A drainage layer consisting of OGM stabilized with Portland cement.

A4.2. Material.

A4.2.1. Aggregates. Aggregates should consist of clean, sound, hard, durable, angular particles of crushed stone, crushed slag, or crushed gravel which meet the specification requirements. Slag should be an air-cooled, blast-furnace product having a dry weight of not less than 1040 kilograms per cubic meter (65 pounds per cubic foot) determined by ASTM C 29/C 29M, *Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate*. The aggregates should be free of silt and clay as defined by ASTM D 2487, *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*, vegetable matter, and other objectionable materials or coatings.

A4.2.1.1. Aggregate Quality.

A4.2.1.1.1. The aggregate should have a soundness loss not greater than 18% weighted averaged at 5 cycles when tested in magnesium sulfate in accordance with ASTM C 88, *Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate*. This value has proven effective in many localities, but may be altered based on the knowledge of both coarse and fine aggregates in the areas.

A4.2.1.1.2. The aggregate should have loss on abrasion not to exceed 40% after 500 revolutions as determined by ASTM C 131, *Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine*. Loss on abrasion of 40% is normally used, except that a value up to 50% may be used where experience with local materials indicates such an increase is justified.

A4.2.1.1.3. The percentage of flat and/or elongated particles should be determined by ASTM D 4791, *Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate*, with the following modifications: the aggregates should be separated into two size fractions - particles greater than 12.5-millimeter sieve; and particles passing the 12.5-millimeter sieve and retained on the 4.75-millimeter (No. 4) sieve.

A4.2.1.1.4. Flat and/or elongated particles in either fraction should not exceed 20%. A flat particle is one having a ratio of width to thickness greater than 3; an elongated particle is one having a ratio of length to width greater than 3.

A4.2.1.1.5. When the aggregate is supplied from more than one source, aggregate from each source should meet the specified requirements.

A4.2.1.1.6. When the aggregate is supplied from crushed gravel it should be manufactured from gravel particles, 90% of which by weight are retained on the maximum-size sieve listed in Table A8. In the portion retained on each sieve specified, the crushed gravel should contain at least 90% by weight of crushed pieces having two or more freshly fractured faces, with the area of each face being at least equal to 75% of the smallest midsectional area of the face. When two fractures are contiguous, the angle between planes of the fractures must be at least 30° in order to count as two fractured faces. Fractured faces may be reduced to 75% if the required CBR is 50 or less.

A4.2.1.2. Gradation Requirements. The gradation or gradations applicable to the specific job will depend on the type of drainage and the finished surface desired. Select RDM and/or OGM, depending on the required permeability and material availability. RDM should provide a permeability of 300 to 1500 meters (1000 to 5000 feet) per day. OGM should provide a permeability greater than 1500 meters per day. RDM is well graded enough to be stable to work on; however, OGM will require choke stone, asphalt cement, or Portland cement for stability. The gradation for the choke stone matches ASTM gradation No. 8. Table A8 provides gradation limits for the drainage layer:

Table A8. Gradation of Drainage Layer Material

Sieve Designation	Percentage by Weight Passing Square-Mesh Sieve		
	RDM	OGM	Choke Stone
37.50 mm (1.5 inch)	100%	100%	100%
25.00 mm (1 inch)	70-100%	95-100%	100%
19.00 mm (0.75 inch)	55-100%		100%
12.50 mm (0.5 inch)	40-80%	25-80%	100%
9.50 mm (0.375 inch)	30-65%		80-100%

4.75 mm (No. 4)	10-50%	0-10%	10-100%
2.36 mm (No. 8)	0-25%	0-5%	5-40%
1.18 mm (No. 16)	0-5%		0-10%

Notes:

1. Particles having diameters less than 0.02 millimeters (0.0008 inch) should not be in excess of 1.5% by weight of the total sample tested.
2. The values are based on aggregates of uniform specific gravity, and the percentages passing the various sieves may require appropriate correction when aggregates of varying specific gravities are used.
3. Choke stone, asphalt cement, or Portland cement will be required to stabilize the OGM. Choke stone should be made up of hard, durable, crushed aggregate having 90% of the stone with fractured faces. The gradation for the choke stone should be based on the following criteria:
   a. The ratio of the diameter of aggregate (millimeter) at specified percentage passing (D15) of the OGM to the D15 of the choke stone should be less than 5.
   b. The ratio of the D50 of the OGM to the D50 of the choke stone should be greater than 2.
4. For RDM, the coefficient of uniformity (CU) should be greater than 3.5. (CU = D60/D10).

A4.2.2. Bituminous Materials. Refer to UFC 3-250-03, *Standard Practice Manual for Flexible Pavements,* for information on choosing the appropriate type and grade of bituminous material. Asphalt cement to be mixed with aggregates should conform to either ASTM D 946, *Standard Specification for Penetration-Graded Asphalt Cement for Use in Pavement Construction*, or ASTM D 3381, *Standard Specification for Viscosity-Graded Asphalt Cement for Use in Pavement Construction*, grade as described in UFC 3-250-03. In addition, the asphalt cement should show a negative spot when subjected to the spot test in accordance with AASHTO T 102, *Spot Test of Asphaltic Materials*, using the standard naphtha specified.

A4.2.3. Cementitious Materials. Refer to UFC 3-250-03 for information on choosing the appropriate type and grade of cementitious material. Portland cement to be mixed with aggregates should conform to either ASTM C 150 (Portland cement) Type I, IA, II, or IIA, or ASTM C 595, *Standard Specification for Blended Hydraulic Cements*, Type IS or IS.

A4.2.4. Bituminous- or Cement-stabilized Job-Mix Formula (JMF). The bituminous-stabilized mix consists of a mixture of OGM and a minimum of 2% asphalt cement by weight. Tolerances for bituminous-stabilized material should be maintained for field production at ±0.25% for asphalt cement and ±14 °C (25 °F) for mixing temperatures.

The cement-stabilized mix consists of OGM and a minimum of 90 kilograms (200 pounds) of Portland cement per cubic meter (yard) with a water/cement ratio of 0.37. Based on the test section performance, adjust (increase) the asphalt cement or Portland cement quantities to ensure the stabilized drainage layer will not rut or be disturbed by the paving method in the project.

A4.2.5. Field Compaction. Field compaction requirements are based on the results of a test section, using the materials, methods, and equipment proposed for use in the work (see paragraph A4.2.6).

A4.2.6. Test Section. It is good practice, given the time, to construct a test section to evaluate the ability to carry traffic and the constructability of the drainage layer, including required mixing, placement, and compaction procedures. Test section data generally allows for determination of the required number of passes and the field dry density requirements for full-scale production. Typically, the test section is constructed at least 30 days prior to the start of full-scale production to provide sufficient time for an evaluation of the proposed materials, equipment, and procedures, including QA testing. The test section is normally placed outside the production paving limits in an area with similar subgrade and subbase conditions. The test section is usually at least 30 meters (100 feet) long and one full paving lane wide.

A4.2.6.1. Constructing Test Section. For construction of the test section, compaction equipment speed should be no greater than 2.4 kilometers per hour (1.5 miles per hour). Construct the test section with aggregate in a moist state to establish a correlation between the number of roller passes and dry density achievable during field production. Conduct density and moisture content tests at the surface and at 50-millimeter intervals of depth down for the total layer thickness, in accordance with ASTM D 2922 and ASTM D 3017, *Standard Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth)*. Conduct sieve analysis tests on composite samples, taken adjacent to the density test locations, which represent the total layer thickness. Take one set of tests (i.e., density, moisture, and sieve analysis) before compaction and after each subsequent compaction pass at three separate locations. Continue compaction passes and density readings until the difference between the average dry densities of any two consecutive passes is less than or equal to 8 kilograms per cubic meter (0.5 pound per cubic foot). If choke stone is used to stabilize the surface of OGM, place the choke stone after compaction of the final lift of OGM. Spread the choke stone in a thin layer no thicker than 13 millimeters and work into the surface of the OGM using two passes of a vibratory roller and wet. Complete the test section by making one final pass with the roller in the static mode and observing any change in the drainage layer surface texture.

A4.2.6.2. Testing Bituminous- or Cement-stabilized Drainage Layer. For bituminous- or cement-stabilized drainage layer, conduct density tests at the surface and at intervals of 50 millimeters of depth for the total layer thickness in accordance with ASTM D 2922. Take a composite sample representing the total layer thickness adjacent to each density test location. Visually examine each composite sample to determine if and when crushing of aggregate occurs. Take one density test and composite sample before compaction and after each subsequent compaction pass at three separate locations. Continue compaction passes and density readings until the difference between the average total densities of any two consecutive passes is less than or equal to 8 kilograms per cubic meter.

A4.2.6.3. Evaluation of Test Section Data. For aggregate drainage layer material, plot the in-place density and percent passing the 4.75-millimeter (No. 4) and 1.18-millimeter (No. 16) sieve sizes against cumulative passes. For bituminous or cement-stabilized drainage layer material, plot in-place density against cumulative passes and degradation should be based on visual observations in lieu of sieve analyses. With these results, try to maximize dry density while minimizing aggregate degradation. Generally, after between three and six passes, only slight increases in dry density (8 kilograms per cubic meter) will be achieved. At this point the measured field density is at or near the optimum density obtainable for this material, for the given field conditions. The required field dry density should then be set slightly lower than this optimum field dry density. Set the field dry density at 98% of the optimum density obtained in the test section. For aggregate drainage layer material only, the data on the percent passing should be looked at closely to determine if degradation of the aggregate is occurring. If the percent passing the given sieve sizes is increasing, then the aggregate is being broken down by the compaction effort. If this is occurring, selection of a field control density will be more difficult. The field density selected will have to be balanced between aggregate degradation, dry density and stability of the drainage layer surface. Stability of the layer surface should take precedence.

A4.3. Construction.

A4.3.1. Equipment.

A4.3.1.1. Placement Equipment. An asphalt paving machine should be used to place drainage layer material. Alternate methods may be used if it can be demonstrated in the test section that these methods obtain the specified results.

A4.3.1.2. Compaction Equipment. A dual or single smooth drum roller which provides a maximum compactive effort without crushing the drainage layer aggregate should be used to compact drainage layer material.

A4.3.1.3. Bituminous Mixing Plant. The bituminous mixing plant should be an automatic or semiautomatic controlled, commercially manufactured unit capable of producing a bituminous-stabilized aggregate mixture consistent with the JMF. Drum mixers should be prequalified at the production rate to be used during full scale operations. The prequalification tests include extraction methods in accordance with ASTM D 2172, *Standard Test Method for Quantitative Extraction of Bitumen form Bituminous Paving Mixtures*, and recovery of the asphalt cement in accordance with ASTM D 1856, *Recovery of Asphalt by Abson Method*. The penetration of the recovered asphalt binder should not be less than 60% of the original penetration in accordance with ASTM D 5, *Standard Test Method for Penetration of Bituminous Materials*.

A4.3.1.4. Cementitious Mixing Plant. The cementitious mixing plant should be an automatic or semiautomatic controlled, commercially manufactured unit capable of producing a cement-stabilized aggregate mixture consistent with the JMF determined by the Government. Sufficiently mix dry aggregate and cement to prevent cement balls from forming when water is added.

A4.3.2. Weather Limitation. Place drainage layer material when the atmospheric temperature is above 2 °C (35 °F). Areas of completed drainage layer or underlying courses that are damaged by freezing, rainfall, or other weather conditions, or by contamination from sediments, dust, dirt, or foreign material, should be corrected to meet specified requirements.

A4.3.3. Stockpiling Aggregates. Clear and level stockpile areas prior to stockpiling aggregates. Stockpiling aggregates helps to prevent segregation and contamination. Stockpile aggregates obtained from different sources separately.

A4.3.4. Test Section. If possible, construct the test section as described in paragraph A4.2.6.1.

A4.3.5. Preparation of Underlying Course. Prior to constructing the drainage layer, clean the underlying course of all foreign materials. During construction, the underlying course should contain no frozen material. The underlying course should conform to other sections in these specifications dealing specifically with earthwork or subgrades. Correct ruts or soft yielding spots in the underlying courses (having inadequate compaction and deviations of the surface from the requirements set forth herein) by loosening and removing soft or unsatisfactory material and by adding approved material, reshaping to line and grade, and recompacting to specified density. Do not disturb the finished underlying course by traffic or other operations and maintain in a satisfactory condition until the drainage layer is placed.

A4.3.6. Transporting Material. The aggregate drainage layer material should be transported to the site in a manner which prevents segregation and contamination of materials. Bituminous-stabilized material should be transported from the mixing plant to the site in trucks having tight, clean, smooth beds lightly coated with an approved releasing agent to prevent adhesion of the stabilized material to the truck beds. Drain excessive releasing agent prior to loading. Cover each load with canvas or other approved material of ample size to protect the stabilized material from the weather and to prevent loss of heat. Reject loads that have crusts of cold, unworkable material or have become wet. Do not haul over freshly placed material. Cement-stabilized material should be transported from the mixing plant to the site in trucks equipped with protective covers. Loads that have crusts of unworkable material or have become excessively wet will be rejected. Hauling over freshly placed material will not be permitted.

A4.3.7. Placing.

A4.3.7.1. General Requirements. Place drainage layer material on the underlying course in lifts of uniform thickness using equipment meeting the requirements of paragraph A4.3.1. When a compacted layer 150 millimeters or less in thickness is required, place the material in a single lift. When a compacted layer in excess of 150 millimeters is required, place the material in lifts of equal thickness. No lift should exceed 150 millimeters or be less than 75 millimeters when compacted. The lifts, when compacted after placement, should be true to the grades or levels required with the least possible surface disturbance. Where the drainage layer is placed in more than one lift, clean the previously constructed lift of loose and foreign material. Make such adjustments in placing procedures or equipment to obtain true grades and minimize segregation and degradation of the drainage layer material. Spread choke stone used to stabilize the surface of the OGM in a thin layer no thicker than 13 millimeters.

A4.3.7.2. Placement of Bituminous-stabilized Material. Reject bituminous-stabilized material having temperatures less than 80 °C (175 °F) when dumped into the asphalt paving machine. Adjust the paving machine so that the surface of the lift being laid will be smooth and continuous without tears and pulls. Correct irregularities in alignment of the lift left by the paving machine by trimming directly behind the machine. Thoroughly compact the edges of the lift immediately after trimming. Do not distort the lift during tamping. If more than one lift is required, offset the longitudinal joint in one lift from the joint in the lift immediately below by at least 300 millimeters; however, the joint in the top layer should be at the centerline of the pavement. Offset transverse joints in one layer by at least 0.6 meter (2 feet) from transverse joints in the previous layer. Offset transverse joints in adjacent strips a minimum of 3 meters.

A4.3.7.3. Placing Adjacent Bituminous-stabilized Strips. Place the bituminous-stabilized material in consecutive adjacent strips having a minimum width of 3 meters, except where edge lanes require strips less than 3 meters to complete the area. In placing adjacent strips, overlap the screed of the paving machine with the previously placed strip by 75 to 100 millimeters. Ensure the overlap is sufficiently high so that compaction will produce a smooth, dense joint. Push back the stabilized material placed on the edge of the previously placed strip to the edge of the strip being placed. Remove any waste excess stabilized material.

A4.3.7.4. Hand Spreading. In areas where machine spreading is impractical, drainage layer material should be spread by hand. Spread the material uniformly in a loose layer to prevent segregation. The material should conform to the required grade and thickness after compaction.

A4.3.8. Compaction Requirements. Accomplish compaction using rollers meeting the requirements of paragraph A4.3.1 and operating at a rolling speed of no greater than 2.4 kilometers per hour. Compact each lift of drainage material, including shoulders when specified under the shoulders, with the number of passes of the roller as determined by the test section. In addition, maintain a minimum field dry density as determined by the test section. If the required field dry density is not obtained, adjust the number of roller passes in accordance with paragraph A4.3.12. Avoid excessive rolling resulting in crushing of aggregate particles. Work choke stone used to stabilize the surface of the OGM into the surface of the OGM by two passes of a vibratory roller and wetting. Begin compaction of bituminous-stabilized material immediately when the material has cooled to 77 °C (170 °F). No more than 30 minutes should elapse between the start of moist mixing of cement-stabilized material and the start of field compaction, and complete field compaction within 60 minutes. In all places not accessible to the rollers, the drainage layer material should be compacted with mechanical hand-operated tampers.

A4.3.9. Curing of Cement-stabilized Material. Cure the completed cement-stabilized drainage layer with water for a period of 12 hours following completion of compaction. Commence curing operations within 3 hours after compaction by sprinkling the surface of the drainage layer with a fine spray of water every 2 hours for the required 12-hour period. Apply curing water so that the cement paste on the surface of the mixture will not be eroded. Do not permit water trucks on the completed cement-stabilized drainage layer.

A4.3.1.10. Finishing. Finish the top surface of the drainage layer after final compaction as determined from the test section. Make adjustments in rolling and finishing procedures to obtain grades and minimize segregation and degradation of the drainage layer material.

A4.3.11. Edges of Drainage Layer. Place shoulder material along the edges of the drainage layer course in a quantity that will compact to the thickness of the layer being constructed. When the drainage layer is being constructed in two or more lifts, roll and compact at least a 300-millimeter width of the shoulder simultaneously with the rolling and compacting of each lift of the drainage layer.

A4.3.12. Deficiencies.

A4.3.12.1. Grade and Thickness. Correct deficiencies in grade and thickness so that both grade and thickness tolerances are met. Do not add thin layers of material to the top surface of the drainage layer to meet grade or increase thickness. If the elevation of the top of the drainage layer is too high (see paragraph A4.4), trim to grade and finish in accordance with paragraph A4.3.1.10. If the elevation of the top surface of the drainage layer is 13 millimeters or more below the required grade, scarify the surface of the drainage layer to a depth of at least 75 millimeters, add new material, and blend and compact the layer to bring it to grade. Where the measured thickness of the drainage layer is deficient by more than 13 millimeters, correct by excavating to the required depth and replace with new material to obtain a compacted lift thickness of at least 75 millimeters. Control the depth of required excavation to keep the final surface elevation within grade requirements and to preserve layer thicknesses of materials below the drainage layer.

A4.3.12.2. Density. Density is deficient if the field dry density test results are below the dry density determined by the test section. If the densities are deficient, roll the layer with two additional passes of the specified roller. If the dry density is still deficient, stop work until the cause of the low dry densities is determined.

A4.3.12.3. Smoothness. Correct deficiencies in smoothness as if they are deficiencies in grade or thickness. Maintain all tolerances for grade and thickness while correcting smoothness deficiencies.

A4.4. QC Testing.

A4.4.1. Sampling. Aggregate samples should be taken in accordance with ASTM D 75, *Standard Practice for Sampling Aggregates*. Bituminous samples should be taken in accordance with ASTM D 140, *Standard Practice for Sampling Bituminous Materials*.

A4.4.2. Test Methods. Sieve analyses should be made in accordance with ASTM C 117, *Materials Finer Than 75 pm (No. 200) Sieve in Mineral Aggregates by Washing*, and ASTM C 136, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*. Field density tests should be made in accordance with ASTM D 2922. When using this method, ASTM D 3017 should be used to determine the moisture content of the aggregate drainage layer material. The calibration curves furnished with the moisture gauges should be checked along with density calibration checks as described in ASTM D 3017. The calibration checks of both the density and moisture gauges should be made by the prepared containers of material method, as described in paragraph "Calibration" of ASTM D 2922, on each different type of material being tested at the beginning of a job and at intervals as directed herein. Soundness tests should be made in accordance with ASTM C 88. Los Angeles abrasion tests should be made in accordance with ASTM C 131. Flat and/or elongated particle tests should be made in accordance with ASTM D 4791. When aggregates are supplied from crushed gravel, use the test methods stated herein to assure the aggregate meets the requirements for fractured faces in paragraph A4.2.1. Bitumen extraction tests should be made in accordance with ASTM D 2172.

A4.4.3. Testing Frequency.

A4.4.3.1. Aggregate Layer. Perform sieve analyses, field density, and moisture content tests at a rate of at least one test for every 1000 square meters (1200 square yards) of completed area and not less than one test for each day's production. Perform soundness tests, Los Angeles abrasion tests, fractured faces tests, and flat and/or elongated particle tests at the rate of one test for every ten sieve analysis tests.

A4.4.3.2. Stabilized Layer. Perform sieve analyses on aggregates prior to addition of asphalt or Portland cement, at a rate of at least one test for every 1000 square meters of production and not less than one test for each day's production. Perform extraction tests on bituminous-stabilized material at the same frequency. Perform soundness tests, Los Angeles abrasion tests, fractured faces tests, and flat and/or elongated particle tests at the rate of one test for every ten sieve analysis tests. Perform field density tests at a rate of at least one test for every 1000 square meters of completed area and not less than one test for each day's production.

A4.4.4. Smoothness Test. The surface of the top lift should not deviate more than 10 millimeters when tested with a 3-meter or 3.6-meter straightedge applied parallel with and at right angles to the centerline of the area to be paved. Correct deviations exceeding 10 millimeters in accordance with paragraph A4.3.12.

A4.4.5. Thickness Control. The completed thickness of the drainage layer should be within 13 millimeters of the thickness indicated. Measure thickness at intervals providing at least one measurement for each 500 square meters (600 square yards) of drainage layer. Conduct measurements in test holes at least 75 millimeters in diameter. Where the measured thickness is deficient by more than 13 millimeters, correct such areas in accordance with paragraph A4.3.12. Where the measured thickness is 13 millimeters more than indicated, it will be considered as conforming to the requirements (if grades are sufficient). The average job thickness should be the average of all job measurements as specified above, but within 8 millimeters of the thickness shown on the drawings.

A4.5. Additional Reference. See ASTM D 1250, *Petroleum Measurement Tables.*

EARTHWORK REQUIREMENTS

A5.1. General. This specification covers the requirements for earthwork.

A5.2. Materials. Suitability of materials to be incorporated into the work covered under this specification will rely on the classification of the soil in accordance with ASTM D 2487. The following materials will be considered suitable: GW, GP, GM, GP-GM, GC, GP-GC, GM-GC, SW, SP, SM, SW-SM, SC, SW-SC, SP-SM, SP-SC, CL, ML, and CL-ML. Materials unsuitable for use in this section include CH, OH, and MH. Suitable materials with rocks larger than 200 millimeters in size should also be considered unsuitable. Materials with rocks larger than 100 millimeters should not be used in the top 300 millimeters of fill material in the shoulder or graded areas.

A5.3. Execution.

A5.3.1. Material Use. Engineering judgement should be used in determining the best use of suitable and possible use of unsuitable materials. Traffic areas should use more granular material. Granular materials are those beginning with G or S in their classification. Where possible, these granular materials should be used closer to the surface as they are stronger. Unsuitable materials may be suitable for use outside the areas to receive traffic if they can be properly compacted. Materials with stones larger than 200 millimeters may be used outside the cleared area.

A5.3.2. Excavation. Excavation should be performed to the required lines and grades of the subgrade. Topsoil (normally the top 100 to 152 millimeters of in-situ soil) should be removed and stockpiled for later use. Judicious use should be made of all excavated materials. Where possible, materials should be moved immediately to fill areas.

A5.3.3. Backfill.

A5.3.3.1. Preparation of the Surface. The surface of the ground to receive fill should be free from topsoil or frozen ground, scarified and moistened, or dried to ±3% of optimum moisture content, and the first lift of fill material placed.

A5.3.3.2. Material Placement. Fill material will be placed in lifts and moistened or dried to ±3% of optimum moisture content, before compaction. The lift thickness will be adjusted to match the capacity of the compactor and the soil being compacted. Usual lift thickness may vary from 100 to 200 millimeters, with normal thickness being 152 millimeters.

A5.3.3.3. Compaction. Compaction should be sufficient to reach the required density. Degree of compaction required is expressed as a percentage of maximum density obtained by ASTM D 1557. In general, required percent compaction is 90% for cohesive materials and 95% for cohesionless materials; however, no compaction is required on all areas outside of the pavement areas for the top 100 millimeters. In areas to receive traffic the requirements of Table A9 should apply:

Table A9. Subgrade Compaction Requirements

Airfield Type	Traffic Area	Depth of Compaction (Measured from Pavement Surface)							
		Cohesive Soils				Cohesionless Soils			
		100%	95%	90%	85%	100%	95%	90%	85%
Light	A	0.3 m (1 ft)	0.5 m (1.5 ft)	0.8 m (2.5 ft)	0.9 m (3 ft)	0.5 m (1.5 ft)	0.8 m (2.5 ft)	1.2 m (4 ft)	1.7 m (5.5 ft)
	B	0.3 m (1 ft)	0.5 m (1.5 ft)	0.6 m (2 ft)	0.9 m (3 ft)	0.5 m (1.5 ft)	0.8 m (2.5 ft)	1.1 m (3.5 ft)	1.5 m (5 ft)
	C	0.3 m (1 ft)	0.5 m (1.5 ft)	0.6 m (2 ft)	0.8 m (2.5 ft)	0.5 m (1.5 ft)	0.8 m (2.5 ft)	0.9 m (3 ft)	1.2 m (4 ft)
Medium	A	0.5 m (1.5 ft)	0.8 m (2.5 ft)	1.2 m (4 ft)	1.5 m (5 ft)	0.8 m (2.5 ft)	1.5 m (5 ft)	2.1 m (7 ft)	2.7 m (9 ft)
	B	0.5 m (1.5 ft)	0.8 m (2.5 ft)	1.2 m (4 ft)	1.5 m (5 ft)	0.8 m (2.5 ft)	1.4 m (4.5 ft)	2.1 m (7 ft)	2.6 m (8.5 ft)
	C	0.3 m (1 ft)	0.6 m (2 ft)	0.9 m (3 ft)	1.2 m (4 ft)	0.6 m (2 ft)	1.2 m (4 ft)	1.8 m (6 ft)	2.3 m (7.5 ft)
	D	0.3 m (1 ft)	0.5 m (1.5 ft)	0.6 m (2 ft)	0.9 m (3 ft)	0.5 m (1.5 ft)	0.8 m (2.5 ft)	1.2 m (4 ft)	1.7 m (5.5 ft)
Heavy	A	0.6 m (2 ft)	0.9 m (3 ft)	1.4 m (4.5 ft)	1.8 m (6 ft)	0.9 m (3 ft)	1.8 m (6 ft)	2.6 m (8.5 ft)	3.2 m (10.5 ft)
	B	0.6 m (2 ft)	0.9 m (3 ft)	1.4 m (4.5 ft)	1.8 m (6 ft)	0.9 m (3 ft)	1.8 m (6 ft)	2.6 m (8.5 ft)	3.2 m (10.5 ft)
	C	0.5 m (1.5 ft)	0.8 m (2.5 ft)	1.1 m (3.5 ft)	1.7 m (5.5 ft)	0.8 m (2.5 ft)	1.4 m (4.5 ft)	2.1 m (7 ft)	2.7 m (9 ft)
	D	0.3 m (1 ft)	0.5 m (1.5 ft)	0.8 m (2.5 ft)	0.9 m (3 ft)	0.5 m (1.5 ft)	0.9 m (3 ft)	1.4 m (4.5 ft)	1.9 m (6.5 ft)

Modified Heavy	A	0.5 m (1.5 ft)	0.9 m (3 ft)	1.2 m (4 ft)	1.7 m (5.5 ft)	0.9 m (3 ft)	1.7 m (5.5 ft)	2.4 m (8 ft)	3 m (10 ft)
	B	0.5 m (1.5 ft)	0.8 m (2.5 ft)	1.2 m (4 ft)	1.7 m (5.5 ft)	0.9 m (3 ft)	1.5 m (5 ft)	2.3 m (7.5 ft)	2.9 m (9.5 ft)
	C	0.3 m (1 ft)	0.6 m (2 ft)	1.1 m (3.5 ft)	1.4 m (4.5 ft)	0.6 m (2 ft)	1.4 m (4.5 ft)	1.9 m (6.5 ft)	2.6 m (8.5 ft)
	D	0.3 m (1 ft)	0.5 m (1.5 ft)	0.6 m (2 ft)	0.8 m (2.5 ft)	0.5 m (1.5 ft)	0.8 m (2.5 ft)	1.2 m (4 ft)	1.7 m (5.5 ft)
Short Field	A	0.3 m (1 ft)	0.6 m (2 ft)	0.8 m (2.5 ft)	1.1 m (3.5 ft)	0.6 m (2 ft)	0.9 m (3 ft)	1.5 m (5 ft)	1.9 m (6.5 ft)

Note: Shoulders and overruns have same compaction requirements as Type D traffic areas.

- Cohesive (LL > 25 or PI > 5)
- Cohesionless (LL 1 25 and PI 1 5)

A5.3.4. Subgrade Requirements. Subgrade will be constructed to within ±15 millimeters.

A5.3.5. Undercutting. Do not keep rock, shale, hardpan, loose rock, boulders, or other unsatisfactory material in runway safety areas, subgrades, roads, shoulders, or any areas intended for turfing. Excavate these unsuitable materials to a minimum depth of 300 millimeters below the subgrade. Muck, peak, matted roots, or other yielding material, unsatisfactory for subgrade foundation, will be removed to the depth so as not to interfere with the required depth of compactions as shown in Table A9. Refill the excavated materials with suitable material, obtained from the grading operations or borrow areas, and thoroughly compact by rolling. Ensure any rock cuts are refilled with selected material and any pockets created in the rock surface are drained.

A5.4. QC Testing.

A5.4.1. Density: Density tests should be made for each 30 cubic meters (1000 cubic yards) of material placed per layer. The in-place field density will be determined in accordance with ASTM D 1556 or ASTM D 2167. ASTM D 2922 may be used if the tests are calibrated with one of the other two methods.

A5.4.2. Smoothness.

A5.4.2.1. In those areas upon which a subbase or base course is to be placed, the top of the subgrade will be of such smoothness that, when tested with a 4.8-meter (16-foot) straightedge applied parallel and at right angles to the centerline, it will not show any deviation in excess of 12 millimeters, or will not be more than 15 millimeters from true grade as established by grade hubs or pins. Correct any deviations in excess of these amounts by loosening, adding, or removing materials; reshaping; and recompacting by sprinkling and rolling.

A5.4.2.2. On runway safety areas, the surface will be of such smoothness that it will not vary more than 30 millimeters from true grade as established by grade hubs. Correct any deviation in excess of this amount by loosening, adding or removing materials, and reshaping.

A5.5. Additional Reference: See ASTM D 698, *Tests for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures, Using 5.5-pound (2.5 kg) Rammer and 12-inch (300 mm) Drop.*

HOT MIX ASPHALT (HMA) FOR AIRFIELDS

A6.1. General. The following is provided as guidance only, but should be used to the maximum extent possible and practical to ensure a quality product.

A6.2. Material.

A6.2.1. Aggregates. Aggregates should consist of crushed stone, crushed gravel, crushed slag, screenings, natural sand, and mineral filler, as required. The portion of material retained on the 4.75-millimeter (No. 4) sieve is coarse aggregate. The portion of material passing the 4.75-millimeter (No. 4) sieve and retained on the 0.075-millimeter (No. 200) sieve is fine aggregate. The portion passing the 0.075-millimeter (No. 200) sieve is defined as mineral filler.

A6.2.1.1. Coarse aggregate should consist of sound, tough, durable particles, free from films of material that would prevent thorough coating and bonding with the asphalt material and free from organic matter and other deleterious substances. The coarse aggregate particles should meet the following requirements:

A6.2.1.1.1. The percentage of loss should not be greater than 40% after 500 revolutions when tested in accordance with ASTM C 131.

A6.2.1.1.2. The percentage of loss should not be greater than 12% after five cycles when tested in accordance with ASTM C 88, using magnesium sulfate.

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

A6.2.1.1.3. At least 75% by weight of coarse aggregate retained on the 4.75-millimeter (No. 4) sieve and each coarser size should have at least two or more fractured faces when tested in accordance with COE CRD-C 71, *Test for Ultimate Tensile Strain Capacity of Concrete*. Fractured faces should be produced by crushing.

A6.2.1.1.4. The particle shape should be essentially cubical, and the aggregate contain not more than 20%, by weight, of flat and elongated particles (3:1 ratio of maximum to minimum) when tested in accordance with ASTM D 4791.

A6.2.1.1.5. Slag should be air-cooled blast furnace slag, and have a compacted weight of not less than 1200 kilograms per cubic meter (75 pounds per cubic foot) when tested in accordance with ASTM C 29/C 29M.

A6.2.1.2. Fine aggregate should consist of clean, sound, tough, durable particles. The aggregate particles should be free from coatings of clay, silt, or any objectionable material, and contain no clay balls. The fine aggregate particles should meet the following requirements:

A6.2.1.2.1. The quantity of natural sand (noncrushed material) added to the aggregate blend should not exceed 15% by weight of total aggregate.

A6.2.1.2.2. The fine aggregate should have a sand equivalent value greater than 45 when tested in accordance with ASTM D 2419, *Sand Equivalent Value of Soils and Fine Aggregate*.

A6.2.1.2.3. The fine aggregate portion of the blended aggregate should have an uncompacted void content greater than 45% when tested in accordance with ASTM C 1252, *Test Methods for Uncompacted Void Content of Fine Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading)*, Method A.

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

A6.2.1.3. Mineral filler. Mineral filler should be nonplastic material meeting the requirements of ASTM D 242, *Mineral Filler for Bituminous Paving Mixtures*.

A6.2.1.4. Aggregate gradation. The combined aggregate gradation should conform to gradations specified in Table A10, when tested in accordance with ASTM C 136 and ASTM C 117, and not vary from the low limit on one sieve to the high limit on the adjacent sieve or vice versa, but grade uniformly from coarse to fine.

Note: Disregard the gradations from Table A10 that will not be used as a part of this project. Generally the layer thickness should be at least three times the nominal aggregate size shown in Table A10.

Table A10. Aggregate Gradations

Sieve Size	Nominal Percent Passing by Mass		
	Gradation 1	Gradation 2	Gradation 3
	19 mm (0.75 in)	12.5 mm (0.5 in)	9.5 mm (0.375 in)
25 mm (1 in)	100%		
19 mm (0.75 in)	76-96%	100%	
12 mm (0.5 in)	68-88%	76-96%	100%
9.5 mm (0.375 in)	60-82%	69-89%	76-96%
4.75 mm (No. 4)	45-67%	53-73%	58-78%

2.36 mm (No. 8)	32-54%	38-60%	40-60%
1.18 mm (No. 16)	22-44%	26-48%	28-48%
0.60 mm (No. 30)	15-35%	18-38%	18-38%
0.30 mm (No. 50)	9-25%	11-27%	11-27%
0.15 mm (No. 100)	6-18%	6-18%	6-18%
0.075 mm (No. 200)	3-6%	3-6%	3-6%

A6.2.2. Asphalt Cement Binder. Asphalt cement binder will conform to ASTM D 3381, Table 2, Viscosity Grade AC-20, AASHTO MP1, *Standard Specification for Performance Graded Asphalt Binder*, PG Grade 70-22, ASTM D 946, Penetration Grade 60-70.

Note: When selecting PG-graded asphalt cements, it is recommended that 98% reliability be used. Also consider local experience and availability of desired asphalt grade.

A6.2.3. Mix Design. Design the mix in accordance with Asphalt Institute MS-2, *Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types*, and the criteria in Table A11. If the tensile strength ratio (TSR) of the composite mixture, as determined by ASTM D 4867/D 4867M, *Standard Test Method for Effect of Moisture on Asphalt Paving Mixtures*, is less than 75, treat the aggregate with an approved anti-stripping agent. The amount of anti-stripping agent added should be sufficient to produce a TSR of not less than 75.

Table A11. Marshall Design Criteria

Test Property	75 Blow Mix	50 Blow Mix
Stability (minimum)	8 kN (1800 lb)*	5.3 kN (1200 lb)*
Flow, 0.25 mm (0.01 in)	8-16	8-18
Air voids	3-5%	3-5%
Percent of voids in mineral aggregate (minimum)	See Table A12	See Table A12
TSR (minimum)	75%	75%

*This is a minimum requirement. The average during construction should be significantly higher than this number to ensure compliance with the specifications.

Note: Use a 75 blow (compactive effort) Marshall mix for all airfield pavements. Use a 50 blow mix for shoulder pavements. Disregard the column (50 blow mix or 75 blow mix) which does not apply, unless the project includes both 75 blow and 50 blow mixes.

Table A12. Minimum Percent Voids in Mineral Aggregate (VMA)

Aggregate (See Table A10)	Minimum VMA
Gradation 1	13%
Gradation 2	14%
Gradation 3	15%

* Calculate VMA in accordance with Asphalt Institute MS-2 and based on the ASTM bulk specific gravity for the aggregate.

Note: Select the appropriate gradation and VMA requirements consistent with the gradation chosen in Table A10. Disregard the other two rows in Table A12.

A6.3. Construction.

A6.3.1. Preparation of Asphalt Binder Material. The asphalt cement material should be heated in a manner that will avoid local overheating and provide a continuous supply of the asphalt material to the mixer at a uniform temperature. The temperature of the neat asphalt cement material delivered to the mixer should be sufficient to provide a suitable viscosity for adequate coating of the aggregate particles, but should not exceed 325 °F (160 °C). Modified asphalt should be no more than 350 °F (174 °C) when added to the aggregates.

A6.3.2. Preparation of Mineral Aggregate. The aggregate for the mixture should be heated and dried prior to mixing. The maximum temperature and rate of heating should be such that no damage occurs to the aggregates. The temperature of the aggregate and mineral filler should not exceed 175 °C when the asphalt cement is added. The temperature should not be lower than is required to obtain complete coating and uniform distribution on the aggregate particles.

A6.3.3. Rollers. Rollers should be in good condition and will be operated at slow speeds to avoid displacement of the asphalt mixture. The number, type, and weight of rollers should be sufficient to compact the mixture to the required density while it is still in a workable condition. Equipment, which causes excessive crushing of the aggregate, should not be used.

A6.3.3.1. A good rolling pattern is as follows:

A6.3.3.1.1. Steel wheel breakdown rolling – two coverages only.

A6.3.3.1.2. Rubber tire intermediate rolling – at least eight coverages.

A6.3.3.1.3. Steel wheel finish rolling – sufficient coverages to remove roller marks (usually three coverages are adequate).

A6.3.3.2. For a good rolling pattern using a vibrating roller, apply three coverages by vibrating roller, followed by four to five coverages by a rubber tire roller.

A6.3.3.3. The following are recommended weights for compacting airfield pavements:

A6.3.3.3.1. Steel wheel breakdown roller – 9 metric tons (10 tons).

A6.3.3.3.2. Rubber tire intermediate roller – 22.6 to 27.2 metric tons (25 to 30 tons); tire pressure a minimum of 0.62 megapascals (90 psi).

A6.3.3.3.3. Steel wheel finish roller – 9 metric tons.

A6.3.4. Preparation of the Underlying Surface. Immediately before placing the HMA, the underlying course should be cleaned of all dust and debris. A prime coat and/or tack coat should be applied, as required.

Note: If the underlying surface to be paved is an unbound granular layer, a prime coat should be applied, especially if this layer will be exposed to weather for an extended period of time prior to covering with an asphalt mixture. The prime coat should be applied after the base course is completed, with another coat added just before paving with HMA. Benefits derived from a prime coat include an additional weatherproofer of the base, improving the bond between the base and HMA layer, and preventing the base from shifting under construction equipment. If the underlying surface to be paved is an existing asphalt or concrete layer, a tack coat should always be used to ensure an adequate bond between layers. Tack coat should be placed directly prior to paving with HMA.

A6.3.5. Placing of the Asphalt Mix. The mix should be placed and compacted at a temperature suitable for obtaining density, surface smoothness, and other specified requirements. Typical ranges of temperature for placement are 82 to 121 °C (180 to 250 °F). The mix will not be further compacted after it cools past 65 °C (150 °F). Upon arrival, the mixture should be placed to the full width by an asphalt paver. It should be struck off in a uniform layer of such depth that, when the work is completed, it has the required thickness and conforms to the proper grade and contour. The speed of the paver should be regulated to eliminate pulling and tearing of the asphalt mat. Placement of the mixture normally begins along the centerline of a crowned section or on the high side of areas with a one-way slope. The mixture is placed in consecutive adjacent strips having a minimum width of 3 meters. The longitudinal joint in one course should offset the longitudinal joint in the course immediately below by at least 0.3 meter (1 foot); however, the joint in the surface course should be at the centerline of the pavement. Transverse joints in one course are offset by at least 3 meters from transverse joints in the previous course. Transverse joints in adjacent lanes are offset a minimum of 3 meters. On isolated areas where irregularities or unavoidable obstacles make the use of mechanical spreading and finishing equipment impractical, the mixture may be spread and luted by hand tools.

A6.3.6. Compaction of Mixture. After placing, the mixture should be thoroughly and uniformly compacted by rolling. The surface should be compacted as soon as possible in a manner that does not cause undue displacement, cracking, or shoving. The sequence of rolling operations and the type of rollers are optional. Not more than three passes should be made with a vibratory roller in the vibrating mode.

A6.3.6.1. The speed of the roller should, 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, should be corrected at once. Make sure there are sufficient rollers to handle the output of the plant. Rolling continues until the surface is of uniform texture, true to grade and cross section, and the required field density (98% of Marshall laboratory density) is obtained. To prevent adhesion of the mixture to the roller, keep the wheels properly moistened, but do not use excessive water.

A.6.3.6.2. In areas not accessible to the roller, the mixture can be thoroughly compacted with hand tampers. Any mixture that becomes loose and broken, mixed with dirt, contains check-cracking, or is in any way defective, should be removed full depth and replaced with fresh hot mixture and immediately compacted to conform to the surrounding area. Skin patching is not allowed.

A6.3.7. Joints. The formation of all joints will be made in such a manner as to ensure a continuous bond between the courses and obtain the required density. All joints will have the same texture as other sections of the course and meet the requirements for smoothness and grade.

A6.3.7.1. Transverse Joints. The roller should 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, place a bulkhead or taper the course. The tapered edge should be cut back to its full depth and width on a straight line to expose a vertical face prior to placing the adjacent lane. The cutback material is removed from the project. In both methods, all contact surfaces are given a light tack coat of asphalt material before placing any fresh mixture against the joint.

A6.3.7.2. Longitudinal Joints. Longitudinal joints which are irregular, damaged, uncompacted, cold, or otherwise defective, should be cut back a minimum of 50 millimeters with a cutting wheel to expose a clean, sound surface for the full depth of the course. All cutback material will be removed from the project. All contact surfaces are given a light tack coat of asphalt material prior to placing any fresh mixture against the joint.

A6.3.8. Test Section.

A6.3.8.1. If possible, place a test section for each JMF used. A test section 76 to 152 meters (250 to 500 feet) long and two paver-passes wide placed in two lanes, with a longitudinal cold joint provides best results. The test section should be of the same depth as the course which it represents. The underlying grade or pavement structure upon which the test section is to be constructed should be the same as the remainder of the course represented by the test section. The equipment used in construction of the test section should be the same equipment used on the remainder of the course represented by the test section.

A6.3.8.2. If the initial test section is unacceptable, make the necessary adjustments to the JMF, plant operation, placing procedures, and/or rolling procedures. A second test section is then placed. Additional test sections, as required, should be constructed and evaluated for conformance to the specifications

A6.4. QC Testing.

Note: Testing is normally based on a "lot," defined as 1814 metric tons (2000 tons).

A6.4.1. Asphalt Content. A minimum of two tests to determine asphalt content will be performed per lot by either the extraction method, in accordance with ASTM D 2172 (Method A or B), the ignition method, in accordance with ASTM D 6307, *Standard Test Method for Asphalt Content of Hot-Mix Asphalt by Ignition Method*, or the nuclear method, in accordance with ASTM D 4125, *Standard Test Methods for Asphalt Content of Bituminous Mixtures by the Nuclear Method*, provided the nuclear gauge is calibrated for the specific mix being used. For the extraction method, the weight of ash, as described in ASTM D 2172, should 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 will be used in the calculation of the asphalt content for the mixture.

A6.4.2. Gradation. Aggregate gradations are determined at least twice per lot from mechanical analysis of recovered aggregate in accordance with ASTM D 5444, *Test Method for Mechanical Size Analysis of Extracted Aggregate*. When asphalt content is determined by the nuclear method, aggregate gradation should be determined from hot bin samples on batch plants, or from the cold feed on drum mix plants. For batch plants, aggregates are tested in accordance with ASTM C 136, using actual batch weights to determine the combined aggregate gradation of the mixture.

A6.4.3. Temperatures. Check temperatures at least four times per lot, at necessary locations to determine the temperature at the dryer, the asphalt cement in the storage tank, the asphalt mixture at the plant, and the asphalt mixture at the job site.

A6.4.4. Aggregate Moisture. The moisture content of aggregate used for production is determined at least once per lot in accordance with ASTM C 566, *Standard Test Method for Total Moisture Content of Aggregate by Drying.*

A6.4.5. Moisture Content of Mixture. The moisture content of the mixture should be determined at least once per lot in accordance with ASTM D 1461, *Standard Test Method for Moisture or Volatile Distillates in Bituminous Paving Mixtures*, or an approved alternate procedure.

A6.4.6. Laboratory Air Voids and Density. For air void and density testing, each lot is divided into four equal sublots. One random mixture sample for determining laboratory air voids and theoretical maximum density is taken from a loaded truck delivering the mixture to each sublot, or other appropriate location for each sublot. All samples will be selected randomly, using commonly recognized methods of assuring randomness (ASTM D 3665) and employing tables of random numbers or computer programs. Laboratory air voids will be determined from three laboratory compacted specimens of each sublot sample in accordance with ASTM D 1559, *Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus*. The specimens will be compacted within two hours of the time the mixture was loaded into trucks at the asphalt plant. Samples will not be reheated prior to compaction and insulated containers will be used as necessary to maintain the temperature. Laboratory air voids will be calculated by determining the Marshall density of each lab-compacted specimen using ASTM D 2726, *Standard Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures*, and determining the theoretical maximum density of every other sublot sample using ASTM D 2041, *Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures*. Laboratory air void calculations for each sublot should use the latest theoretical maximum density values obtained, either for that sublot or the previous sublot. The mean absolute deviation of the four laboratory air void contents (one from each sublot) from the JMF air void content will be determined. The Government should complete all laboratory air void tests within 24 hours after completion of construction of each lot.

A6.4.7. In-place Density. For determining in-place density, one random core will be taken from the mat (interior of the lane) of each sub-lot, and one random core will be taken from the joint (the core should be centered over the joint with approximately 50% of the material from the mat on each side of the joint) of each sub-lot. Each random core will be the full thickness of the layer being placed. When the random core is less than 25 millimeters thick, it will not be included in the analysis; in this case, another random core will be taken. After air drying to a constant weight, cores obtained from the mat and from the joints will be used for in-place density determination. The average in-place mat and joint densities are expressed as a percentage of the average Marshall density for the lot. The Marshall density for each lot is determined as the average Marshall density of the four random samples (three specimens compacted per sample). The average in-place mat density and joint density for a lot will be determined. When the Marshall density on both sides of a longitudinal joint is different, the average of these two densities will be used as the Marshall density needed to calculate the percent joint density. All density results for a lot will be completed and reported within 24 hours after the construction of that lot.

A6.4.8. Grade. Test the final wearing surface of the pavement for conformance with the following plan grade requirements. Determine the grades by running lines of levels at intervals of 7.6 meters (25 feet) or less longitudinally and transversely to determine the elevation of the completed pavement surface.

A6.4.9. Smoothness. After completion of final rolling of a lot, the inspector will test the final wearing surface with a 3.6-meter straightedge. Measurements will be made parallel to and across all joints at equal distances along the joint not to exceed 7.6 meters. Locations that fail the straightedge test will be recorded. Use the criteria in Table A13.

Table A13. Surface Smoothness Tolerance

<table>
<tr><th>Pavement Category</th><th>Direction of Testing</th><th>Tolerance</th></tr>
<tr><td rowspan="2">Runways and taxiways</td><td rowspan="2">Longitudinal transverse</td><td>3 mm (0.125 in)</td></tr>
<tr><td>6 mm (0.25 in)</td></tr>
<tr><td rowspan="2">All other airfields and helicopter paved areas</td><td rowspan="2">Longitudinal transverse</td><td>6 mm (0.25 in)</td></tr>
<tr><td>6 mm (0.25 in)</td></tr>
</table>

A6.4.10. JMF. During construction, the inspector should plot gradation results to ensure the gradation remains within the JMF tolerances. Plot results on a 0.45 power curve to ensure the mix is well graded, within the specified gradation band, and all other mix properties meet specifications.

A6.4.10.1. As an example, the criteria in Tables A14 and A15 were specified for an airfield project.

Table A14. Sample Aggregate Criteria

Sieve Size	Percentage Passing
25 mm (1 in)	100%
19 mm (0.75 in)	76-96%
12.5 mm (0.5 in)	68-88%
9.5 mm (0.375 in)	60-82%
4.75 mm (No. 4)	45-67%
2.36 mm (No. 8)	32-54%
1.18 mm (No. 16)	22-44%
0.6 mm (No. 30)	15-35%
0.3 mm (No. 50)	9-25%
0.15 mm (No. 100)	6-18%
0.075 mm (No. 200)	3-6%

Table A15. Sample Mix Criteria

Marshall Design Property	Criteria for 75 Blow Mix
Stability (minimum)	8 kN (1800 lb)
Flow, 0.25 mm (0.01 in)	8-16
Air voids	3-5%
VMA	13% minimum

A6.4.10.2. The aggregates from the three stockpiles shown in Table A16 were combined to meet the specification:

Table A16. Sample Stockpile Aggregates

Sieve Size	Percentage From Each Stockpile			Combined Gradation
	Stockpile 1 60%	Stockpile 2 20%	Stockpile 3 20%	
25 mm (1 in)	100%	100%	100%	100%
19 mm (0.75 in)	85%	100%	100%	91%
12.5 mm (0.5 in)	70%	100%	100%	82%
9.5 mm (0.375 in)	55%	90%	100%	71%
4.75 mm (No. 4)	30%	85%	98%	55%
2.36 mm (No. 8)	20%	70%	94%	45%
1.18 mm (No. 16)	8%	42%	85%	30%
0.6 mm (No. 30)	6%	25%	6%7	22%
0.3 mm (No. 50)	5%	15%	50%	16%
0.15 mm (No. 100)	4%	10%	25%	9%
0.075 mm (No. 200)	2%	6%	10%	4.4%

A6.4.10.3. The mix was designed in accordance with MS-2 and obtained the following mix properties:

- Stability – 9.78 kN (2200 pounds)
- Flow - 13
- Air voids - 4%
- VMA - 15.4%
- Asphalt cement (AC) content – 5.2%

A6.4.10.4. A plot of the proposed gradation (Figure A1) indicates it is well graded and falls within the gradation band in the specification. Since all other mix properties meet specification, the JMF is acceptable. If the test results exceed tolerances, adjustments should be made to the JMF, plant operation, placing procedure and/or rolling procedures, as necessary, and new test sections placed until tolerances are met. The JMF used on the accepted test section becomes the JMF for the project. Specified action and suspension limits are then plotted to control/analyze test results and trends.

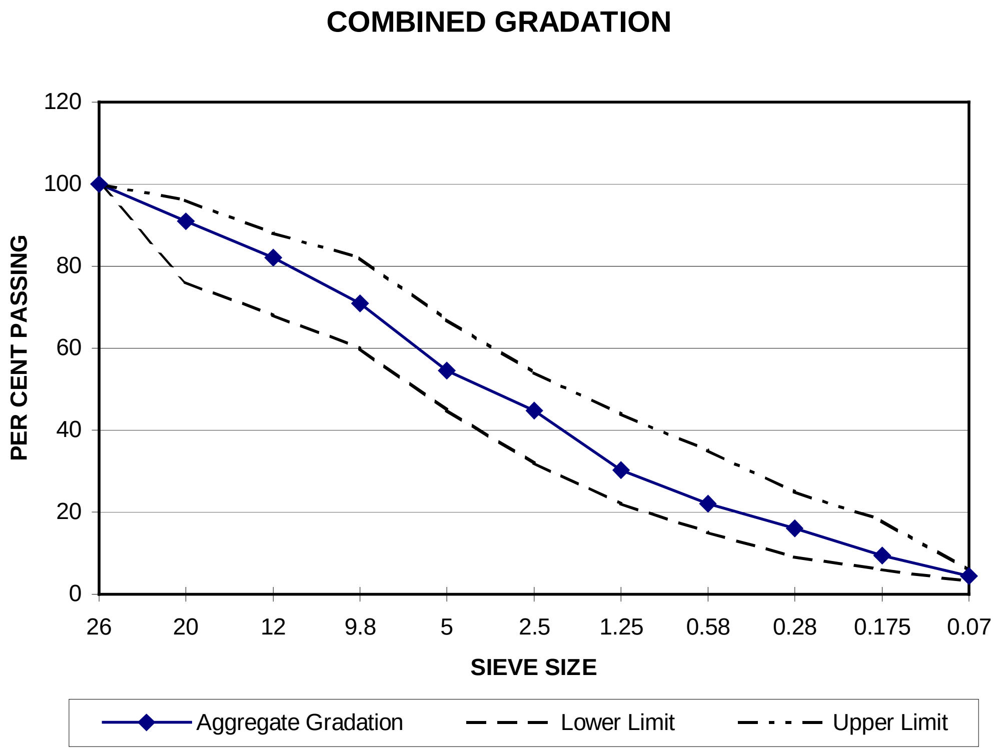

Figure A1. Proposed Gradation Plot

A6.4.11. Additional Tests. The following tests are also required for QC:

A6.4.11.1. Aggregate Tests.

A6.4.11.1.1. Aggregate Gradation (ASTM C 136). Ensure gradation meets the requirements of the JMF.

A6.4.11.1.2. Los Angeles Abrasion Test (ASTM C 131). A measure of abrasion resistance. Compare with requirements in the specification.

A6.4.11.1.3. Flat and Elongated Particles (ASTM D 4791). Flat and elongated particles require more asphalt cement and are difficult to place and compact. Compare to specification.

A6.4.11.1.4. Fractured Faces (CRD C-71). This test is very important. Compare to specification. Mixes with improperly crushed aggregate may be difficult to compact, lack stability, provide low skid resistance, and tend to strip.

A6.4.11.1.5. Natural Sand Content. Excess natural sand reduces stability and may result in poor bonding between the sand and the asphalt cement. It is very important to limit sand content to 15%.

A6.4.11.2. Asphalt Concrete Tests (Asphalt Institute MS-2):

A6.4.11.2.1. Marshall Stability. This is a rough measure of mix stability. Compare to specification. A change in stability may be an indication of a change in other mix properties, such as aggregate gradation or asphalt content.

A6.4.11.2.2. Marshall Flow. Compare to specification. The flow is a general indication of a brittle mix or an unstable mix. A value less than 8 generally indicates a brittle mix; a value above 16 generally indicates an unstable mix.

A6.4.11.2.3. Voids in Total Mix (VTM). When the VTM is too high, the mix will be stiff and have low durability. When the VTM is too low, the mix may be unstable under traffic and there may be bleeding problems.

A6.4.11.2.4. Voids Filled with Asphalt. A high percent of voids filled with asphalt indicates an unstable mix that may tend to bleed, while a low percent indicates a stiff mix with low durability.

A6.4.11.2.5. VMA. This is intergranular void space between aggregate particles; essentially, the sum of air voids plus effective AC content (not counting AC absorbed by aggregates) expressed as percentage of bulk volume of compacted mix.

A6.4.11.2.6. Percentage Asphalt Cement. Air voids are small air spaces between coated aggregates. Field compacted voids should be in the range of 3 to 8%. Mixtures will become unstable when voids are under 3% and are too porous when voids are over 8%.

A6.4.12. Control Charts. Control charts should be used for process control. Linear control charts on both individual samples and the running average of last four samples for the parameters listed in the Table A17 are recommended (to be plotted on individual and running average control charts). These control charts are posted in a satisfactory location and should be kept current at all times. The control charts identify the test parameter plotted, the individual sample numbers, the action and suspension limits applicable to the test parameter being plotted, and the test results. Target values from the JMF should also be shown on the control charts as indicators of central tendency for the cumulative percentage passing, asphalt content, and laboratory air void parameters. When the test results exceed either applicable action limit, take immediate steps to bring the process back in control. When the test results exceed either applicable suspension limit, halt production until the problem is solved. Use the control charts as part of a process control system for identifying trends so that potential problems can be corrected before they occur. Decisions concerning mix modifications are based on analysis of the results provided in the control charts.

Table A17. Action and Suspension Limits

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

A6.4.13. Inspector Checklist for Asphalt Concrete Pavement. Table A18 is a partial checklist to assist the inspector.

Table A18. Asphalt Concrete Pavement Checklist

Task	Yes	No
Crushed face results meet specification requirement?		
Natural sand within specification limits?		
Aggregate gradation complies with JMF?		
AC has been tested and meets specification?		
Mix design conducted in accordance with Asphalt Institute MS-2?		
Laboratory used a manual hammer weighing 4.5 kg (10 lb) and having a 450-mm (18-in) drop to establish the JMF? (An automatic hammer can be used but must be correlated to obtain the same density as the manual hammer. Check hammer foundation to make sure it is sound and stable as this can affect compaction effort.)		
75 blow compactive effort used for airfield pavements?		
Asphalt plant is calibrated to provide proportions specified in the JMF?		
Prime coat absorbed into base prior to paving?		
A tack coat used to bond overlays?		
Was a stringline used for grade control?		
Grade and smoothness checked and results reported?		
Cores obtained and tested for QA densities? (A nuclear density gage can be used to control density but should not be used for acceptance.)		
Asphalt content compared to JMF?		
Diary notes any deficiencies, and deficiencies are corrected?		
Were joints cut back to obtain required density?		
Control charts reviewed daily?		

Table A19. Troubleshooting Asphalt Concrete Pavement

Problem	Symptom	Test	Potential Cause
Low asphalt content	• Dry appearance • Stiff mix • Uncoated aggregate • Brown color	Extraction	• Mix design • Faulty scales or metering
High asphalt content	• Shiny appearance • Mix slumps in truck	Extraction	• Mix design • Faulty scales or metering

Improper gradation	• Coarse appearance • Fine appearance • Dry appearance • Shiny appearance	Sieve analysis	• Faulty scales • Cold feed setting • Segregation during handling • Change in gradation delivered to plant • Mix design
Low density	Voids in surface	Density test	• Roller type, weight and pattern • Mix temperature • Low asphalt content • Aggregate gradation • Mix design
Grade	Birdbaths	Survey	Not using stringline or stringline not set properly
Smoothness	Birdbaths and/or rough ride	Straightedge	• Stopping and starting paver • Quick starts and stops with rollers • Parking rollers on finished surface • Underlying surface is uneven • Excessive manual operation of thickness control on paver

Roller checking	Hairline cracks	Visual	• Mix too hot • Excessive rolling with steel wheel roller • Too much tack coat • Dirty existing surface • Too many fines in mix
Improper bond to underlying layer	Hairline cracks	Inspection of cores	• Too much tack • Not enough tack • Dirty existing surface • Bad tack material

FIELD-MOLDED JOINT SEALANT REQUIREMENTS FOR RIGID PAVEMENTS

A7.1. General. This specification covers the requirements for field-molded sealant for sealing rigid pavements.

A7.2. Materials. For areas where fuel spillage can be expected (aprons), sealant meeting the requirements of ASTM D 3569, *Standard Specification for Joint Sealant, Hot-Applied, Elastomeric Jet-Fuel-Resistant-Type for Portland Cement Concrete Pavements,* should be used. For areas that will be subject to jet blast and/or fuel spillage, sealant meeting U.S. Federal Specification (FS) SS-S-200, *Sealing Compounds, Two-Component Elastomeric, Polymer Type, Jet-Fuel-Resistant, Cold Applied*, Type H or Type M should be used. For areas not subject to jet blast or fuel spillage, ASTM D 3405, *Standard Specification for Joint Sealants, Hot-Applied, for Concrete and Asphalt Pavements*, can be used. Sealant meeting ASTM D 3569 and ASTM D 3405 should be required to meet the additional requirements of COE CRD-C 525, *Corps of Engineers Test Method for Evaluation of Hot-Applied Joint Sealants for Bubbling due to Heating*, because these sealants tend to bubble when heated. Backer rods and bond breaking tape will be compatible with the sealant and sealant installation temperatures. Backer material will have a width of 25%±5% greater than the joint sealant reservoir.

A7.3. Construction.

A7.3.1. The pavement joint sealant reservoir should be sawn into the existing pavement to the width and depth shown on the drawings.

A7.3.2. Thoroughly clean the joints by sandblasting and/or water blasting to remove all residue from joint sawing or curing material.

A7.3.3. Clean with compressed air. Under windy conditions, clean *with* the wind to prevent the wind from blowing the dust and debris back into the joint sealant reservoir.

A7.3.4. Install backer material or bond breaking tape into the joint reservoir as per manufacturer's recommendations.

A7.3.5. Apply sealant as per manufacturer's recommendations. Sealants meeting the requirements of ASTM D 3569 and ASTM 3405 will require heating pots. Sealant meeting FS SS-S-200 will require mixing two components before application. Heating will not be required.

A7.4. QC Testing. Follow manufacturer's recommendations. Ensure joints to be sealed remain clean.

LIME-STABILIZED BASE COURSE, SUBBASE, OR SUBGRADE

A8.1. General. This guide specification covers the requirements for lime stabilization of subgrades, subbases, and base courses for airfield pavements and for roads, streets, and parking areas.

A8.2. Material.

A8.2.1. Lime-stabilized Course. Lime-stabilized course, as used in this specification, is a mixture of lime and in-place or select borrow material uniformly blended, wetted, and thoroughly compacted to produce a pavement course which meets the criteria set forth in the plans and this specification.

A8.2.2. Lime.

A8.2.2.1. Lime should be a standard brand of quicklime or hydrated lime. Table A20 provides some advantages and disadvantages to quicklime, hydrated lime, and a slurry of lime:

Table A20. Use of Lime

Material	Advantages	Disadvantages
Dry hydrated lime	• Can be applied two or three times faster than a slurry. • Very effective in drying out soil.	• Produces a dusting problem that makes its use undesirable in urban areas. • The fast drying action requires an excess amount of water during the dry, hot seasons.
Dry quicklime	• More economical as it contains approximately 25% more available lime. • Greater bulk density for smaller-size soils. • Faster drying action in wet soils. • Faster reaction with soils. • Construction season can be extended, in both spring and fall, because of faster drying.	• Field hydration less effective than commercial hydrators, producing a coarser material with poorer distribution in soil mass. • Requires more water than hydrate for stabilization, which may present a problem in dry areas. • Greater susceptibility to skin and eye burns.

Slurry of lime (made from hydrated lime or quicklime)	• Dust-free application is more desirable from an environmental standpoint. • Better distribution. • Lime spreading and sprinkling operations are combined, thereby reducing job costs. • During summer months slurry application pre-wets the soil and minimizes drying action. • The added heat when slurry is made from quicklime speeds drying action, which is especially desirable in cooler weather.	• Application rates are slower. High-capacity pumps are required to achieve acceptable application rates. • Extra equipment is required, so costs are higher. • Extra manipulation may be required for drying purposes during cool, wet, humid weather, which could occur during the fall, winter, and spring construction season. • Not practical for use with very wet soils.

A8.2.2.2. The following are physical and chemical requirements:

A8.2.2.2.1. Lime should be of such gradation that 99.5% passes a 0.85-millimeter (No. 20) sieve, and a minimum of 85% passes a 0.15-millimeter (No. 100) sieve.

A8.2.2.2.2. Combined calcium oxide and magnesium oxide should be not less than 92% or 70%, depending on the form of lime.

A8.2.3. Bituminous Material. If bituminous material will be used in conjunction with lime stabilization, the bituminous material should conform to Table A21.

Table A21. Bituminous Material

Material	Type
Cutback Asphalt*	AASHTO M 81
	AASHTO M 82
	ASTM D 2027
	ASTM D 2028, Grade RC-250, RC-800, MC-250, or MC-800
Emulsified Asphalt	ASTM D 977, Type RS-1 or RS-2
Tar	ASTM D 490, Grade RT-7, RT-8, RT-9, or RT-10

***Note:** In many places in the U.S. and Europe, cutback asphalt is not allowed for use due to environmental standards. Check local conditions before using.

A8.2.4. Material to be Stabilized. Soils classified as CH, CL, MH, SC, and GC have potential for lime stabilization; however, it is not recommended to use lime alone for the stabilization of sandy soils. Refer to TM 5-822-14 and UFC 3-260-02, *Airfield Pavement Design,* for further guidance. Material to be stabilized should consist of either in-place material or select material hauled to the site. Select material should be free of deleterious substances such as sticks, debris, organic matter, and stones greater than 75 millimeters in any dimension. At least 10% of the material should pass the 0.425-millimeter (No. 40) sieve. Plasticity index should be greater than 12.

A8.2.5. Water. Water should be clean, fresh, and free from injurious amounts of oil, acid, salt, alkali, organic matter, and other substances deleterious to the lime or soil-lime mixture.

A8.2.6. Mix Design. Determine the compressive strength requirement based on the use of the final pavement. Generally, a compressive strength of 1.035 megapascals (150 psi) is minimum. Refer to TM 5-822-14 and UFC 3-260-02 for further guidance, including applicability of stabilization with lime. Develop a proposed mix design prior to stabilization work. Develop the mix using samples of the material to be stabilized. Mix design should be capable of producing a compressive strength of 1.035 megapascals when compacted to the design percent of laboratory maximum density. Samples should not show any significant loss of strength after 12 cycles of the durability test.

A8.3. Construction:

A8.3.1. Stockpiling Materials. Selected material, including approved material available from excavation and grading, should be stockpiled for use during construction. Before stockpiling, clear and slope to drain material storage sites.

A8.3.2. Plant, Equipment, Machines, and Tools:

A8.3.2.1. Steel-wheeled Rollers. Steel-wheeled rollers should be the self-propelled type with a total weight of not less than 9 metric tons, and a minimum weight of 135 kilograms per millimeter (300 pounds per inch) width of rear wheel. Wheels of the rollers should be equipped with adjustable scrapers. The use of vibratory rollers is optional.

A8.3.2.2. Pneumatic-tired Rollers. Pneumatic-tired rollers should have four or more tires, each loaded to a minimum of 13.6 metric tons (15 tons) and inflated to a minimum pressure of 1.035 megapascals. The loading should be equally distributed to all wheels, and the tires should be uniformly inflated. Towing equipment should have pneumatic tires.

A8.3.2.3. Mechanical Spreader. The mechanical spreader should be self-propelled or attached to a propelling unit capable of moving the spreader and material truck. The device should be steerable and should have variable speeds forward and reverse. The spreader and propelling unit should be carried on tracks, rubber tires, or drum-type steel rollers that will not disturb the underlying material. The spreader should contain a hopper, an adjustable screed, and outboard bumper rolls; and should be designed to have a uniform, steady flow of material from the hopper. The spreader should be capable of laying material without segregation across the full width of the lane to a uniform thickness and to a uniform loose density so that when compacted, the layer or layers should conform to thickness and grade requirements indicated.

A8.3.2.4. Sprinkling Equipment. Sprinkling equipment should consist of tank trucks, pressure distributors, or other approved equipment designed to apply controlled quantities of water uniformly over variable widths of surface.

A8.3.2.5. Tampers. Tampers should be mechanical type, operated by either pneumatic pressure or internal combustion, and should have sufficient weight and striking power to produce the compaction required.

A8.3.2.6. Straightedge. Furnish and maintain at the site a 3.6-meter straightedge for use in the testing of the finished surface. Straightedges should be constructed of aluminum or other lightweight metal and should have blades of box or box-girder cross section with flat bottom reinforced to insure rigidity and accuracy. Straightedges should have handles to facilitate movement on pavement.

A8.3.3. Weather Limitations. Do not perform stabilization work during freezing temperatures. When the temperature is below 5 °C, protect the completed course against freezing by a sufficient covering of straw, or by other methods, until the course has dried out. Any areas of completed course that are damaged by freezing, rainfall, or other weather conditions should be brought to a satisfactory condition. Lime should not be applied when the atmospheric temperature is less than 5 °. Do not apply lime to soils that are frozen or contain frost, or when the underlying material is frozen. If the temperature falls below 2 °C, protect completed lime-treated course against any detrimental effects of freezing.

A8.3.4. Degree of Compaction. Degree of compaction required is expressed as a percentage of the maximum density obtained by the test procedure presented in ASTM D 1557, abbreviated as percent laboratory maximum density.

A8.3.5. Lime Stabilization Mixture. The material to be stabilized should be thoroughly pulverized and, when lime is applied in the dry state, the mix should be thoroughly blended at a moisture content below optimum. After mixing is completed, the proportions of the mixture should be in accordance with the approved mix design. After blending, blend water into the dry mix in amounts necessary to bring the moisture content to optimum. Control field moisture content within ±2% of optimum. When the stabilized course is constructed in more than one layer, clean the previously constructed layer of loose and foreign matter by sweeping with power sweeper or power brooms, except that hand brooms may be used in areas where power cleaning is not practicable. Provide adequate drainage during the entire construction period to prevent water from collecting or standing on the area to be stabilized or on pulverized, mixed, or partially mixed material. Provide line and grade stakes as necessary for control. Grade stakes should be in lines parallel to the centerline of the area under construction and suitably spaced for string lining.

A8.3.6. Preparation of Area to be Stabilized. Clean the area of debris. Inspect the area for adequate compaction and ensure it is capable of withstanding, without displacement, the compaction specified for the soil-lime mixture. Dispose of debris and remove unsatisfactory in-place material.

A8.3.6.1. In-place Material to be Stabilized. Grade the entire area to conform to the lines, grades, and cross sections shown in the plans prior to being processed. Soft or yielding subgrade areas should be made stable before construction is begun.

A8.3.6.2. In-place Material to Receive Stabilized Course. Correct soft, yielding areas and ruts or other irregularities in the surface. The material in the affected areas should be loosened and unsatisfactory material removed. Approved select material should be added where unsatisfactory material is removed. Shape the area to line, grade, and cross section, and compact to the specified density. Subgrade should conform to Attachment 5. Subbase course should conform to Attachment 2.

A8.3.6.3. Grade Control. Excavate underlying material to sufficient depth for the required stabilized-course thickness so that the finished stabilized course with the subsequent surface course will meet the fixed grade. Finished and completed stabilized area should conform to the lines, grades, cross section, and dimensions on the plans.

A8.4. Installation.

A8.4.1. Mixed-in-place Method.

A8.4.1.1. Scarifying and Pulverizing of Soil. Prior to application of lime, the soil should be scarified and pulverized to the depth shown required by the mix design and pavement design. Scarification should be controlled so that the layer beneath the layer to be treated is not disturbed. Depth of pulverizing should not exceed the depth of scarification.

A8.4.1.2. Application of Lime. Shape pulverized material to approximately the cross section indicated. Apply lime so that when uniformly mixed with the soil, the specified lime content is obtained, and a sufficient quantity of lime-treated soil is produced to construct a compacted lime-treated course conforming to the lines, grades, and cross section indicated. Mechanical spreaders should be used in applying bulk lime. Use distributors in applying slurry. If lime is spread by hand, place the bags accurately on the area being stabilized so that when the bags are opened the lime will be dumped and spread uniformly on the area being processed. No equipment except that used in spreading and mixing should pass over the freshly applied lime.

A8.4.1.3. Initial Mixing. Immediately after the lime has been distributed, mix the lime and soil. Initial mixing should be sufficient to alleviate any dusting or wetting of the lime that might occur in the event of wind or rainstorms. This may be accomplished several days in advance of the final application and mixing.

A8.4.1.4. Water Application and Moist Mixing. Determine the moisture content of the mixture in preparation for final mixing. Moisture in the mixture following final mixing should not be less than the water content determined to be optimum based on dry weight of soil, and should not exceed the optimum water content by more than 2%. Water may be added in increments as large as the equipment will permit; however, such increment of water should be partially incorporated in the mix to avoid concentration of water near the surface. After the last increment of water has been added, continue mixing until the water is uniformly distributed throughout the full depth of the mixture, including satisfactory moisture distribution along the edges of the section.

A8.4.1.5. Edges of Stabilized Course. Place material along the edges of the stabilized course in a quantity that will compact to the thickness of the course being constructed, or to the thickness of each layer in a multiple-layer course, allowing at least a 300-millimeter width of the shoulder to be rolled and compacted simultaneously with the rolling and compacting of each layer of the stabilized course.

A8.4.2. Central-plant Method. Use the central plant method for mixing select material for subbase or base course construction. Plant should be capable of producing a uniform lime-treated mixture at the specified lime and moisture contents. Haul mixture to the job in trucks equipped with protective covers. Thoroughly moisten underlying course and place the mixture on the prepared area in a uniform layer with mechanical spreaders. The layer should be uniform in thickness and surface contour, and the completed layer, after compaction, should conform to the required grade and cross section.

A8.4.3. Traveling-plant Method. Use the traveling plant for mixing in-place material for subbase and base course construction. Traveling plant should move at a uniform rate of speed and should accomplish thorough mixing of the materials in one pass. Water and lime should be delivered from supply trucks or bins at a predetermined rate. Windrows of prepared soil-lime mixture should cover a predetermined width to the indicated compacted thickness.

A8.4.4. Layer Thickness. Determine compacted thickness of the stabilized course by a pavement design. Thickness usually varies from 100 to 200 millimeters, depending on the pavement design, and should be not more than 200 millimeters, or less than 75 millimeters, in compacted thickness.

A8.4.5. Compaction. Density will be based on the material being stabilized. Before compaction operations are started and as a continuation of the mixing operation, thoroughly loosen and pulverize the mixture to the full depth. Start compaction immediately after mixing is completed. During final compaction, moisten the surface, if necessary, and shape to the required lines, grades, and cross section. Density of compacted mixture should be at least 90% of laboratory maximum density. Begin rolling at the outside edge of the surface and proceed to the center, overlapping on successive trips at least one-half the width of the roller. Alternate trips of the roller should be slightly different lengths. At all times, the speed of the roller should not cause displacement of the mixture to occur. Areas inaccessible to the rollers should be compacted with mechanical tampers, and should be shaped and finished by hand methods.

A8.4.6. Finishing. Finish the surface of the top layer to the grade and cross section shown. The surface should be of uniform texture. Light blading during rolling may be necessary for the finished surface to conform to the lines, grades, and cross sections. If the surface for any reason becomes rough, corrugated, uneven in texture, or traffic-marked prior to completion, scarify, rework, relay, or replace the unsatisfactory portions. If any portion of the course, when laid, becomes watersoaked for any reason, remove that portion immediately, and place the mix in a windrow and aerate until moisture content is within the limits specified. Then spread, shape, and roll as specified in paragraph A8.4.5.

A8.4.7. Construction Joints. At the end of each phase of construction, form a straight transverse construction joint by cutting back into the completed work to form a true vertical face free of loose or shattered material. Remove material along construction joints that is not properly compacted. Replace with soil-lime mixture that is mixed, moistened, and compacted as specified.

A8.4.8. Curing and Protection. It may be advantageous to cure only by bituminous curing pavements that are to receive bituminous surfacing. Use either the following moist curing method or one of the bituminous methods described in paragraph A8.4.8.3. Immediately after the soil-lime area has been finished as specified in paragraph A8.4.6, protect the surface against rapid drying for seven days by one of the following methods:

A8.4.8.1. Moist Curing. Moisten the area by sprinkling, and keep moist for the seven-day curing period.

A8.4.8.2. Bituminous Material. Use one of the materials provided in Table A22 at the temperature range specified.

Table A22. Bituminous Material

Material	Type	Temperature Range
Cutback asphalt*	RC-250, MC-250	65-105 °C (145-220 °F)
	RC-800, MC-800	80 –125 °C (180-255 °F)
Emulsified asphalt	RS-1	25 –55 °C (75-130 °F)
	RS-2	45 –70 °C (110-160 °F)
Tar	RT-7	65 –105 °C (150-225 °F)
	RT-8	65 –105 °C (150-225 °F)
	RT-9	65-105 °C (150-225 °F)
	RT-10	80-120 °C (175-250 °F)

***Note:** In many places in the U.S. and Europe, cutback asphalt is not allowed for use due to environmental standards. Check local conditions before using.

A8.4.8.3. Bituminous material will be uniformly applied by means of a bituminous distributor within the temperature ranges stated in Table A22. Apply bituminous material in quantities of not less than 0.45 liters per square meter (0.1 gallon per square yard) nor more than 1.13 liters per square meter (0.25 gallon per square yard). Areas inaccessible to or missed by the distributor should be properly treated using the manually operated hose attachment. Bituminous material should be applied only to the top layer. At the time the bituminous material is applied, the surface of the area should be free of loose or foreign matter and should contain sufficient moisture to prevent excessive penetration of the bituminous material. When necessary, sprinkle the area immediately before the bituminous material is applied. The treated surface may be sanded or dusted to prevent the bituminous material from being picked up by traffic.

A8.4.9. Traffic. Completed portions of the lime-treated soil area may be opened immediately to light traffic, provided the curing is not impaired. After the curing period has elapsed, completed areas may be opened to all traffic, provided the stabilized course has hardened sufficiently to prevent marring or distorting of the surface by equipment or traffic. Heavy equipment should not be permitted on the area during the curing period. Lime and water may be hauled over the completed area with pneumatic-tired equipment. Finished portions of lime-stabilized soil that are traveled on by equipment used in constructing an adjoining section should be protected in a manner to prevent equipment from marring or damaging completed work.

A8.4.10. Maintenance. Maintain the stabilized area in a satisfactory condition until the completed work is accepted. Maintenance should include immediate repairs of any defects and should be repeated as often as necessary to keep the area intact. Correct defects as specified herein.

A8.4.11. Disposal of Unsatisfactory Materials. Dispose of removed in-place materials that are unsuitable for stabilization, material that is removed for the required correction of defective areas, waste material, and debris.

A8.5. QC Testing.

A8.5.1. General Requirements. The intent of testing is to perform tests in sufficient numbers and at required locations and times to ensure that materials and compaction meet specified requirements. Keep certified copies of the test results.

A8.5.2. Results. Results should verify that the material complies with the specification. When either the source of materials is changed or deficiencies are found, repeat the initial analysis and retest the material already placed to determine the extent of unacceptable material. Replace all in-place unacceptable material.

A8.5.3. Sampling. All aggregate samples for laboratory testing should be taken in accordance with ASTM D 75. Samples of lime should be taken in accordance with ASTM C 50, *Standard Practice for Sampling, Sample Preparation, and Marking of Lime and Limestone Products*. Specimens for the unconfined compression tests should be prepared in accordance with ASTM D 1632, *Making and Curing Soil-Cement Compression and Flexure Test Specimens in the Laboratory*.

A8.5.4. Sieve Analysis. Before starting work, test one sample of material to be stabilized in accordance with ASTM C 136 and ASTM D 422*, Standard Test Method for Particle-Size Analysis of Soils*, on sieves conforming to ASTM E 11*, Wire-Cloth Sieves for Testing Purposes Y 17 R*. After the initial test, perform a minimum of one analysis for each 900 metric tons (1000 tons) of material placed, with a minimum of three analyses for each day's run until the course is completed.

A8.5.5. LL and PI. Perform one LL and PI test for each sieve analysis. LL and PI should be in accordance with ASTM D 4318*, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*.

A8.5.6. Chemical Analysis. Lime should be tested for the specified chemical requirements in accordance with ASTM C 25, *Standard Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime*. Conduct three tests for each delivery of lime.

A8.5.7. Unconfined Compression Testing. Unconfined compression tests should be conducted in accordance with ASTM D 1633, *Compressive Strength of Molded Soil-Cement*. Conduct three tests for each mix design tested. Cure samples at a constant moisture content and temperature for 28 days. Wet-dry tests should be conducted in accordance with AASHTO T 135, *Wetting-and-Drying Testing of Compacted Soil-*

Cement Mixtures, or ASTM D 559, *Standard Test Methods for Wetting and Drying Compacted Soil Cement Mixtures*. Freeze-thaw tests (if necessary for the climate), should be conducted in accordance with AASHTO T 136, *Freezing-and-Thawing Tests of Compacted Soil-Cement Mixtures*, or ASTM D 560, *Standard Test Methods for Freezing and Thawing Compacted Soil-Cement Mixtures*. Conduct three tests for each mix design tested. Omit the scratch portion of the test.

A8.5.8. Field QC. Tests should provide a moisture-density relationship for the lime-soil mixture. Results of field QC testing should verify that materials comply with this specification. When a material source is changed, the new material should be tested for compliance. When deficiencies are found, the initial analysis should be repeated and the material already placed should be retested to determine the extent of unacceptable material. Replace or repair all in-place unacceptable material.

A8.5.8. Thickness Control.

A8.5.9.1. When subbase or base courses are constructed less than 150 millimeters in total thickness, a deficiency of 13 millimeters in thickness is considered excessive. Applicable to job conditions, thickness tolerance provisions may be modified to restrict all deficiencies to no more than 6 millimeters.

A8.5.9.2. Completed thicknesses of the stabilized course should be within 13 millimeters of the thickness indicated. Where the measured thickness of the stabilized course is deficient by more than 13 millimeters, correct such areas by scarifying, adding mixture of proper gradation, reblading, and recompacting. Where the measured thickness of the stabilized course is more than 13 millimeters thicker than indicated, it conforms to the specified thickness requirement. Average job thickness is the average of all thickness measurements taken for the job, but should be within 6 millimeters of the thickness indicated. Measure the thickness of the stabilized course at intervals of one measurement for each 400 square meters (500 square yards) of stabilized course. Conduct measurements in 75-millimeter diameter test holes penetrating the stabilized course.

A8.5.10. Field Density. Field in-place density should be determined in accordance with ASTM D 1556, ASTM D 2167, or ASTM D 2922. When ASTM D 2922 is used, the calibration curves should be checked, and adjusted if necessary, using the sand cone method as described in paragraph *Calibration* of ASTM D 2922. ASTM D 2922 results in a wet unit weight of soil, and when using this method, ASTM D 3017 should be used to determine the moisture content of the soil. The calibration curves furnished with the moisture gauges should be checked along with density calibration checks as described in ASTM D 3017. If ASTM D 2922 is used, in-place densities should be checked by ASTM D 1556 at least once per lift for each 836 square meters (1000 square yards) of stabilized material. Perform at least one field density test for each 209 square meters (250 square yards) of each layer of base material.

A8.5.11. Smoothness Test. This test is used only if the stabilized material is the final surface. The surface of a stabilized layer should show no deviations in excess of 10 millimeters when tested with the 3.6-meter straightedge. Correct deviations exceeding this amount by removing material and replacing with new material, or by reworking existing material and compacting. Take measurements for deviation from grade and cross section shown in successive positions parallel to the road centerline with a 3.6-meter straightedge. Also, take measurements perpendicular to the road centerline at 15-meter (50-foot) intervals.

A8.6. Additional Reference. See ASTM D 633, *Volume Correction Table for Road Tar.*

POROUS FRICTION COURSE (PFC) FOR AIRFIELDS

A9.1. General. This specification covers the requirements for bituminous PFC for airfields. See Attachment 6 for construction techniques.

A9.2. Materials.

A9.2.1. Aggregates. Aggregates should consist of natural sand, crushed stone, crushed gravel, crushed slag, and screenings, as required. The portion of materials retained on the 4.75-millimeter (No. 4) sieve should be known as coarse aggregate, the portion passing the 4.75-millimeter (No. 4) sieve and retained on the 0.075-millimeter (No. 200) sieve as fine aggregate, and the portion passing the 0.075-millimeter (No. 200) sieve as mineral filler. Aggregate gradation should be in accordance with Table A23. Table A23 is based on aggregates of uniform specific gravity; the percentage passing various sieves may be changed when aggregates of varying specific gravities are used. Adjustments of percentages passing various sieves may be used when aggregates vary more than 0.2 in specific gravity.

Table A23. Aggregate Gradation

Sieve Designation	Percent Passing by Weight of Total Aggregates	
	Gradation "A" 19 mm (0.75 in) Maximum (Compacted Nominal Thickness - 25 mm [1 in])	Gradation "B" 13 mm (0.5 in) Maximum (Compacted Nominal Thickness - 19 mm [0.75 in])
19 mm (0.75 in)	100%	100%
12.5 mm (0.5 in)	70-100%	100%
9.5 mm (0.375 in)	45-75%	80-100%
4.75 mm (No. 4)	25-40%	25-40%
2.36 mm (No. 8)	10-20%	10-20%
0.60 mm (No. 30)	3-10%	3-10%
0.075 mm (No. 200)	0-5%	0-5%

A9.2.1.1. Coarse Aggregate. Coarse aggregate should consist of clean, sound, durable particles meeting the following requirements:

A9.2.1.1.1. Abrasion. The Los Angeles abrasion test is used in excluding aggregates known to be unsatisfactory or for evaluating aggregates from new sources. Use values of percentage of loss of aggregates based on aggregates in the area that have been previously approved or that have a satisfactory service record in bituminous pavement construction. Upper limits of 25% for airfields and 40% for roads are normal values for maximum percentage of loss after 500 revolutions, as determined in accordance with ASTM C 131.

A9.2.1.1.2. Crushed Slag. Slag should be air-cooled blast furnace slag. Other slag will not be permitted. The dry weight of crushed slag should not be less than 1200 kilograms per cubic meter (75 pounds per cubic foot), as determined in accordance with ASTM C 29/C 29M.

A9.2.1.1.3. Crushed Gravel. Crushed gravel retained on the 4.75-millimeter (No. 4) sieve and each coarser sieve should contain at least 90% by weight of crushed pieces having at least one fractured face, and 75% by weight of crushed pieces having two or more fractured faces, with the area of each face equal to at least 75% of the smallest midsectional area of each piece. When two fractures are contiguous, the angle between planes of fractures should be at least 30° to count as two fractured faces.

A9.2.1.1.4. Particle Shapes. Particle shape of crushed aggregates should be essentially cubical. The quantity of flat and elongated particles in any sieve size should not exceed 8% by weight when determined in accordance with ASTM D 4791.

A9.2.1.1.5. Aggregate Soundness. Use values of percentage of loss based on knowledge of aggregates in the area that have been previously used or that have a satisfactory service record in PFCs or other bituminous pavements of at least five years. For airfield pavements, the percentage of soundness loss after five cycles performed in accordance with ASTM C 88, using magnesium sulfate, should not exceed 12%. This should not be confused with the less-restrictive 18% for dense graded mixtures.

A9.2.1.2. Fine Aggregate. Fine aggregate should consist of clean, sound, durable, angular particles produced by crushing stone, slag, or gravel that meets quality requirements specified for coarse aggregate. Fine aggregate produced by crushing gravel should have at least 90% by weight of crushed particles having two or more fractured faces in the portion retained on the 0.6-millimeter (No. 30) sieve. This requirement should apply to material before blending with natural sand, when blending is necessary. The quantity of natural sand to be added to the PFC should not exceed 5% by weight of total aggregate. Natural sand should be clean and free from clay and organic matter.

A9.2.2. Bituminous Materials:

A9.2.2.1. Refer to UFC 3-250-03 for the appropriate types and grades of bituminous materials for the pavement's use and climatic environment. Use requirements of ASTM D 946 to specify penetration-graded asphalt cement, or ASTM D 3381 for viscosity-graded asphalt cement. The use of modified bituminous materials such as polymers, latex rubbers, and reclaimed tire rubber should be considered for improving PFC pavement performance. The rubber-modified asphalt cement properties in Table A24, as an example, were specified for a PFC pavement project in the Northwest. The rubber, 1 to 2% by weight, was added to the asphalt cement at the refinery, and is usually a Neoprene synthetic rubber latex or a synthetic styrene butadiene rubber. Refineries in the project vicinity should be contacted, and the specification limits of the asphalt cement should be based on the pavement's use and climatic environment (see UFC 3-250-03).

Table A24. Rubber-modified Asphalt Cement Properties

Specification Property	ASTM No.	Minimum	Maximum
Viscosity at 60 °C (140 °F), Poises	ASTM D 2171	1600	2400
Viscosity at 135 °C (275 °F), CS	ASTM D 2170	325	
Pen at 25 °C (77 °F) (100 gm/5 sec)	ASTM D 5	80	110
Flash point, degrees C (degrees F), Cleveland open cup (C.O.C.) test	ASTM D 92	232 °C (450 °F)	
Duct at 25 °C (77 °F) (5 cm/min) cm	ASTM D 113	100	
Duct at 4 °C (39 ° F) (5 cm/min) cm	ASTM D 113	50	
Synthetic rubber, weight percent (percent by weight rubber solids)		2.0	
Toughness, newton meter (pound foot)		*	12.4 N•m (110)
Tenacity, newton meter (pound foot)		*	8.5 N•m (75)
Spot test, base asphalt	AASHTO T 102 (10% xylene)	Neg.	
Rolling thin film circulating			
Oven test	ASTM D 2872**		
Tests on Residue	**ASTM No.**	**Minimum**	**Maximum**
Viscosity at 60 °C (140 °F), Poise	ASTM D 2171	8000	
Toughness, newton meter (pound foot?)		*	11.3 N•m (100)
Tenacity, newton meter (pound foot?)		*	8.5 N•m (75)
Duct at 25 °C (77 °F) (5 cm/min) cm	ASTM D 113	100	
4 °C (39.2 °F) (5 cm/min) cm	ASTM D 113	25	

*Benson Method of Toughness and Tenacity: Scott Tester, N•m (newton meter) (pound foot) at 25 °C (77 °F), 500 millimeters (20 inches) per minute pull. Tension head 22.2-millimeter (0.875-inch) diameter.

**ASTM D 1754, *Standard Test Method for Effects of Heat and Air on Asphaltic Materials (Thin-Film Oven Test)*, may be used, but "rolling thin-film circulating oven" should be the referee method.

A9.2.2.2. Asphalt cement should conform to either ASTM D 946 or ASTM D 3381.

A9.2.3. Additives. Additives should not be incorporated into the mix without prior testing. The use of additives such as antistripping agents, antifoaming agents, and silicone alters the performance of PFC and should be studied prior to use.

A9.2.4. JMF:

A9.2.4.1. The procedures for determining the JMF to be used in the mixtures are described in UFC 3-260-02 and UFC 3-250-03. Proportioning of the aggregates for the JMF should be carefully determined because the gradations will be those on which the tolerances will be applied. Application of these tolerances may cause the gradation to be outside the limits of the gradation in Table A23, but this is acceptable.

A9.2.4.2. The estimated asphalt content (percent by weight of aggregate) to be used in the JMF will be determined by the equation 2.0 Kc + 4.0, where Kc, a surface area constant, is determined by conducting CDT-01 tests on the proposed job aggregates. A mixing temperature to provide an asphalt viscosity of 275±25 square millimeters per second (centistokes) will be determined in accordance with ASTM D 2170, *Standard Test Method for Kinematic Viscosity of Asphalts (Bitumens)*. The formula will indicate the percentage of each stockpile (as based on samples furnished) and mineral filler, the percentage passing each sieve size, the percentage of bitumen, the amount of anti-stripping agent, if needed, and the temperature of the completed mixture when discharged from the mixer. Tolerances are given in Table A25 for bitumen content, temperature, and aggregate grading for tests conducted on the mix as discharged from the mixing plant. Reject bituminous mix that deviates more than 14 °C from JMF. The JMF may be adjusted during construction to improve paving mixtures. Tolerances shown may permit the aggregate gradation to be outside the band specified in Table A23.

Table A25. Job-Mix Tolerance

Material	Tolerance
Aggregate passing 4.75-mm (No. 4) or larger sieves	±4%
Aggregate passing 2.36- and 0.60-mm (No. 8 and No. 30) sieves	±3%
Aggregate passing 0.075 mm (No. 200) sieve	±1%
Bitumen	±0.30%
Temperature of mixing	±14 °C (25 °F)

A9.2.5. Retained Coating. The antistripping agent, when added to the mix, must provide a mixture which will have a retained coating area of at least 95%. The aggregate passing the 10-millimeter sieve and retained on the 6-millimeter sieve should have a retained coating area of at least 95%. When the retained coating area is less than 95%, the aggregate stripping tendencies should be countered by the use of hydrated lime or by treating the bitumen with an approved antistripping agent. The hydrated lime will be considered as mineral filler and will be considered in the gradation requirements. The amount of hydrated lime or antistripping agent added to the bitumen will be determined during development of the JMF and will be sufficient to produce a retained coating area greater than 95%. Use of additional antistripping agent may be directed during progress of the work, if necessary.

A9.3. Construction. The basic requirement is to avoid traffic damage to the PFC. The minimum suggested cure time for PFCs on roads is 12 hours. The time requirements can be shortened, provided that no sharp turning or stopping of the traffic on the PFC is allowed. PFCs on airfield pavement require an absolute minimum of 2 days to cure sufficiently to be able to satisfactorily handle carefully controlled aircraft traffic. Short or locked wheel turns should never be permitted on the PFC.

Note: See paragraph A6.3.

A9.4. QC Testing.

A9.4.1. Minimum extent of testing and inspection should be as follows:

A9.4.1.1. Quality and gradation tests should be made on samples of aggregate as it is delivered to the site, at least one for every 2250 metric tons (2500 tons) of each size of aggregate.

A9.4.1.2. Gradation test should be made on samples of aggregate from the cold feed, at least one for every 225 metric tons (250 tons) of each size of aggregate.

A9.4.1.3. Depth of uncompacted bituminous courses should be tested with a probe, immediately behind the paver and at least once for every 15 meters (50 feet) of lane.

A9.4.1.4. Check and recalibrate scales, other measuring devices, and batching or proportioning equipment prior to starting production, and at least once every 4500 metric tons (5000 tons) of PFC produced.

A9.4.2. Smoothness measurements will be made perpendicular to and across all joints at equal distances along the joint, not to exceed 8 meters. The location and amount of deviation from straightedge for all measurements will be recorded. Any joint or mat-area-surface deviation which exceeds the tolerance by more than 50% should be corrected to meet the specification requirements.

Table A26. Surface Smoothness Tolerance

Pavement Category	Direction of Testing	PFC Course Tolerance
Runways and taxiways	Longitudinal	3 mm (0.125 in)
	Transverse	6 mm (0.25 in)
Roads	Longitudinal	6 mm (0.25 in)
	Transverse	6 mm (0.25 in)

A9.4.3. Final compacted thickness of the PFC will be determined by core holes (100 millimeters in diameter), drilled in a random fashion, with a minimum of one test per each day's production. Fill all core holes with hot PFC mixture and compact. When the measurement of any core indicates that the pavement is deficient in thickness by more than 3 millimeters, additional cores should be drilled parallel to the centerline of the lane at 8-meter intervals on each side of the deficient core until the cores indicate that the deficiency in thickness is 3 millimeters or less. The pavement area determined to be deficient in thickness should be removed and replaced.

A9.5. Additional References:

- ASTM C 127, *Specific Gravity and Absorption of Coarse Aggregate*
- ASTM C 128, *Specific Gravity and Absorption of Fine Aggregate*
- ASTM C 174/C 174M, *Measuring Length of Drilled Concrete Cores*
- ASTM C 183, *Sampling and the Amount of Testing of Hydraulic Cement*
- ASTM D 1250, *Petroleum Measurement Tables*
- ASTM D 2216, *Laboratory Determination of Water (Moisture) Content of Soil and Rock*
- California Department of Transportation (CDT) 01, *Standard Method of Test for Centrifuge Kerosene Equivalent and Approximate Bitumen Ratio*

PORTLAND-CEMENT-STABILIZED SURFACE

A10.1. General.

A10.1.1. Definition. Portland-cement-stabilized surface, base, or subbase course, as used herein, is a mixture of Portland cement and in-place, or select borrow, material uniformly blended and thoroughly compacted to produce a pavement course which meets the criteria set forth in the drawings and specifications.

A10.1.2. Weather Limitations. Cement should not be applied when the atmospheric temperature is less than 5 °C. Cement should not be applied to soils that are frozen or contain frost, or when the underlying material is frozen. If the temperature falls below 2 °C, completed cement-treated areas should be protected against detrimental effects of freezing.

A10.2. Material.

A10.2.1. Material to be Stabilized. The material to be stabilized should consist of in-place material. Stones retained on a 50-millimeter sieve and deleterious substances such as sticks, debris, and organic matter should be removed.

A10.2.2. Water. Water should be clean, fresh, and free from injurious amounts of oil, acid, salt, alkali, organic matter, and other substances deleterious to the hardening of soil-cement

A10.2.3. Burlap. Burlap should conform to AASHTO M 182, *Burlap Cloth Made From Jute or Kenaf*.

A10.2.4. Impervious Sheeting. Sheeting should conform to ASTM C 171, *Standard Specification for Sheet Materials for Curing Concrete*, and should be white waterproof paper, white opaque polyethylene film, or white burlap-polyethylene sheets.

A10.3. Mix Design.

A10.3.1. Refer to AFJMAN 32-1019, *Soil Stabilization for Pavements*, and UFC 3-260-02 for further guidance on restrictions or requirements added to the mix design paragraph, and information on applicability of stabilization with Portland cement.

A10.3.2. Mix should be developed using the aggregate or soil-aggregate material to be stabilized. Mix should have a minimum compressive strength of 5 megapascals (750 psi) for base.

A10.3.3. For the project's mix design, perform laboratory tests to determine the minimum amount of cement required to achieve compressive strength of 5 megapascals.

A10.4. Initial Sampling and Testing for Mix Design.

A10.4.1. Laboratory Density. Moisture-density tests should be conducted in accordance with the procedure contained in AASHTO T 134, *Moisture Density of Soil Cement*, or ASTM D 558, *Standard Test Methods for Moisture-Density Relations of Soil-Cement Mixtures*; however, the apparatus and procedures outlined in ASTM D 1557 should be used to compact the soil-cement mixture.

A10.4.2. Unconfined Compression Testing. Unconfined compression tests should be conducted in accordance with ASTM D 1633. Three tests should be conducted for each mix design tested. Samples should be cured at a constant moisture content and temperature for seven days.

A10.4.3. Sieve Analysis. A minimum of one analysis should be performed for each 907 metric tons (1000 tons) of material to be stabilized, with a minimum of three analyses for each day's run until the course is completed. When the source of materials is changed and/or deficiencies are found, the analysis should be repeated and/or the material already placed should be retested to determine the extent of unacceptable material. All in-place unacceptable material should be replaced.

A10.5. Construction.

A10.5.1. General Requirements. Cement should not be applied if the soil moisture content exceeds optimum moisture content specified for the cement-treated mixture. After mixing is completed, the proportions of the mixture should be in accordance with the approved mix design. When application of water and mixing are completed, on the basis of dry weight, moisture should not be below the optimum moisture content of the mixture, nor should it be more than 2% above the optimum moisture content. When the stabilized course is constructed in more than one layer, the previously constructed layer should be cleaned of loose and foreign matter by sweeping with power sweepers or power brooms, except that hand brooms may be used in areas where power cleaning is not practicable. Adequate drainage should be provided during the entire construction period to prevent water from collecting or standing on the areas to be stabilized, or on pulverized, mixed, or partially mixed material. Line and grade stakes should be provided as necessary for control. Grade stakes should be placed in lines parallel to the centerline of the area under construction and suitably spaced for string lining.

A10.5.2. Preparation of Area to be Stabilized. Area to be stabilized should be cleaned of debris, and should be inspected for adequate compaction; and should be capable of withstanding, without displacement, the compaction specified for the soil-cement mixture. Debris and removed unsatisfactory in-place material should be disposed of as specified.

Note: The subgrade should be exposed in order to compact the top 152 millimeters to provide a surface for compacting the surface course against. If the stabilized section is going to be placed on the existing surface, the existing surface must be adequate for supporting the stabilized layer. If the material to be stabilized is the existing surface material, it should be removed so the underlying layer can be compacted.

A10.5.3. In-place Material to be Stabilized. The entire area to be stabilized should be graded and shaped to conform to the lines, grades, and cross sections shown in the plans, prior to being processed. Soft or yielding areas should be made stable before construction is begun.

Note: The depth of material to be removed from the surface, the material to be stabilized, is the total thickness of the stabilized section plus 10% for waste and compaction.

A10.5.4. In-place Materials to Receive Stabilized Course. Soft, yielding areas and ruts or other irregularities in the surface should be corrected. Material in the affected areas should be loosened and unsatisfactory material removed. Approved select material should be added where directed. The area should then be shaped to line, grade, and cross section, and should be compacted to the specified density.

A10.5.5. Select Material. Sufficient select material should be used to provide the required thickness of the soil-cement layer after compaction and should be processed to meet the requirements specified before cement stabilization is undertaken.

A10.6. Installation.

A10.6.1. Edges of Stabilized Course. Approved material should be placed along the edges of the stabilized course in such quantity as will compact to the thickness of the course being constructed, or to the thickness of each layer in a multiple-layer course, allowing at least a 300-millimeter width of the shoulder to be rolled and compacted simultaneously with the rolling and compacting of each layer of the stabilized course.

A10.6.2. Scarifying and Pulverizing Soil. Prior to the application of cement, the soil should be scarified and pulverized. Scarification should be carefully controlled so that the layer beneath the layer to be stabilized is not disturbed. Depth of pulverizing should not exceed the depth of scarification. Unless otherwise permitted, the area scarified and pulverized should not exceed the area that can be completed in two working days.

A10.6.3. Application of Cement. Pulverized material should be shaped approximately to the cross section indicated. Cement should be applied so that when uniformly mixed with the soil, the specified cement content is obtained, and a sufficient quantity of cement-treated soil is produced to construct a compacted cement-treated course conforming to the lines, grades, and cross section indicated. Equipment, except that used in spreading and mixing operations, should not pass over the freshly spread soil cement.

A10.6.4. Dry Mixing. Immediately after the cement has been distributed, it should be mixed with the soil. The cement should not be mixed below the required depth. Mixing should continue until the cement has been sufficiently blended with the soil to prevent the formation of cement balls when water is applied.

A10.6.5. Water Application and Moist Mixing. Moisture content of the mixture should be determined immediately after completion of mixing the soil and cement. Water-supply and pressure-distributing equipment should be provided that will permit the continuous application within three hours of all water required on the section being processed. Water should be incorporated in the mix so that concentration of water near the surface does not occur. After all the mixing water has been added, mixing should be continued until the water is uniformly distributed throughout the full depth of the mixture, with no portion of the mixture remaining undisturbed during mixing for more than 30 minutes. Any portion of the mixture remaining undisturbed more than 30 minutes during mixing should be disposed of as specified. Satisfactory moisture distribution should occur along the edges of the section.

A10.6.6. Layer Thickness.

A10.6.6.1. Compacted thickness of the stabilized course should be 150 millimeters. No layer should be in excess of 175 millimeters (7 inches) nor less than 125 millimeters (5 inches) in compacted thickness.

A10.6.6.2. Following compaction of the subgrade, the first lift of material to be stabilized should be placed at proper grade and elevation, plus approximately 10 to 25% of the final design thickness. This additional thickness is to provide for a reduction in thickness after compaction. During construction, the amount of reduction in thickness should be monitored so that pre-compaction layer thickness can be adjusted to result in the final desired thickness. The grades should not change significantly after the addition of the stabilizing agent. Ensuring the proper grades and elevations before introduction of the stabilizing agent will limit the amount of grading adjustment. If grade adjustments are required and thin layers are built into the stabilized course, these thin layers may delaminate and result in early failure of the stabilized section. In addition, the reworking of the surface of the stabilized layer following the addition of cement and compaction of the layer will disturb the hydration process, resulting in a reduction of strength and a subsequent reduction in performance.

A10.6.7. Compaction.

A10.6.7.1. Stabilized Course. Density is based on the material being stabilized. Before compaction operations are started, and, as a continuation of the mixing operation, the mixture should be thoroughly loosened to the full depth. At the beginning of compaction, at least 80% of the soil should pass a 4.75-millimeter (No. 4) sieve, and

100% should pass the 25-millimeter sieve. Compaction should be started immediately after mixing is completed. The concrete stabilized material should be compacted as soon as possible after addition of the cement. In no case should the compaction be completed more than four hours after the initial introduction of the cement to the material to be stabilized. Density of compacted soil-cement mixture should be at least 100% of the maximum density obtained from the laboratory prepared samples. Loose mixture should be uniformly and continuously compacted until the entire depth and width of the area are compacted to the density specified. The moisture content at the surface should be maintained near optimum at all times through the rolling, but should be less than that quantity which will cause the soil-cement mixture to become unstable during compaction. Rolling should begin at the outside edge of the surface and proceed to the center, overlapping on successive trips at least one-half the width of the roller. Alternate trips of the roller should be slightly different lengths. Displacement of the mixture should not occur due to the speed of the roller. Areas inaccessible to rollers should be compacted with mechanical tampers.

A10.6.7.2. Subgrade. As necessary, the subgrade should be exposed and compacted with a sheep foot roller or a large (preferably a 36-metric-ton [40-ton]) rubber-tired roller. Any soft, shoving, or yielding areas of the subgrade should be removed and replaced with select fill. The select fill should be compacted similarly to the existing subgrade material that did not yield.

A10.6.8. Finishing. The surface should be moistened, if necessary, and shaped to the required lines, grades, and cross section. If necessary, the surface should be lightly scarified to eliminate any imprints made by the compacting or shaping equipment. The surface should then be thoroughly compacted to the specified density with rubber-tired rollers and smooth-wheel tandem rollers to the extent necessary to provide a smooth, dense, uniform surface that is free of surface checking, ridges, or loose material, and that conforms to the crown, grade, and line indicated. These finishing operations should be completed within two hours after completion of mixing operations. In places not accessible to finishing and shaping equipment, the mixtures should be compacted with mechanical tampers to the density specified and should be shaped and finished by hand methods. Any portion of the compacted mix that has density less than that specified, that has not properly hardened, or that is improperly finished should be corrected.

A10.6.9. Construction Joints. At the end of each day's construction, a straight transverse construction joint should be formed by cutting back into the completed work to form a true vertical face free of loose or shattered material. Material along construction joints not properly compacted should be removed and replaced with soil-cement that is mixed, moistened, and compacted as specified.

A10.6.10. Curing and Protection. The finished surface should be protected against rapid drying for seven days by one of the following methods:

A10.6.10.1. Moist Curing.

A10.6.10.1.1. A 50-millimeter covering of soil, or not less than 2.2 kilograms per square meter (4 pounds per square yard) of straw, should be applied. The material should be moistened initially and kept moistened throughout the curing period. In multiple-layer construction, the soil used in moist curing, if of approved select material, may be used for constructing the succeeding stabilized course.

A10.6.10.1.2. Following final grading and compaction, the surface should be moist-cured for a minimum of seven days (preferably 28 days). Curing compounds or asphalt are not recommended for curing since these products become foreign object debris (FOD) when an aircraft starts operating on the surface.

A10.6.10.2. Burlap. Burlap covers should consist of two or more layers of burlap having a combined weight of 400 grams (14 ounces) or more per square meter in a dry condition. Burlap should be either new or should have been used only for curing concrete. Burlap strips should have a length, after shrinkage, at least 300 millimeters greater than necessary to cover the entire width and edges of the finished stabilized area. Mats should overlap each other at least 150 millimeters. Mats should be thoroughly wetted before placing and should be kept continuously wet and in contact with the surface and edges of the finished stabilized area for the entire curing period.

A10.6.10.3. Impervious Sheeting. The surface of the finished stabilized area should be moistened with a fine spray of water and then covered with impervious sheeting. The burlap of the polyethylene-coated burlap should be thoroughly saturated with water before placing. Sheeting should be placed with the light-colored side up. Sheets should extend over the edges of the stabilized area and should be held securely in place throughout the curing period. Edges of sheets should overlap each other at least 300 millimeters and should be securely cemented or taped to form continuous closed joints. Tears and holes in sheets should be repaired immediately.

A10.6.11. Maintenance. The stabilized area should be maintained in a satisfactory condition until the completed work is accepted. Maintenance should include immediate repairs to any defects and should be repeated as often as necessary to keep the area intact.

A10.6.12. Traffic. Completed portions of the cement-treated soil area may be opened immediately to light traffic provided the curing is not impaired. After the curing period has elapsed, completed areas may be opened to all traffic provided that the cement-stabilized course has hardened sufficiently to prevent marring or distorting of the surface by equipment or traffic. Heavy equipment will not be permitted on the area during the curing period. Cement and water may be hauled over the area with pneumatic-tired equipment as approved. Finished portions of cement-stabilized soil that are traveled on by equipment used in constructing an adjoining section should be protected in a manner that prevents equipment from marring or damaging the completed work.

A10.6.13. Disposal of Unsatisfactory Materials. Remove in-place materials that are unsuitable for stabilization. Material that is removed for the required correction of defective areas, waste material, and debris should be disposed of.

A10.7. QC Testing.

A10.7.1. Grade Control. Underlying material should be excavated to sufficient depth for the required stabilized-course thickness. The finished stabilized course with the subsequent surface course should meet the fixed grade. Finished and completed stabilized area should conform to the lines, grades, cross section, and dimensions indicated.

A10.7.2. Smoothness Test. The surface of a stabilized layer should show no deviations in excess of 10 millimeters when tested with the straightedge. Deviations exceeding this amount should be corrected by removing material and with replacing new material, or by reworking existing material and compacting. Measurements for deviation from grade and cross section shown should be taken in successive positions parallel to the runway centerline with a straightedge. Measurements should also be taken perpendicular to the runway centerline at 15-meter intervals.

A10.7.3. Thickness Control. The completed thickness of the stabilized course should be within 25 millimeters of the thickness indicated. Where the measured thickness is deficient by more than 25 millimeters, such areas should be corrected by scarifying, adding mixture of proper gradation, reblading, and recompacting. Where the measured thickness is more than 25 millimeters thicker than indicated, the course should be considered as conforming with the specified thickness requirements. Average job thickness should be the average of all thickness measurements taken for the job, but should be within 13 millimeters of the thickness indicated. The thickness of the stabilized course should be measured at intervals which ensure one measurement for each 4100 square meters (5000 square yards) of stabilized course. Measurements should be made in 75-millimeter-diameter test holes penetrating the stabilized course.

A10.7.4. Field Density.

A10.7.4.1. Field density tests should be performed in accordance with ASTM D 1556 or ASTM D 2922. ASTM D 2922 results in a wet unit weight of soil, and when using this method, ASTM D 3017 should be used to determine the moisture content of the soil. Calibration curves furnished along with the density gauge should be checked as described in ASTM D 3017. Calibration checks of the density gauge should be made at the beginning of a job on each type of material encountered. If ASTM D 2922 is used, in-place densities should be checked by ASTM D 1556 at least once per lift for each 4000 square meters of stabilized material. Calibration curves and calibration test results should be furnished within 24 hours of conclusion of the tests. At least one field density test should be performed for each 4000 square meters of each layer of base material.

A10.7.4.2. Test cylinders should be made during construction, or core samples should be taken to check strength gain. When the cores/test cylinders reach the design strength, limited traffic may begin. The airfield should be fully capable within approximately 28 days of construction of the final lift of the cement-stabilized layer. The recommended minimum design strength for the cement-stabilized soil is 5 megapascals.

A10.7.5. Sieve Analysis. A minimum of one analysis should be performed for each 1000 metric tons of material to be stabilized, with a minimum of three analyses for each day's run until the course is completed. When the source of materials is changed and/or deficiencies are found, the analysis should be repeated and/or the material already placed should be retested to determine the extent of unacceptable material. All in-place unacceptable material should be replaced.

PAVEMENT MARKING REQUIREMENTS

A11.1. General. This specification covers the requirements for pavement marking.

A11.2. Materials.

A11.2.1. Paint. Paint will conform to FS TT-P-1952*, Paint, Traffic and Airfield Marking, Water Emulsion Base*, color as indicated on the drawings, be homogeneous, and show no hard settlement or other objectionable characteristics.

A11.2.2. Reflective Media. Reflective media will conform to FS TT-B-1325, *Beads (Glass Sphere) Retroreflective*, Type I, Gradation A.

A11.3. Construction.

A11.3.1. Surface Preparation. Surfaces to be marked should be thoroughly cleaned and free of dust, dirt, or water. For rigid pavements requiring painting, a pretreatment with an aqueous solution containing 3% phosphoric acid and 2% zinc chloride should be applied to areas to be painted prior to applying the paint. Paint should not be applied to Portland cement concrete pavement until the concrete in the areas to be painted is clean of curing material. Paint should not be applied to asphaltic surfaces until the surface is allowed to cure. For 50 to 100 millimeters of asphaltic surface course, wait 72 hours before applying paint.

A11.3.2. Paint Application. Paint should be applied to clean dry surfaces and only when the air and pavement temperatures are at least 5 °C, and not more than 35 °C (95 °F), and when the weather is not foggy or windy.

A11.3.3. Reflective Media. Reflective media should be applied directly to the wet paint immediately after applying the paint.

A11.3.4. Rate of Application. Paint should be applied at the rate of 9.7±0.5 square meters per 3.8 liters (105±5 square feet per gallon), and reflective media at the rate of 0.2 kilogram of media per 3.8 liters (0.5 pound of media per gallon) of paint.

A11.4. QC Testing.

A11.4.1. Application rates should be checked at the start of the job and verified by QA. Paint and media containers should be examined for signs of age, separation, or damage. Surface preparation should be approved by QA before paint is placed.

A11.4.2. The edges of the markings should not vary from a straight line more than 12 millimeters in 15 meters, and the dimensions should be within a tolerance of ±5%.

A11.4.3. Check the rate of application of both paint and reflective media throughout construction.

PAVEMENT RECLAMATION

A12.1. General. This specification covers the requirements for preparation of a rehabilitated subbase course. The work consists of pulverizing and mixing in place the existing pavement, to a depth as indicated by the pavement design, and compaction to final grades and dimensions as indicated on the plans. Any excess material may be removed or stockpiled and reused in other areas.

A12.2. Materials The material should be pulverized to a gradation of 100% passing the 89-millimeter (3.5-inch) sieve and 50 to 100% passing the 19-millimeter sieve. Other paragraphs in this attachment detail compaction requirements. The material produced as a result of coldmilling (paragraph A12.3.2.2) may be spread uniformly over the area to be reclaimed by the process outlined here, and incorporated into the pulverizing of the pavement area.

A12.3. Construction.

A12.3.1. Sawed Butt Joints. Saw the existing pavement to a depth shown on the plans at the limits of work to prepare a sawed construction joint for butt joints of new bituminous concrete pavement. Do not use pneumatic pavement breakers as they will damage the remaining pavement.

A12.3.2. Equipment.

A12.3.2.1. The equipment to be used must have an established capability of crushing/pulverizing/mixing bituminous concrete pavements to produce a crushed and blended material which conforms to the gradation specified herein. In addition, the equipment must have an established record of being capable of producing the crushed/pulverized/mixed material at a rate of production consistent with the time allowed for the project. The equipment must have the capability to adjust the crushers, grinders and/or screens to allow minor adjustments if the gradation of the crushed material does not fall within the gradation requirements during the crushing process.

A12.3.2.2. In general, equipment such as a road planer or coldmilling road machine which is designed to "mill" and/or "shred" the existing bituminous concrete pavement course, rather than crush and fracture (pulverize), is not considered capable of achieving the specified gradation.

A12.3.3. Crushing and Mixing.

A12.3.3.1. After the butt joints have been saw cut, the existing bituminous concrete pavement should be pulverized, and the size of the pieces be as described in paragraph A12.2. All cobbles having a diameter greater than 89 millimeters should be "culled out" and wasted. The existing bituminous concrete pavement and the top of the existing base course material should be crushed/pulverized/mixed together. The total thickness of the existing base course to be mixed with the existing bituminous pavement (if any) should be determined by the pavement design for the project and findings of the exploratory corings made before beginning the project. Typically, up to 200 millimeters of the existing base is pulverized and mixed with the surface bituminous course. Limitations of the equipment may limit the depth of reclamation.

A12.3.3.2. The crushing/pulverizing/mixing should be accomplished by a traveling plant. The material will be crushed until the gradation and uniformity of the mixture is satisfactory to these specifications.

A12.3.3.3. If the material produced by the crushing/pulverizing/mixing operation does not meet the gradation specified, recrush/repulverize, or remove by other methods all oversized pieces of pavement, and furnish material of the gradation which, when blended with existing material, will produce material of the specified gradation.

A12.3.4. Method of Placing. Grade, blade, or otherwise transport to meet the grades as shown on the plans, the crushed/pulverized/mixed material along the sides of the newly reconstructed pavement. Excavate and stockpile the excess pulverized material.

A12.3.5. Compacting.

A12.3.5.1. Thoroughly compact the reclaimed material immediately after completion of the spreading operations and the removal of excess material. The number, type, and weight of rollers should be sufficient to compact the mixture to the required density.

A12.3.5.2. Do not roll a layer when the underlying course is soft or yielding or when the rolling causes undulation in the base course. When rolling develops irregularities that exceed 9.5 millimeters when tested with a 4.8-meter straightedge, loosen the irregular surface, refill with the kind of material used in constructing the course, and roll again as required.

A12.3.6. Finishing Reclaimed.

A12.3.6.1. After watering and rolling the reclaimed material, the entire surface should be scarified to a depth of at least 75 millimeters and shaped to the exact slope and cross section with a blade grader. Re-water and thoroughly roll the scarified material. Continue rolling until the material is bonded and compacted into a dense, unyielding mass, true to grade and cross section. Follow the initial rolling of the surface with the scarifying and rolling by no more than four days. When the material is constructed in two layers, scarify the surface to a depth of 50 millimeters.

A12.3.6.2. In reclamation areas that will receive seeding and mulching, the surface of the reclaimed material should not appear glazed or cemented to the extent that the seeding and mulching will not penetrate properly. In these areas, scarify the surface of the reclaimed material immediately prior to seeding and mulching.

A12.3.7. Protection. Hauling equipment may be routed over completed portions of the reclaimed pavement course, provided no damage results and provided that such equipment is routed over the full width of the base course to avoid rutting or uneven compaction.

A12.3.8. Maintenance. Keep the finished surface of reclamation clean and free from foreign material. Ensure good drainage at all times.

A12.4. QC Testing.

A12.4.1. Field Density. The field density of the compacted material should be at least 90% of the maximum density of laboratory specimens prepared from samples of the reclaimed material. The laboratory specimens should be compacted and tested in accordance with ASTM D 1557. The in-place field density should be determined in accordance with ASTM D 1556, ASTM D 2167, or ASTM D 2922. ASTM D 2922 results in a wet unit weight of soil, and when using this method, ASTM D 3017 should be used to determine the moisture content of the soil. Calibration curves furnished along with the density gauge should be checked as described in ASTM D 3017. Calibration checks of the density gauge should be made at the beginning of a job on each type of material encountered. If ASTM D 2922 is used, in-place densities should be checked by ASTM D 1556 at least once per lift for each 4180 square meters of stabilized material. Calibration curves and calibration test results should be furnished within 24 hours of conclusion of the tests. At least one field density test should be performed for each 4180 square meters of each layer of base material. The moisture content of the material at the start of compaction should not be below, nor more than, 1.5% above the optimum moisture content.

A12.4.2. Surface Test.

A12.4.2.1. After the course has been completely compacted, test the surface for smoothness and accuracy of grade and crown. The finished surface should not vary more than 9.5 millimeters from a 4.8-meter straightedge when applied to the surface parallel with, and at right angles to, the centerline. The finished surface should not vary more than 6 millimeters from the design elevations as shown on the plans. Scarify, reshape, and recompact any portion lacking the required smoothness or failing in accuracy of grade or crown until the required smoothness and accuracy are obtained.

A12.4.2.2. Measure in successive positions parallel to the runway centerline throughout the entire project. Also measure perpendicular to the runway centerline at 15-meter intervals.

A12.4.3. Thickness Control. The completed thickness of the reclaimed pavement should be within 25 millimeters of the thickness indicated on the plans. Where the measured thickness is deficient by more than 25 millimeters, such areas should be corrected by scarifying, adding reclaimed material, reblading, and recompacting. Where the measured thickness is more than 25 millimeters thicker than indicated, the course should be considered as conforming with the specified thickness requirements (unless the area fails the surface test). Average job thickness should be the average of all thickness measurements taken for the job, but should be within 13 millimeters of the thickness indicated. The thickness of the compacted reclaimed material should be measured at intervals which ensure one measurement for each 4180 square meters of material. Measurements should be made in test holes, 76 millimeters in diameter, penetrating the course.

A12.4.4. Sieve Analysis. A minimum of one analysis should be performed for each 900 metric tons of material to be stabilized, with a minimum of three analyses for each day's run until the course is completed. When the source of materials is changed (i.e., additional material from an off-site source is used to augment the volume of reclaimed material) and/or deficiencies are found, the analysis should be repeated and/or the material already placed should be retested to determine the extent of unacceptable material. All in-place unacceptable material should be replaced.

A12.5. Additional References:

- AASHTO T 89, *Liquid Limit*
- AASHTO T 90, *Plastic Limit and Plasticity Index*

BITUMINOUS SEAL COAT - SPRAY APPLICATION

A13.1. General. This specification covers the requirements for bituminous seal coating for roads, parking areas, and other general applications. Refer to UFC 3-250-03.

A13.2. Material.

A13.2.1. Bituminous Material.

A13.2.1.1. Specify the type of bituminous material most suited to the project.

A13.2.1.1.1. Cutback Asphalt. Cutback asphalt grades MC- or RC-800, and MC- or RC-250, in order of preference, are recommended for most normal seal coat applications where a rapid-setting binder providing maximum "hold" of cover aggregate is desired. These grades are also preferred where cooler ambient temperatures, 10 to 26.7 °C (50 to 80 °F) are anticipated. For seal coat applications during periods of high ambient temperatures (>26.7 °C), the preferred cutback asphalt grades would be either MC- or RC-3000.

Note: In some areas of the United States and Europe, cutback has been banned due to environmental concerns. Check local regulations.

A13.2.1.1.2. Emulsified Asphalt. Emulsified asphalt grades RS-1, RS-2, CRS-1, and CRS-2 are suitable for seal coat applications. Emulsions are better suited to coat aggregate when the aggregate moisture content is over 1% but less than 3%. The following considerations should be included in the evaluation of alternate grades to be specified for the project:

A13.2.1.1.2.1. Local practice and experience, as well as availability and cost of various grades within the area.

A13.2.1.1.2.2. The rapid-setting emulsions, particularly the cationic types, are effective when damp aggregates must be used.

A13.2.1.1.2.3. Where cooler temperatures are anticipated, consider the use of CRS-1 and CRS-2 grades.

A13.2.1.1.2.4. Anionic emulsions provide better adhesion to basic aggregates such as limestone, while cationic emulsions are better with acidic aggregates such as silicates.

A13.2.1.1.3. Asphalt Cement Grades. Asphalt cement penetration Grades 120-150 and 200-300, in order of preference, are suitable for most normal seal coat applications. Where cooler temperatures are anticipated, preference should be given to using Grade 200-300.

A13.2.1.1.4. Tar. Tar Grades RT-9 and RT-8 are suitable for most normal seal coat applications. Where cooler temperatures are anticipated, consider the use of grades RT-6 and RT-7. Consider the use of grades RT-10 and RT-11 in very warm climates when work will be performed during periods of high ambient temperature.

A13.2.1.2. Bituminous material will conform to AASHTO M 20, *Penetration Graded Asphalt Cement*, AASHTO M 81, *Rapid Curing Cutback Asphalt*, AASHTO M 82, *Medium Curing Cutback Asphalt*, AASHTO M 226*, Viscosity Graded Asphalt Cement*, or ASTM D 490, *Specification for Road Tar*, ASTM D 946, ASTM D 977, ASTM D 2027, ASTM D 2028, ASTM D 2397, or ASTM D 3381.

A13.2.2. Mineral Aggregate. Table A27 shows various aggregate gradations. Aggregate will consist of crushed stone, crushed gravel, crushed slag, sand, and screenings. The moisture content of the aggregate will be not greater than 1 to 3%, such that the aggregate will readily bond with the bituminous material. Drying may be required. The aggregate will conform to the gradation shown in Table A27. The aggregate gradation will be allowed the tolerances given in Table A28.

Table A27. Aggregate Gradations

Sieve Size	Percent by Weight Passing Square-Mesh Sieves		
	Gradation No. 1	Gradation No. 2	Gradation No. 3
12.5 mm (0.5 in)	100%		
9.5 mm (0.375 in)	85-100%	100%	
4.75 mm (No. 4)	10-30%	85-100%	100%
2.36 mm (No. 8)	0-10%	10-40%	10-40%
1.18 mm (No. 16)	0-5%	0-10%	0-10%
0.30 mm (No. 50)		0-5%	0-5%

Table A28. Aggregate Gradation Tolerances

Material	Tolerances
Aggregate passing the 9.5-mm (0.375-in) sieve and larger sieves	± 5%
Aggregate passing the 4.75-mm (No. 4) sieve and smaller sieves	± 3%

A13.2.3. Coarse Aggregate. Coarse aggregate will consist of clean, sound, durable particles meeting the following requirements:

A13.2.3.1. Film Retention. The aggregate will exhibit at least 95% retention of bituminous film.

A13.2.3.2. Particle Shapes. The quantity of flat and elongated particles on any sieve will not exceed 20% by weight when determined in accordance with ASTM D 4791.

A13.2.3.3. Weight Loss. Weight loss will not exceed 40% after 500 revolutions, as determined in accordance with ASTM C 131.

A13.2.3.4. Friable Particles. The amount of friable particles will not exceed 0.1% of the total weight of aggregate sample when tested in accordance with ASTM C 142, *Standard Test Method for Clay Lumps and Friable Particles in Aggregates*.

A13.2.3.5. Crushed Slag. The dry weight of crushed slag will not be less than 1200 kilograms per cubic meter (75 pounds per cubic foot), as determined in accordance with ASTM C 29/C 29M.

A13.2.3.6. Crushed Aggregate. Crushed aggregate retained on the 4.75-millimeter (No. 4) sieve and each coarser sieve will contain at least 75% by weight of crushed pieces having one or more fractured faces, with the area of each face equal to at least 75% of the smaller midsectional area of the aggregate particle. When two fractures are contiguous, the angle between the planes of fractures will be at least 30° to count as two fractured faces.

A13.2.4. Fine Aggregate. Fine aggregate will consist of clean, sound, durable particles of crushed stone, slag, or gravel. The aggregate will meet its requirements for stripping, abrasion resistance, and percentage of friable particles as specified for coarse aggregate.

A13.3. Construction.

A13.3.1. Equipment.

A13.3.1.1. Bituminous Distributors. The distributor will have pneumatic tires of sufficient size and number to prevent rutting, shoving, or otherwise damaging any part of the pavement structure. The distributor will be designed and equipped to distribute the bituminous material in a uniform double or triple lap at the specified temperature, at readily determined and controlled rates, with an allowable variation from the specified rate of not more than ±5%, and at variable widths. Distributor equipment will include a separate power unit for the bitumen pump, full-circulation spray bars, tachometer, pressure gauges, volume-measuring devices, adequate heaters for heating of materials to the proper application temperature, a thermometer for reading the temperature of tank contents, and a hand-held hose attachment suitable for applying bituminous material manually to areas inaccessible to the distributor. The distributor will be equipped to circulate and agitate the bituminous material during the heating process.

A13.3.1.2. Aggregate Spreader. The aggregate-spreading equipment will be adjustable and capable of uniformly spreading aggregate at the specified rate in a single-pass operation over the surface to be sealed.

A13.3.1.3. Pneumatic-tired Roller. The pneumatic-tired roller will be of sufficient size to seat the cover aggregate into the bituminous material without fracturing the aggregate particles.

A13.3.1.4. Power Brooms and Power Blowers. Power brooms and power blowers will be suitable for cleaning surfaces to which the seal coat is to be applied.

A13.3.1.5. Storage Tanks. Tanks will be capable of heating the bituminous material, under effective and positive control at all times, to the required temperature. Heating will be accomplished by steam coils, hot oil, or electricity. An armored thermometer will be affixed to the tank so that the temperature of the bituminous material may be read at all times.

A13.3.2. Weather Limitations. The seal coat will be applied when the existing surface is dry, and when the weather is not foggy or rainy. The seal coat will not be applied when the atmospheric temperature is below 15 °C (60 °F) in the shade, when the pavement surface temperature is below 10 °C, or when the wind velocity will prevent the uniform application of the bitumen or aggregates.

A13.3.3. Preparation of Surface. Prior to applying the seal coat, damaged pavement will be repaired and cracks filled. Immediately before applying the seal coat, all loose material, dirt, clay, or other objectionable material will be removed from the surface to be sealed. Material removed from the surface will not be mixed with the cover aggregate.

A13.3.4. Bituminous Material Application. The bituminous material will be spread in the quantities shown in Table A29. The exact quantities within the range specified may be varied to suit field conditions.

Table A29. Application of Material

Gradation No.	Quantities Per Square Meter (Square Yard)	
	Bitumen	Aggregate
1	0.60-0.90 L (0.15-0.20 gal)	8-10 kg (15-20 lb)
2	0.45-0.60 L (0.10-0.15 gal)	5-8 kg (10-15 lb)
3	0.45-0.60 L (0.10-0.15 gal)	5-8 kg (10-15 lb)

A13.3.4.1. Temperature. Asphalt application temperature will provide an application viscosity between 10 and 60 seconds, Saybolt Furol, or between 20 and 120 square millimeters per second (20 and 120 centistokes), kinematic. If tar is used, tar application temperature will be within the following ranges:

- RT-6: 26-65 °C (80-150 °F)
- RT-7: 65-107 °C (150-225 °F)
- RT-8: 65-107 °C
- RT-9: 65-107 °C
- RT-10: 52-120 °C (125-250 °F)
- RT-11: 52-120 °C

A13.3.4.2. Application of Bituminous Material. Following the preparation and inspection of the pavement surface, the seal coat material will be applied at the specified rates. The bituminous material will be uniformly applied in a single pass of the distributor and with either a double or triple lap spray over the surface to be sealed. Building paper will be spread on the surface for a sufficient distance back from the ends of each application so that flow through the spray bar may be started and stopped on the paper and all sprays will be operating at the proper pressure on the surface to be sealed. Immediately after the application, the building paper will be removed. Spots missed by the distributor will be properly treated with bituminous material. No smoking, fires, or flames other than the heaters that are a part of the equipment will be permitted within 8 meters of heating, distributing, and transferring operations of bituminous material other than bituminous emulsions. If tar is used, a full-face organic vapor-type respirator and protective creams will be used by personnel exposed to fumes. Protective creams will not be used as a substitute for cover clothing.

A13.3.5. Aggregate Application.

A13.3.5.1. The aggregate will be spread in the quantities shown in Table A29. The exact quantities within the range specified may be varied to suit field conditions. The aggregate weights shown in Table A29 are those of aggregate having a specific gravity of 2.65. If the specific gravity of the aggregate to be used is less than 2.55 or greater than 2.75, adjustments will be made in the number of kilograms (pounds) of aggregate required per square meter (square yard) to ensure a constant volume of aggregate per square meter (square yard) of treatment.

A13.3.5.2. The specified quantity of cover aggregate will be spread uniformly over the bituminous material. Before the bituminous material is applied, sufficient aggregate to cover the distributor load of bituminous material will be on trucks at the site of the work. No bituminous material will be down more than three minutes before it is covered with aggregate. Spreading will be done uniformly with aggregate-spreading equipment. Trucks spreading aggregate will be operated backwards, covering the bituminous material ahead of the truck wheels. Areas having insufficient cover will be lightly recovered with additional aggregate by hand during the operations whenever necessary.

A13.3.6. Rolling and Brooming. Immediately following the application of cover aggregate, rolling operations will begin. Rolling will be accomplished with pneumatic-tired rollers. The rollers will be operated at a speed that will not displace the aggregate. Rolling will continue until the aggregate is uniformly distributed and keyed into the bituminous material. All surplus aggregate will be swept off the surface and removed not less than 24 hours, nor more than four days, after rolling is completed.

A13.3.7. Traffic Control. Protect freshly placed seal coats from damage by traffic.

A13.4. QC Testing. Field tests will be performed in sufficient numbers to assure that the specifications are being met. Testing will be performed by an approved commercial laboratory. The following number of tests, if performed at the appropriate time, are considered to be the minimum acceptable for each type of operation:

A13.4.1. Aggregates. Initial tests for determining the suitability of aggregate will include: gradation in accordance with ASTM C 136; abrasion resistance in accordance with ASTM C 131; clay lumps and friable particles in accordance with ASTM C 142; unit weight and voids in accordance with ASTM C 29/C 29M; and flat and elongated particles in accordance with ASTM D 4791. Aggregate samples for laboratory tests will be taken in accordance with ASTM D 75.

A13.4.1.1. Gradation. Gradation tests will be performed in accordance with ASTM C 136. A minimum of three gradations for each day's run will be performed. When the source of materials is changed or deficiencies are found, the gradation will be repeated and the material already placed will be retested to determine the extent of the unacceptable material. All in-place unacceptable material will be replaced.

A13.4.1.2. Abrasion Resistance. Abrasion resistance tests will be performed in accordance with ASTM C 131. One test will be performed for every 1000 cubic meters of aggregate placed.

A13.4.2. Bituminous Material. Samples of bituminous material will be taken in accordance with AASHTO T 40, *Sampling Bituminous Materials*, or ASTM D 140.

A13.4.2.1. Initial Tests. Calibration of the bituminous distributor will be in accordance with ASTM D 2995, *Standard Practice for Determining Application Rate of Bituminous Distributors*. Prior to applying the seal coat, a test section at least 30 meters (100 feet) long by 6 meters (20 feet) wide will be placed using the materials chosen for the project. The materials will be placed and rolled in accordance with the specified requirements. Tests will be made to determine the application rates of the bitumen and aggregate. If the test indicates that the seal coat test section does not conform to the specification requirements, necessary adjustments to the application equipment and to the spreading and rolling procedures will be made, and additional test sections will be constructed for conformance to the specifications. Where test sections do not conform to specification requirements, remove the seal coat.

A13.4.2.2. Sampling and Testing During Construction. There is no standard minimum sampling frequency for bituminous materials. Perform sufficient tests to ensure the consistency of the material for the duration of construction.

A13.5. Additional References:

- ASTM D 633, *Volume Correction Table for Road Tar*
- ASTM D 1250, *Petroleum Measurement Tables*

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