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

11 MAR 2009

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

SUBJECT: **Engineering Technical Letter** (**ETL) 09-2: Contingency Airfield Pavement Specifications**

1. Purpose. This ETL provides specifications for construction of contingency airfields. **This ETL supersedes ETL 01-6, *Contingency Airfield Pavement Specifications,* 12 June 2001.**

2. Application. Requirements of this ETL are voluntary but are 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. Intended Users:
- 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:
- Engineering Technical Letter (ETL) 97-2, *Maintenance and Repair of Rigid Airfield Pavement Surfaces, Joints, and Cracks*, with Change 1
- ETL 97-5, *Proportioning Concrete Mixtures with Graded Aggregates for Rigid Airfield Pavements*, with Change 1
- ETL 04-2, *Standard Airfield Pavement Marking Schemes*, with Change 1
- ETL 07-8, *Spall Repair of Portland Cement Concrete (PCC) Airfield Pavements in Expeditionary Environments*
- ETL 08-2, *Testing Protocol for Rigid Spall Repair Materials*
- ETL 08-4, *Testing Protocol for Polymeric Spall Repair Materials*

All are available at http://www.wbdg.org/ccb/.

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

- AASHTO M 81, *Standard Specification for Cutback Asphalt (Rapid-Curing Type)*
- AASHTO M 82, *Standard Specification for Cutback Asphalt (Medium-Curing Type)*
- AASHTO M 147, *Standard Specification for Materials for Aggregate and Soil-Aggregate Subbase, Base, and Surface Courses*
- AASHTO M 182, *Standard Specification for Burlap Cloth Made From Jute or Kenaf and Cotton Mats*
- AASHTO M 320, *Standard Specification for Performance-Graded Asphalt Binder*
- AASHTO T 40, *Standard Method of Test for Sampling Bituminous Materials*
- AASHTO T 89, *Standard Method of Test for Determining the Liquid Limit of Soils*
- AASHTO T 90, *Standard Method of Test for Determining the Plastic Limit and Plasticity Index of Soils*
- AASHTO T 102, *Standard Method of Test for Spot Test of Asphaltic Materials*
- AASHTO T 134, *Standard Method of Test for Moisture-Density Relations of Soil-Cement Mixtures*
- AASHTO T 135, *Standard Method of Test for Wetting-and-Drying Test of Compacted Soil-Cement Mixtures*
- AASHTO T 136, *Standard Method of Test for Freezing-and-Thawing Tests of Compacted Soil-Cement Mixtures*
- AASHTO T 245, *Standard Method of Test for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus*

All are available at http://www.transportation.org/.

3.3. American Concrete Institute (ACI):

- ACI 211.1, *Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete*
- ACI 301, *Specifications for Structural Concrete*
- ACI 305.1, *Specification for Hot Weather Concreting*

All are available at http://www.concrete.org/bookstore/bookstore.htm.

3.4. Asphalt Institute (AI):

- AI MS-2, *Mix Design Methods*, available at http://www.asphaltinstitute.org/

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 and Plain Carbon-Steel Bars 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, Packaging, 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 94/C 94M, *Standard Specification for Ready-Mixed Concrete*
- ASTM C 117, *Standard Test Method for Materials Finer Than 75 µm (No. 200) Sieve in Mineral Aggregates by Washing*
- ASTM C 123, *Standard Test Method for Lightweight Particles in 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/C 173M, *Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method*
- 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 469, *Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression*
- ASTM C 494/C 494M, *Standard Specification for Chemical Admixtures for Concrete*
- ASTM C 509, *Standard Specification for Elastomeric Cellular Preformed Gasket and Sealing Material*
- ASTM C 531, *Standard Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings, and Polymer Concretes*

- ASTM C 566, *Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying*
- ASTM C 595, *Standard Specification for Blended Hydraulic Cements*
- ASTM C 618, *Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete*
- ASTM C 666/C 666M, *Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing*
- ASTM C 685/C 685M, *Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing*
- ASTM C 881/C 881M, *Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete*
- ASTM C 882/C 882M, *Standard Test Method for Bond Strength of Epoxy-Resin Systems Used with Concrete by Slant Shear*
- ASTM C 977, *Standard Specification for Quicklime and Hydrated Lime for Soil Stabilization*
- ASTM C 989, *Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars*
- ASTM C 1059/C 1059M, *Standard Specification for Latex Agents for Bonding Fresh to Hardened Concrete*
- ASTM C 1240, *Standard Specification for Silica Fume Used in Cementitious Mixtures*
- ASTM C 1252, *Standard Test Methods for Uncompacted Void Content of Fine Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading)*
- ASTM C 1260, *Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)*
- ASTM C 1567, *Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)*
- ASTM C 1581, *Standard Test Method for Determining Age at Cracking and Induced Tensile Stress Characteristics of Mortar and Concrete under Restrained Shrinkage*
- ASTM C 1602/C 1602M, *Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete*
- ASTM D 5, *Standard Test Method for Penetration of Bituminous Materials*
- ASTM D 75, *Standard Practice for Sampling Aggregates*
- ASTM D 140, *Standard Practice for Sampling Bituminous Materials*
- ASTM D 242, *Standard Specification for Mineral Filler for Bituminous Paving Mixtures*
- ASTM D 422, *Standard Test Method for Particle-Size Analysis of Soils*
- ASTM D 490, *Standard Specification for Road Tar*
- ASTM D 558, *Standard Test Methods for Moisture-Density (Unit Weight) 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, *Standard Volume Correction Table for Road Tar*
- ASTM D 698, *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))*
- ASTM D 789, *Standard Test Methods for Determination of Solution Viscosities of Polyamide (PA)*
- 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 1241, *Standard Specification for Materials for Soil-Aggregate Subbase, Base, and Surface Courses*
- ASTM D 1250, *Standard Guide for Use of the Petroleum Measurement Tables*
- 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-Cone Method*
- ASTM D 1557, *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft–lbf/ft^3 (2,700 kN-m/m^3))*
- ASTM D 1633, *Standard Test Methods for Compressive Strength of Molded Soil-Cement Cylinders*
- ASTM D 1751, *Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)*
- ASTM D 1752, *Standard Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction*
- ASTM D 1856, *Standard Test Method for Recovery of Asphalt from Solution by Abson Method*
- ASTM D 2026, *Standard Specification for Cutback Asphalt (Slow-Curing Type)*
- ASTM D 2027, *Standard Specification for Cutback Asphalt (Medium-Curing Type)*
- ASTM D 2028, *Standard 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 Weight of Soil in Place by the Rubber Balloon Method*
- ASTM D 2172, *Standard Test Method for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures*
- ASTM D 2397, *Standard Specification for Cationic Emulsified Asphalt*
- ASTM D 2419, *Standard Test Method for 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 2995, *Standard Practice for Estimating Application Rate of Bituminous Distributors*
- ASTM D 3381, *Standard Specification for Viscosity-Graded Asphalt Cement for Use in Pavement Construction*
- ASTM D 3665, *Standard 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 4718, *Standard Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles*
- ASTM D 4791, *Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate*
- ASTM D 4867/D 4867M, *Standard Test Method for Effect of Moisture on Asphalt Concrete Paving Mixtures*
- ASTM D 5102, *Standard Test Method for Unconfined Compressive Strength of Compacted Soil-Lime Mixtures*
- ASTM D 5444, *Standard Test Method for Mechanical Size Analysis of Extracted Aggregate*
- ASTM D 5893, *Standard Specification for Cold Applied, Single Component, Chemically Curing Silicone Joint Sealant for Portland Cement Concrete Pavements*
- ASTM D 6307*, Standard Test Method for Asphalt Content of Hot-Mix Asphalt by Ignition Method*
- ASTM D 6690, *Standard Specification for Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavements*
- ASTM D 6938, *Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)*
- ASTM D 7116, *Standard Specification for Joint Sealants, Hot Applied, Jet Fuel Resistant Types, for Portland Cement Concrete Pavements*
- ASTM E 11, *Standard Specification for Wire Cloth and Sieves for Testing Purposes*

All are available at http://www.astm.org/.

3.6. National Ready-Mixed Concrete Association – Concrete Plant Manufacturers Bureau

- NRMCA CPMB 100, *Concrete Plant Standards of the Concrete Plant Manufacturers Bureau*, available at http://www.cpmb.org/about_CPMB.htm.
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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 171, *Standard Test Method for Determining Percentage of Crushed Particles in Aggregate*
- 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*

All are available at http://www.wes.army.mil/SL/MTC/handbook/handbook.htm.

3.8. Federal Specifications (FS):

- FS SS-S-200E, *Sealants, Joint, Two-Component, Jet-Blast Resistant, Cold-Applied, for Portland Cement Concrete Pavement*, with Amendment 2
- FS TT-B-1325C, *Beads (Glass Spheres) Retro-Reflective*, with Notices 1-3
- FS TT-P-1952, *Paint, Traffic and Airfield Marking, Waterborne*, with Notices 1 and 2

All are available at http://www.wbdg.org/ccb/browse_org.php?o=25.

3.9. Unified Facilities Criteria (UFC):

- UFC 3-250-03, *Standard Practice Manual for Flexible Pavements*
- UFC 3-250-04FA, *Standard Practice for Concrete Pavements*
- UFC 3-250-11, *Soil Stabilization for Pavements*
- UFC 3-260-02, *Pavement Design for Airfields*

All are available at http://www.wbdg.org/.

4. Acronyms and Terms:

AASHTO	- American Association of State Highway and Transportation Officials
AC	- asphalt cement
ACI	- American Concrete Institute
AFCESA	- Air Force Civil Engineer Support Agency
AI	- Asphalt Institute
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
COE	- Corps of Engineers
CPMB	- Concrete Plant Manufacturer's Bureau
CU	- coefficient of uniformity
DCP	- dynamic cone penetrometer
DF	- durability factor
ETL	- Engineering Technical Letter
F	- Fahrenheit

FOD	- foreign object debris
FS	- Federal Specification
gal	- gallon
HMA	- hot-mix asphalt
I.D.	- inside diameter
in	- inch
JMF	- job-mix formula
kg	- kilogram
kN	- kilonewton
L	- liter
lb	- pound
lb ft	- pound foot
LL	- liquid limit
PI	- plasticity index
µm	- micrometer
mm	- millimeter
MAJCOM	- major command
N	- newton
NRMCA	- National Ready-Mixed Concrete Association
O.D.	- outside diameter
OGM	- open-graded materials
PCC	- portland cement concrete
QA	- quality assurance
QC	- quality control
RAP	- reclaimed asphalt pavement
RDM	- rapid draining materials
RED HORSE	- Rapid Engineers Deployable - Heavy Operations Repair Squadron Engineers
SM	- square meter
SY	- square yard
SSD	- saturated surface dry
TM	- Technical Manual
TMD	- theoretical maximum density
TSR	- tensile strength ratio
UFGS	- Unified Facilities Guide Specifications
USACE	- U.S. Army Corps of Engineers
VMA	- voids in mineral aggregate
VTM	- voids in total mix
WF	- 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. These specifications were further reorganized and revised in 2008 to align the material requirements with current Unified Facilities Guide Specifications (UFGS) and to add unit price language to each specification.

6. Specifications. Attached are specifications for construction operations on airfields, earthwork, pavement reclamation, lime stabilization, portland cement stabilization, drainage layers, base course, prime and tack coat, asphalt pavement construction and repair, bituminous seal coats, concrete pavement construction and repair, joint sealants, and pavement marking.

7. Contact. Recommendations for improvements to this ETL are encouraged and should be furnished to: HQ AFCESA/CEOA, 139 Barnes Drive, Suite 1, Tyndall AFB, FL 32408-5319, Attention: Pavements Engineer, DSN 523-6439, commercial (850) 283-6439, FAX DSN 523-6219, Internet: AFCESAReachBackCenter@tyndall.af.mil.

LESLIE C. MARTIN, Colonel, USAF
Director, Operations and Programs Support

17 Atchs
1. AF 100, Pay Item Schedule
2. AF 110, Construction Operations on Airfields
3. AF 200, Earthwork
4. AF 210, Pavement Reclamation
5. AF 220, Lime-Stabilized Subgrade
6. AF 230, Portland-Cement-Stabilized Surface, Base, or Subbase
7. AF 240, Drainage Layer
8. AF 250, Base and Subbase Course
9. AF 400, Asphalt Prime and Tack Coat
10. AF 410, Hot-Mix Asphalt (HMA) for Airfields
11. AF 420, Asphalt Pavement Repair
12. AF 430, Bituminous Seal Coat – Spray Application
13. AF 510, Portland Cement Concrete (PCC) for Airfields

14. AF 520, Concrete Pavement Repair
15. AF 600, Field-Molded Joint Sealant for Rigid Pavements
16. AF 610, Airfield Pavement Marking and Removal
17. Distribution List

AF 100
PAY ITEM SCHEDULE

100.1. General. This section includes administrative and procedural requirements for unit prices.

100.2. Definitions.

100.2.1. A unit price is an amount proposed by offerors and stated on the schedule (Table 100-1) as a price per unit of measurement for materials or services. An estimate of the quantities of work to be done and materials to be furnished under these specifications is given in Table 100-1. It is given only as a basis for comparison of proposals and the award of the contract. The Government does not agree expressly or by implication that the actual quantities involved will correspond exactly therewith; nor shall the Contractor plead misunderstanding or deception because of such estimates of quantities, or of the character, location, or other conditions pertaining to the work. Payment to the Contractor will be made only for the actual quantities of work performed or materials furnished according to the plans and specifications.

100.3. Procedures.

100.3.1. Unit prices include all necessary material, plus cost for delivery, installation, insurance, applicable taxes, overhead, and profit. The sum of all extended unit prices in Table 100-1 shall be deemed to include all work described in the contract documents including contract drawings and contract specifications.

100.3.2. Measurement and Payment. Refer to individual sections for work that requires establishment of unit prices. Methods of measurement and payment for unit prices are specified in those sections.

100.3.3. The Government reserves the right to reject the Contractor's measurement of work-in-place that involves use of established unit prices and to have this work measured at the Government’s expense by an independent surveyor acceptable to the Contractor.

100.3.4. List of Unit Prices. A list of unit prices is included at the end of this section. The Contractor shall complete the list and return this section with the bidding documents. Specification sections referenced in the schedule contain requirements for materials described under each unit price.

100.4. Unit Price Schedule.

Table 100-1. Schedule of Unit Prices

Item Number	Description	Estimated Quantity	Unit (SI)	Unit (US)	Unit Price
110-1	Maintenance and Protection of Air Traffic		LS	LS	
110-2	Beam Barricade		EA	EA	
110-3	Bucket Barricade		EA	EA	
110-4	Class A Barricade		EA	EA	
200-1	Bituminous Pavement Removal, [__] Depth		SM	SY	
200-2	PCC Pavement Removal, [__] Depth		SM	SY	
200-3	Unclassified Excavation		CM	CY	
200-4	Embankment		CM	CY	
200-5	Shoulder Adjustment		SM	SY	
210-1	Pavement Reclamation Processing, [__] Depth		SM	SY	
220-1	By-product Lime		MTON	TON	
220-2	Soil Processing, [__] Depth		SM	SY	
230-1	Portland Cement		MTON	TON	
230-2	Soil Processing, [__] Depth		SM	SY	
240-1	Aggregate Drainage Layer		SM	SY	
240-2	Bituminous Stabilized Drainage Layer		SM	SY	
240-3	Cement Stabilized Drainage Layer		SM	SY	
250-1	Aggregate Base Course, [__] Depth		SM	SY	
250-2	Aggregate Base Course		CM	CY	
250-3	Aggregate Base Course		MTON	TON	
250-4	Subbase Course, [__] Depth		SM	SY	
250-5	Subbase Base Course		CM	CY	
250-6	Subbase Base Course		MTON	TON	
400-1	Bituminous Tack Coat		L	GAL	
400-2	Bituminous Prime Coat		L	GAL	
410-1	HMA for Airfields, [__] Depth		SM	SY	
410-2	HMA for Airfields		MTON	TON	
410-3	Bituminous Butt Joint Construction		SM	SY	
420-1	Sand Mix Crack Repair		LM	LF	
420-2	Clean and Seal Bituminous Cracks		LM	LF	
420-3	Bituminous Pavement Milling		SM	SY	
430-1	Bituminous Seal Coat		SM	SY	
430-2	Bituminous Material		L	GAL	
430-3	Aggregate Material		MTON	TON	
510-1	PCC Pavement, [__] Depth		SM	SY	
510-2	PCC Test Batch		LS	LS	
520-1	Partial Depth PCC Spall Repair		SM	SF	
600-1	Remove and Replace Joint Sealant		LM	LF	

Item Number	Description	Estimated Quantity	Unit (SI)	Unit (US)	Unit Price
600-2	Remove, Reface by Sawcut, and Install Joint Sealant		LM	LF	
600-3	Sawcut and Seal Linear Crack		LM	LF	
610-1	Pavement Marking		SM	SF	
610-2	Temporary Pavement Marking		SM	SF	
610-3	Pavement Marking Removal		SM	SF	

100.4.1. Quantity Abbreviations. These abbreviations apply to Table 100-1 and the other specification sections:

LM	linear meter
LF	linear foot
SM	square meter
SF	square feet
SY	square yard
CM	cubic meter
CY	cubic yard
MTON	metric ton (1,000 kilograms)
TON	ton (2,000 pounds)
L	liter
GAL	gallon
EA	each
LS	lump sum

AF 110
CONSTRUCTION OPERATIONS ON AIRFIELDS

110.1. General.

110.1.1. Carry out operations in a manner that will cause minimum interference with air traffic as indicated in the phasing plans, and as shall be required to cooperate with the Government.

110.1.2. Supply barricades and place, maintain, move, and store barricades as indicated in the plans.

110.2. Materials.

110.2.1. Lights and Flags.

110.2.1.1. Furnish and maintain barricades along the edges of the construction area to warn the air and ground traffic to stay clear of the construction work. Place light fixtures as detailed in the plans. Maintain orange warning flags around all equipment, stockpiles, or other areas as directed.

110.2.1.2. Omnidirectional warning lights on beam and bucket barricades shall be steady-burn, omnidirectional, 6 or 12 volt, with red lens.

110.2.1.3. Bidirectional warning lights on Class A barricades shall be steady-burn, bidirectional, 6 or 12 volt, with red lens.

110.2.1.4. Orange warning flags to mark equipment stockpiles or trenches shall be 20 inches by 20 inches square, tacked along a post having a length of 1.5 meters [5 feet] and having a minimum thickness of 25 millimeters [1 inch]. Securely drive posts into the ground or attach to the pavement so that the top of the flag is a minimum 1.2 meters [4 feet] above ground.

110.2.1.5. Ensure that barricade lights and flags are monitored for proper functioning and serviced as needed to maintain visibility.

110.2.2. Barricades.

110.2.2.1. Beam Barricades. Beam barricades shall be as indicated in the drawings. Mark beams with alternating orange and white striping and two battery-operated, steady-burn, omnidirectional red warning lights (see paragraph 110.2.1.2). Mount lights on each end of the beam barricade as indicated. At the completion of the contract, remove beam barricades from the site.

110.2.2.2. Bucket Barricades. Furnish bucket barricades of the type indicated. Mark the paint bucket with alternating orange and white horizontal striping and one battery-operated, steady-burn, omnidirectional red warning light (see paragraph

110.2.1.2) mounted on the top center of each bucket as indicated. At the completion of the contract, remove bucket barricades from the site.

110.2.2.3. Class A Barricades. Furnish Class A barricades of the type indicated. Mark Class A barricades with colors, stripes, and signage patterns as indicated. Mount two battery-operated, steady-burn, red warning lights (see paragraph 110.2.1.3) on the top outer edges of each barricade as indicated. At the completion of the contract, remove Class A barricades from the site.

110.3. Execution.

110.3.1. Control Requirements. The Contractor's responsibility for work areas and marking equipment is as follows:

110.3.1.1. Place nothing upon runways, taxiways, taxilanes, or aprons without written approval of the Government.

110.3.1.2. No vehicle shall enter a paved surface except at predetermined locations.

110.3.1.3. Provide and install barricades, flag lines, and other warning markers as indicated or as directed by the Government.

110.3.1.4. No private vehicles shall be allowed on the runways or taxiways at any time unless approved by the Government.

110.3.1.5. Throughout the duration of the job, immediately rectify any practice or situation that the Government determines to be unsafe or a hindrance to regular airport traffic.

110.3.1.6. The responsibility for controlling the Contractor's employees, subcontractors, and their employees with regard to traffic movement rests with the Contractor.

110.3.1.7. Rebuild, repair, restore, and make good at the Contractor's expense all injuries or damages to any portion of the work occasioned by the Contractor's use of these facilities before completion and acceptance of the Contractor's work.

110.3.1.8. Submit to the Government, in writing, a plan for controlling construction equipment and vehicular movements in the air operations area. This plan shall be submitted before notice to proceed is given. Include material haul roads in the plan.

110.3.1.9. Provide a responsible traffic manager whose duty it shall be to direct all traffic on or near active runways, taxiways, haul roads, and highways. Paved surfaces shall be kept clear and clean at all times and specifically must be kept free from all small stones that might damage aircraft.

110.3.1.10. Furnish a 24-hour emergency contact for maintenance of the barricades and barricade lighting.

110.3.1.11. The control tower shall at all times have control of operations on or near active runways, taxiways, and approach zones. Before entering upon or crossing any runway or taxiway, the Contractor shall receive proper clearance from the control tower. Arrivals and departures of airplanes are under the control of the airport control tower. Emergencies and operating conditions may necessitate sudden changes, both in airport operations and in the operations of the Contractor. Aircraft operations shall always have priority over any and all of the Contractor's operations. If runways or taxiways become required for the use of aircraft or if the control tower or the contracting officer deems the Contractor to be too close to airport areas used by aircraft for safety, the control tower or the Government may, at its discretion, order the Contractor to suspend operations. This may include removing personnel, plant, equipment, and materials to a safe distance and standing by until the runways and taxiways are no longer required for use by aircraft.

110.3.1.12. Where any work is to be done on any operational runway or taxiway, notify the Government sufficiently in advance so that provisions can be made to close the runway or taxiway to aircraft traffic. Such work shall then be prosecuted in the most expeditious manner practicable so that the runway or taxiway can be reopened to air traffic at the earliest date.

110.3.1.13. Coordinate with the Government in advance any action that will require removing, relocating, or adding barricades.

110.3.1.14. Remove all equipment and all materials that would constitute a hazard to air traffic to the designated storage area whenever work is not in progress.

110.3.1.15. Violations of these requirements shall be considered a violation of the contract itself and shall be sufficient cause for halting the work without extending the time limit of the job.

110.3.2. Barricades.

110.3.2.1. Place barricades as indicated or as directed by the Government.

110.3.2.2. Upon completion of each phase of the project, remove barricades from the site or move to a different phase.

110.4. Measurement and Payment.

110.4.1. Measurement.

110.4.1.1. Maintenance and Protection of Air Traffic. This item shall be measured by the lump sum. This quantity shall include overall management of the traffic maintenance plan, for placing, maintaining, and removing flag lines, temporary barricades, closed runway markers, and for incidentals not specifically listed under other pay items.

110.4.1.2. Barricades. The quantity of beam barricades, bucket barricades, and Class A barricades to be paid for under this item shall be the number of barricades delivered to

the site, placed, maintained by the Contractor and ready for operation, and accepted by the contracting officer. Barricades will not be counted separately for each phase. For example, if a barricade for Phase A is also used for Phase B, it will not be counted again for payment.

110.4.2. Payment.

110.4.2.1. The quantities of pay items, determined as specified above, will be paid for at the respective contract unit prices. Payment shall constitute full compensation for all operations necessary to complete the work as specified herein.

110.4.2.2. Payment will be made under:

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NOTE: Edit the pay item list to suit the project.

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Item 110-1	Maintenance and Protection of Air Traffic	per lump sum
Item 110-2	Beam Barricade	per each
Item 110-3	Bucket Barricade	per each
Item 110-4	Class A Barricade	per each

AF 200
EARTHWORK

200.1. General. This specification covers the requirements for earthwork and pavement demolition.

200.2. Materials. The suitability of materials to be incorporated into the work covered under this specification will rely on the classification of the soil in accordance with American Society for Testing and Materials (ASTM) D 2487, *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*. These 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 [8 inches] in size shall also be considered unsuitable. Materials with rocks larger than 100 millimeters shall not be used in the top 300 millimeters [12 inches] of fill material in the shoulder or graded areas.

200.3. Execution.

200.3.1. Material Use. Engineering judgment shall be used in determining the best use of suitable and possible use of unsuitable materials. Traffic areas shall use more granular material. Granular materials are those with a classification beginning with G or S. Where possible, these granular materials shall be used closer to the surface because they are stronger. Unsuitable materials may be suitable for use outside the areas to receive traffic if these materials can be properly compacted. Materials with stones larger than 200 millimeters [8 inches] may be used outside the cleared area.

200.3.2. Excavation. Excavation shall be performed to the required lines and grades of the subgrade. Topsoil (normally the top 100 to 152 millimeters [4 to 6 inches] of in-situ soil) shall be removed and stockpiled for later use. Judicious use shall be made of all excavated materials. Where possible, materials shall be moved immediately to fill areas.

200.3.3. Backfill.

200.3.3.1. Preparation of the Surface. The surface of the ground to receive fill shall 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.

200.3.3.2. Material Placement. Place fill material in lifts and moisten or dry to ±3% of optimum moisture content before compaction. Adjust the lift thickness to match the capacity of the compactor and the soil being compacted. Usual lift thickness may vary from 100 to 200 millimeters [4 to 8 inches], with normal thickness being 152 millimeters [6 inches].

200.3.3.3. Compaction. Compaction shall be sufficient to reach the required density. The degree of compaction required is expressed as a percentage of maximum density

obtained by ASTM D 1557, *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft–lbf/ft^3 (2,700 kN-m/m^3))*. In general, the 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 [4 inches]. In areas to receive traffic, the requirements of Table 200-1 shall apply. See Unified Facilities Criteria (UFC) 3-260-02, *Pavement Design for Airfields*, for definitions of light, medium, modified heavy, heavy, and landing zone airfields, and A, B, C and D traffic areas. Cohesive soils have a liquid limit (LL) greater than 25 or plasticity index (PI) greater than 5, and cohesionless soils have a LL less than 25 or PI less than 5.

Table 200-1. 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]

Airfield Type	Traffic Area	Depth of Compaction (Measured from Pavement Surface)							
		Cohesive Soils				Cohesionless Soils			
		100%	95%	90%	85%	100%	95%	90%	85%
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]	3.0 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]
Landing Zone	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 the same compaction requirements as Type D traffic areas.

200.3.4. Subgrade Requirements. The subgrade will be constructed to within ±30 millimeters [0.1 foot] of the grades and elevations indicated.

200.3.5. 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 [12 inches] below the finished surface. Remove muck, peat, matted roots, or other yielding material unsatisfactory for subgrade foundation to the depth so as not to interfere with the required depth of compactions as shown in Table 200-1. Refill the excavated materials with suitable material obtained from the grading operations or borrow areas, and thoroughly compact by rolling. Ensure that any rock cuts are refilled with selected material and any pockets created in the rock surface are drained.

200.3.6. Bituminous Pavement Removal. When existing bituminous pavement is to be removed and adjacent bituminous pavement is to be left in place, the joint between the removal area and adjoining pavement to stay in place shall first be cut full depth with a standard diamond-type concrete saw. Just prior to placing new hot-mix asphalt against the removal edge, a new saw cut shall be made to remove any spalls, chips, or other damage and ensure that a clean vertical face remains.

200.3.7. PCC Pavement Removal. When existing concrete pavement is to be removed and adjacent concrete is to be left in place, the joint between the removal area and adjoining pavement to stay in place shall first be cut full depth with a standard diamond-type concrete saw. Next, a full-depth saw cut shall be made parallel to the joint

at least 600 millimeters [24 inches] from the joint and at least 150 millimeters [6 inches] from the end of any dowels. All pavement to be removed beyond this last saw cut shall be broken and removed in accordance with the Contractor's demolition work plan. All pavement between this last saw cut and the joint line shall be removed by carefully pulling pieces and blocks away from the joint face with suitable equipment and then picking them up for removal. In lieu of this specified removal method, the slab may be saw-cut full depth to divide it into several pieces and each piece lifted out and removed. Suitable equipment shall be used to provide a truly vertical lift, and safe lifting devices used for attachment to the slab.

200.4. Quality Control (QC) Testing.

200.4.1. Density. Density tests shall be made for each 750 cubic meters [1000 cubic yards] of material placed per layer. Determine the in-place field density in accordance with ASTM D 1556, *Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method*, or ASTM D 2167, *Standard Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method*. ASTM D 6938, *Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)*, may be used if the tests are calibrated with one of the other two methods.

200.4.2. Smoothness.

200.4.2.1. 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 [1/2 inch], or will not be more than 15 millimeters [5/8 inch] 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.

200.4.2.2. On runway safety areas, the surface will be of such smoothness that it will not vary more than 30 millimeters [0.1 foot] from true grade as established by grade hubs. Correct any deviation in excess of this amount by loosening, adding or removing materials, and reshaping.

200.5. Unit Prices.

****

NOTE: Delete unit price paragraphs when lump sum bidding is used. Edit the pay item descriptions to suit the project.

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200.5.1. Measurement.

200.5.1.1. Pavement Removal. The quantity of pavement removal to be paid for shall be the number of square meters [yards] measured in its original position, for the depth specified. The quantity of pavement removal shall include the pavements, aggregate,

and subbase materials, and any soils located above the specified removal depth. Saw cuts associated with pavement removal shall be considered incidental to the removal and shall not be paid separately.

200.5.1.2. Unclassified Excavation. The quantity of unclassified excavation to be paid for shall be the number of cubic meters [yards] measured in its original position. All excavation required to finish the compacted subgrade to plan elevation regardless of its classification shall be measured and paid for as unclassified excavation. Any over-excavation, including rock removal required to finish the compacted subgrade to plan elevation, shall not be measured for payment.

200.5.1.3. Embankment. The quantity of embankment to be paid for shall be the number of cubic meters [yards] measured in its placed and compacted position.

200.5.1.4. Shoulder Adjustment. The quantity of shoulder adjustment to be paid for shall be the number of square meters [yards] of area disturbed to re-grade between the newly constructed shoulder and the nearest ditch line as measured in its original position.

200.5.2. Payment.

200.5.2.1. The quantities of pay items, determined as specified above, will be paid for at the respective contract unit prices. Payment shall constitute full compensation for all operations necessary to complete the work as specified herein.

200.5.2.2. Payment will be made under:

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NOTE: Edit the pay item list to suit the project.

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Item 200-1	Bituminous Pavement Removal, [__] Depth	per SM [SY]
Item 200-2	PCC Pavement Removal, [__] Depth	per SM [SY]
Item 200-3	Unclassified Excavation	per CM [CY]
Item 200-4	Embankment	per CM [CY]
Item 200-5	Shoulder Adjustment	per SM [SY]

200.6. Additional Reference. See ASTM D 698, *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600kN-m/m^3))*.

AF 210
PAVEMENT RECLAMATION

210.1. 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 compacting the material to final grades and dimensions as indicated on the plans. Any excess material may be removed or stockpiled and reused in other areas.

210.2. Materials. The material shall be pulverized to a gradation of 100% passing the 89-millimeter [3.5-inch] sieve and 50 to 100% passing the 19-millimeter [3/4-inch] sieve. Other paragraphs in this section detail compaction requirements. The material produced as a result of cold milling (paragraph 210.3.2.2) may be spread uniformly over the area to be reclaimed by the process outlined here, and incorporated into the pulverizing of the pavement area.

210.3. Construction.

210.3.1. 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 because they will damage the remaining pavement.

210.3.2. Equipment.

210.3.2.1. The equipment to be used must have an established capability of crushing/pulverizing/mixing bituminous concrete pavements to produce a crushed and blended material that 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.

210.3.2.2. In general, equipment such as a road planer or cold-milling road machine that 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.

210.3.3. Crushing and Mixing.

210.3.3.1. After the butt joints have been saw-cut, the existing bituminous concrete pavement shall be pulverized, and the size of the pieces shall be as described in paragraph 210.2. All cobbles having a diameter greater than 89 millimeters [3.5 inches] shall be "culled out" and wasted. The existing bituminous concrete pavement and the top of the existing base-course material shall be crushed/pulverized/mixed together.

The total thickness of the existing base course to be mixed with the existing bituminous pavement (if any) shall 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 [8 inches] of the existing base is pulverized and mixed with the surface bituminous course. Limitations of the equipment may limit the depth of reclamation.

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

210.3.3.3. 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 that, when blended with existing material, will produce material of the specified gradation.

210.3.4. 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.

210.3.5. Compacting.

210.3.5.1. 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 shall be sufficient to compact the mixture to the required density.

210.3.5.2. 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 12 millimeters [1/2 inch] when tested with a 3.6-meter [12-foot] straightedge, loosen the irregular surface, refill with the kind of material used in constructing the course, and roll again as required.

210.3.6. Finishing Reclaimed.

210.3.6.1. After watering and rolling the reclaimed material, scarify the entire surface to a depth of at least 75 millimeters [3 inches] and shape 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 4 days. When the material is constructed in 2 layers, scarify the surface to a depth of 50 millimeters [2 inches].

210.3.6.2. In reclamation areas that will receive seeding and mulching, the surface of the reclaimed material shall 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.

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

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

210.4. Quality Control (QC) Testing.

210.4.1. Field Density. The field density of the compacted material shall be at least 90% of the maximum density of laboratory specimens prepared from samples of the reclaimed material. Compact and test the laboratory specimens in accordance with American Society for Testing and Materials (ASTM) D 1557, *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3 (2,700 kN m/m3))*, and using ASTM D 4718, *Standard Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles*, for oversize particles correction. Determine the in-place field density in accordance with ASTM D 1556, *Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method*, ASTM D 2167, *Standard Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method*, or ASTM D 6938, *Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)*. ASTM D 6938 results in a wet unit weight of soil, which is used to determine the moisture content of the soil. Check calibration curves furnished along with the density gauge as described in ASTM 6938. Make calibration checks of the density gauge at the beginning of a job on each type of material encountered. If ASTM D 6938 is used, check in-place densities by ASTM D 1556 at least once per lift for each 4180 square meters [5000 square yards] of stabilized material. Furnish calibration curves and calibration test results within 24 hours of conclusion of the tests. Complete at least 1 field density test for each 4180 square meters [5000 square yards] of each layer of base material. The moisture content of the material at the start of compaction shall not be below, nor more than 1.5% above, the optimum moisture content.

210.4.2. Surface Test.

210.4.2.1. After the course has been completely compacted, test the surface for smoothness and accuracy of grade and crown. The finished surface shall not vary more than 9.5 millimeters [3/8 inch] from a 4.8-meter [16-foot] straightedge when applied to the surface parallel with, and at right angles to, the centerline. The finished surface shall not vary more than 6 millimeters [1/4 inch] 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.

210.4.2.2. Measure in successive positions parallel to the runway centerline throughout the entire project. Also measure perpendicular to the runway centerline at 15-meter [50-foot] intervals.

210.4.3. Thickness Control. The completed thickness of the reclaimed pavement shall be within 25 millimeters [1 inch] of the thickness indicated on the plans. Where the measured thickness is deficient by more than 25 millimeters [1 inch], correct such areas by scarifying, adding reclaimed material, reblading, and recompacting. Where the measured thickness is more than 25 millimeters [1 inch] thicker than indicated, the course shall be considered as conforming with the specified thickness requirements (unless the area fails the surface test). Average job thickness shall be the average of all thickness measurements taken for the job, but shall be within 12 millimeters [1/2 inch] of the thickness indicated. Measure the thickness of the compacted reclaimed material at intervals that ensure 1 measurement for each 4180 square meters [5000 square yards] of material. Make measurements in test holes, 76 millimeters [3 inches] in diameter, penetrating the course.

210.4.4. Sieve Analysis. Complete a minimum of one analysis for each 900 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 (i.e., additional material from an off-site source is used to augment the volume of reclaimed material) or deficiencies are found, repeat the analysis and/or retest the material already placed to determine the extent of unacceptable material. Remove and replace all in-place unacceptable material.

210.5. Unit Prices.

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NOTE: Delete unit price paragraphs when lump sum bidding is used. Edit the pay item descriptions to suit the project.

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210.5.1. Measurement.

210.5.1.1. Pavement Reclamation Processing. The quantity of pavement reclamation processing to be paid for shall be the number of square meters [yards] processed and accepted, for the depth specified.

210.5.2. Payment.

210.5.2.1. The quantities of pay items, determined as specified above, will be paid for at the respective contract unit prices. Payment shall constitute full compensation for all operations necessary to complete the work as specified herein.

210.5.2.2. Payment will be made under:

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NOTE: Edit the pay item list to suit the project.

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Item 210-1 Pavement Reclamation Processing, [__] Depth per SM [SY]

210.6. Additional References:

- American Association of State Highway and Transportation Officials (AASHTO) T 89, *Standard Method of Test for Determining the Liquid Limit of Soils*
- AASHTO T 90, *Standard Method of Test for Determining the Plastic Limit and Plasticity Index of Soils*

AF 220
LIME-STABILIZED SUBGRADE

220.1. General. This specification covers the requirements for lime stabilization of subgrades for airfield pavements. In some situations, lime can be used to stabilize soil to create a semi-prepared landing zone surface.

220.2. Material.

220.2.1. 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 that meets the criteria set forth in the plans and this specification.

220.2.2. Lime.

220.2.2.1. The lime shall be a standard brand of quicklime or hydrated lime. Table 220-1 provides some advantages and disadvantages of quicklime, hydrated lime, and a slurry of lime.

Table 220-1. 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 because 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 possibility of skin and eye burns.

Material	Advantages	Disadvantages
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 during cool, wet, humid weather, which could occur during the fall, winter, and spring construction seasons. • Not practical for use with very wet soils.

220.2.2.2. Lime shall conform to American Society for Testing and Materials (ASTM) C 977, *Standard Specification for Quicklime and Hydrated Lime for Soil Stabilization*.

220.2.3. Bituminous Material. If bituminous material will be used in conjunction with lime stabilization, the bituminous material shall conform to Table 220-2.

Table 220-2. Bituminous Material Standards

Material	Type
Cutback Asphalt*	American Association of State Highway and Transportation Officials (AASHTO) M 81, *Standard Specification for Cutback Asphalt (Rapid-Curing Type)*
	AASHTO M 82, *Standard Specification for Cutback Asphalt (Medium-Curing Type)*
	ASTM D 2027, *Standard Specification for Cutback Asphalt (Medium-Curing Type)*
	ASTM D 2028, *Standard Specification for Cutback Asphalt (Rapid-Curing Type)*, Grade RC-250, RC-800, MC-250, or MC-800
Emulsified Asphalt	ASTM D 977, *Standard Specification for Quicklime and Hydrated Lime for Soil Stabilization*, Type RS-1 or RS-2

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

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NOTE: 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 Unified Facilities Criteria (UFC) 3-250-11, Soil Stabilization for Pavements*, and UFC 3-260-02,* Pavement Design for Airfields*, for further guidance.*

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220.2.4. Material to be Stabilized. Material to be stabilized shall consist of either in-place material or select material hauled to the site. Select material shall be free of deleterious substances such as sticks, debris, organic matter, and stones greater than 75 millimeters [3 inches] in any dimension. At least 25% of the material shall pass the 0.425-millimeter [No. 40] sieve and have a plasticity index (PI) greater than 12.

220.2.5. Water. Water shall 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.

220.2.6. Mix Design. Determine the compressive strength requirement based on the use of the final pavement. Generally, a compressive strength of 1.035 megapascals [150 pounds per square inch] is the minimum allowable. Refer to UFC 3-250-11 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. The mix design shall be capable of producing a compressive strength of 1.035 megapascals [150 pounds per square inch] when compacted to the design percent of laboratory maximum density. Samples shall not show any significant loss of strength after 12 cycles of the durability test.

220.3. Construction.

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

220.3.2. Plant, Equipment, Machines, and Tools.

220.3.2.1. Steel-wheeled Rollers. Steel-wheeled rollers shall be the self-propelled type with a total weight of not less than 9 metric tons [10 tons], and a minimum weight of 135 kilograms per millimeter [300 pounds per inch] width of rear wheel. The wheels of the rollers shall be equipped with adjustable scrapers. The use of vibratory rollers is optional.

220.3.2.2. Pneumatic-tired Rollers. Pneumatic-tired rollers shall have four or more tires, each loaded adequately to achieve compaction through the entire lift thickness. The loading shall be equally distributed to all wheels, and the tires shall be uniformly inflated. Towing equipment shall have pneumatic tires.

220.3.2.3. Mechanical Spreader. The mechanical spreader shall be self-propelled or attached to a propelling unit capable of moving the spreader and material truck. The device shall be steerable and shall have variable speeds forward and reverse. The spreader and propelling unit shall be carried on tracks, rubber tires, or drum-type steel rollers that will not disturb the underlying material. The spreader shall contain a hopper, an adjustable screed, and outboard bumper rolls, and the spreader shall be designed to have a uniform, steady flow of material from the hopper. The spreader shall 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 shall conform to the thickness and grade requirements indicated on the drawings or in the specifications.

220.3.2.4. Sprinkling Equipment. The sprinkling equipment shall consist of tank trucks, pressure distributors, or other approved equipment designed to apply controlled quantities of water uniformly over variable widths of surface.

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

220.3.2.6. Straightedge. Furnish and maintain at the site a 3.6-meter [12-foot] straightedge for use in testing the finished surface. Straightedges shall be constructed of aluminum or other lightweight metal and shall have blades of box or box-girder cross section with flat bottom reinforced to ensure rigidity and accuracy. Straightedges shall have handles to facilitate movement on pavement.

220.3.3. Weather Limitations. Do not perform stabilization work during freezing temperatures. When the temperature is below 5 °C [40 ºF], 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 shall be brought to a satisfactory condition. Do not apply lime when the atmospheric temperature is less than 5 °C [40 ºF]. 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 [35 ºF], protect the completed lime-treated course against any detrimental effects of freezing.

220.3.4. Degree of Compaction. The degree of compaction required is expressed as a percentage of the maximum density obtained by the test procedure presented in ASTM D 1557, *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft–lbf/ft^3 (2,700 kN-m/m^3))*, abbreviated as percent laboratory maximum density.

220.3.5. Lime Stabilization Mixture. The material to be stabilized shall be thoroughly pulverized and, when lime is applied in the dry state, the mix shall be thoroughly blended at a moisture content below optimum. After mixing is completed, the mixture proportions shall 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 a 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 shall be in lines parallel to the centerline of the area under construction and suitably spaced for string lining.

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

220.3.6.1. 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 processing the area. Make soft or yielding subgrade areas stable before beginning construction.

220.3.6.2. In-place Material to Receive Stabilized Course. Correct soft, yielding areas and ruts or other irregularities in the surface. Remove unsatisfactory material in the affected areas. Add approved select material where unsatisfactory material is removed. Shape the area to line, grade, and cross section, and compact to the specified density. Subgrade shall conform to section AF 200 EARTHWORK.

220.3.6.3. 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. The finished and completed stabilized area shall conform to the lines, grades, cross section, and dimensions on the plans.

220.4. Installation.

220.4.1. Mixed-in-place Method.

220.4.1.1. Scarifying and Pulverizing of Soil. Prior to applying lime, scarify and pulverize the soil to the depth required by the mix design and pavement design. Control scarification so that the layer beneath the layer to be treated is not disturbed. The depth of pulverizing shall not exceed the depth of scarification.

220.4.1.2. 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. Use mechanical spreaders 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 shall pass over the freshly applied lime.

220.4.1.3. Initial Mixing. Immediately after the lime has been distributed, mix the lime and soil. Initial mixing shall 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.

220.4.1.4. Water Application and Moist Mixing. Determine the moisture content of the mixture in preparation for final mixing. Moisture in the mixture following final mixing shall not be less than the water content determined to be optimum based on the dry weight of soil, and shall 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 shall 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.

220.4.1.5. 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 [12-inch] width of the shoulder to be rolled and compacted simultaneously with the rolling and compacting of each layer of the stabilized course.

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

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

220.4.4. Layer Thickness. Determine the compacted thickness of the stabilized course by a pavement design. Thickness usually varies from 100 to 200 millimeters [4 to 8 inches], depending on the pavement design, and shall be not more than 200 millimeters [8 inches] or less than 75 millimeters [3 inches] in compacted thickness.

220.4.5. 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. The density of the compacted mixture shall 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 shall be slightly different lengths. At all times, the speed of the roller shall not cause displacement of the mixture. Areas inaccessible to the rollers shall be compacted with mechanical tampers, and shall be shaped and finished by hand methods.

220.4.6. Finishing. Finish the surface of the top layer to the grade and cross section shown. The surface shall 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 water-soaked for any reason, remove that portion immediately and place the mix in a windrow and aerate until the moisture content is within the limits specified. Then spread, shape, and roll as specified in paragraph 220.4.5.

220.4.7. 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.

220.4.8. Curing and Protection. It may be advantageous to cure only by bituminous curing pavements that are to receive bituminous surfacing. Use either the moist curing method in paragraph 220.4.8.1 or one of the bituminous methods described in paragraph 220.4.8.3. Immediately after the soil-lime area has been finished as specified in paragraph 220.4.6, protect the surface against rapid drying for 7 days by one of these methods:

220.4.8.1. Moist Curing. Moisten the area by sprinkling, and keep it moist for the 7-day curing period.

220.4.8.2. Bituminous Material. Use one of the materials provided in Table 220-3 at the temperature range specified.

Table 220-3. Bituminous Material Temperature Ranges per Type

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]

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

220.4.8.3. Bituminous material shall be uniformly applied by means of a bituminous distributor within the temperature ranges stated in Table 220-3. Apply bituminous material in quantities of not less than 0.45 liter 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 shall be properly treated using the manually operated hose attachment. Bituminous material shall be applied to only the top layer. At the time the bituminous material is applied, the surface of the area shall be free of loose or foreign matter and shall 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.

220.4.9. 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 shall 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 shall be protected in a manner to prevent equipment from marring or damaging completed work.

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

220.4.11. 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.

220.5. Quality Control (QC) Testing.

220.5.1. 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.

220.5.2. Results. The results shall 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.

220.5.3. Sampling. Take all aggregate samples for laboratory testing in accordance with ASTM D 75, *Standard Practice for Sampling Aggregates*. Take samples of lime in accordance with ASTM C 50, *Standard Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products*. Prepare specimens for the unconfined compression tests in accordance with Procedure A of ASTM D 5102, *Standard Test Method for Unconfined Compressive Strength of Compacted Soil-Lime Mixtures*.

220.5.4. Sieve Analysis. Before starting work, test one sample of material to be stabilized in accordance with ASTM C 136, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*, and ASTM D 422*, Standard Test Method for Particle-Size Analysis of Soils*, on sieves conforming to ASTM E 11*, Standard Specification for Wire Cloth and Sieves for Testing Purposes*. 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.

220.5.5. Liquid Limit (LL) and Plasticity Index (PI). Perform one LL and PI test for each sieve analysis. Determine LL and PI in accordance with ASTM D 4318*, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*.

220.5.6. Chemical Analysis. Test lime 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.

220.5.7. Unconfined Compression Testing. Conduct unconfined compression tests in accordance with Procedure A of ASTM D 5102, *Standard Test Method for Unconfined Compressive Strength of Compacted Soil-Lime Mixtures*. Conduct three tests for each mix design tested. Cure samples at a constant moisture content and temperature for 28 days. Conduct wet-dry tests in accordance with AASHTO T 135, *Standard Method of Test for Wetting-and-Drying Test of Compacted Soil-Cement Mixtures*, or ASTM D 559, *Standard Test Methods for Wetting and Drying Compacted Soil-Cement Mixtures*. Conduct freeze-thaw tests (if necessary for the climate) in accordance with AASHTO T 136, *Standard Method of Test for 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.

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

220.5.9. Thickness Control.

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NOTE: When stabilized courses are constructed less than 150 millimeters [6 inches] in total thickness, a deficiency of 12 millimeters [1/2 inch] 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 [1/4 inch].

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220.5.9.1. Completed thicknesses of the stabilized course shall be within 12 millimeters [1/2 inch] of the thickness indicated. Where the measured thickness of the stabilized course is deficient by more than 12 millimeters [1/2 inch], correct such areas by scarifying, adding mixture of proper gradation, reblading, and recompacting. Where the measured thickness of the stabilized course is more than 12 millimeters [1/2 inch] thicker than indicated, it conforms to the specified thickness requirement as long as it does not impact the thickness of the overlying layers. Average job thickness is the average of all thickness measurements taken for the job, but shall be within 6 millimeters [1/4 inch] of the thickness indicated. Measure the thickness of the stabilized course at intervals of 1 measurement for each 400 square meters [500 square yards] of stabilized course. Conduct measurements in 75-millimeter [3-inch] diameter test holes penetrating the stabilized course.

220.5.10. Field Density. Conduct field density tests in accordance with ASTM D 1556, *Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method*, or ASTM D 6938, *Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depths)*. When ASTM D 6938 is used, check and adjust, if necessary, the calibration curves or tables using the methods describe in the Annexes. Make calibration checks of the density gauge at the beginning of a job on each type of material encountered. If ASTM D 6938 is used, check in-place densities by ASTM D 1556 at least once per lift for each 826 square meters [1000 square yards] of stabilized material. Provide the calibration curves and calibration test results within 24 hours of conclusion of the tests. Perform at least one field density test for each 209 square meters [250 square yards] of each layer of base material.

220.5.11. Smoothness Test. This test is used only if the stabilized material is the final surface, such as a landing zone surface. The surface of a stabilized layer shall show no deviations in excess of 12 millimeters [1/2 inch] when tested with the 3.6-meter [12-foot] 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 [12-foot] straightedge. Also, take measurements perpendicular to the road centerline at 15-meter [50-foot] intervals.

220.6. Unit Prices.

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NOTE: Delete unit price paragraphs when lump sum bidding is used. Edit the pay item descriptions to suit the project.

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220.6.1. Measurement.

220.6.1.1. By-Product Lime. The quantity of lime to be paid for shall be the number of metric tons [tons] of material placed, blended, and accepted in the completed subbase, but not in excess of 105% of the amount specified. The lime shall be weighed either at the place of loading the trucks, at the place of unloading the trucks, or at such other point as the engineer may designate. The Contractor shall furnish approved duplicate load tickets upon which is recorded the net weight of the lime in each truck.

220.6.1.2. Soil Processing. The quantity of soil processing to be paid for shall be the number of square meters [yards] processed and accepted, for the depth specified.

220.6.2. Payment.

220.6.2.1. The quantities of pay items, determined as specified above, will be paid for at the respective contract unit prices. Payment shall constitute full compensation for all operations necessary to complete the work as specified herein.

220.6.2.2. Payment will be made under:

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NOTE: Edit the pay item list to suit the project.

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Item 220-1	By-Product Lime	per metric ton [ton]
Item 220-2	Soil Processing, [__] Depth	per SM [SY]

AF 230
PORTLAND-CEMENT-STABILIZED SURFACE, BASE OR SUBBASE

230.1. General.

230.1.1. 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 that meets the criteria set forth in the drawings and specifications.

230.1.2. Weather Limitations. Do not apply cement when the atmospheric temperature is less than 5 °C [40 °F]. Do not apply cement to soils that are frozen or contain frost, or when the underlying material is frozen. If the temperature falls below 2 °C [35 °F], protect completed cement-treated areas against the detrimental effects of freezing.

230.2. Material.

230.2.1. Material to be Stabilized. The material to be stabilized shall consist of in-place material or select material conforming to American Association of State Highway and Transportation Officials (AASHTO) M 147, *Standard Specification for Materials for Aggregate and Soil-Aggregate Subbase, Base, and Surface Courses*, or American Society for Testing and Materials (ASTM) D 1241, *Standard Specification for Materials for Soil-Aggregate Subbase, Base, and Surface Courses*, Gradation A, B, C or D. Stones retained on a 50-millimeter [2-inch] sieve for surface courses or 75-millimeter [3-inch] sieve for base or subbase courses and deleterious substances such as sticks, debris, and organic matter shall be removed.

230.2.2. Water. Water shall 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

230.2.3. Burlap. Burlap shall conform to AASHTO M 182, *Standard Specification for Burlap Cloth Made from Jute or Kenaf and Cotton Mats*.

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

230.3. Mix Design.

230.3.1. Refer to Unified Facilities Criteria (UFC) 3-250-11, *Soil Stabilization for Pavements*, and UFC 3-260-02, *Pavement Design for Airfields*, for further guidance on restrictions or requirements to the stabilization mix design and for information on the applicability of stabilization with portland cement. Test the soil to be stabilized for sulfates in accordance with the procedures described in UFC 3-250-11, Appendix C.

Fine-grained soils containing more than about 1% sulfate shall not be stabilized with portland cement.

230.3.2. Develop the mix using the aggregate or soil-aggregate material to be stabilized. The mix shall have a minimum compressive strength of 10.34 megapascals [1500 pounds per square inch] for cement-stabilized surfaces used for semi-prepared landing zones, taxiways, and aprons; 5.00 megapascals [750 pounds per square inch] for base; and 1.75 megapascals [250 pounds per square inch] for subbase.

230.3.3. For the project's mix design, perform laboratory tests to determine the minimum amount of cement required to achieve the specified compressive strength.

230.4. Initial Sampling and Testing for Mix Design.

230.4.1. Laboratory Density. Conduct moisture-density tests in accordance with the procedure contained in AASHTO T 134, *Standard Method of Test for Moisture-Density Relations of Soil-Cement Mixtures*, or ASTM D 558, *Standard Test Methods for Moisture-Density (Unit Weight) Relations of Soil-Cement Mixtures*; however, use the apparatus and procedures outlined in ASTM D 1557, *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft–lbf/ft^3 (2,700 kN-m/m^3))*, to compact the soil-cement mixture.

230.4.2. Unconfined Compression Testing. Conduct unconfined compression tests in accordance with ASTM D 1633, *Standard Test Methods for Compressive Strength of Molded Soil-Cement Cylinders*. Complete three tests for each mix design tested. Cure samples at a constant moisture content and temperature for 7 days.

230.4.3. Sieve Analysis. Complete a minimum of one analysis 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, repeat the analysis and/or retest the material already placed to determine the extent of unacceptable material. Replace all in-place unacceptable material.

230.5. Construction.

230.5.1. General Requirements. Do not apply cement if the soil moisture content exceeds the optimum moisture content specified for the cement-treated mixture. After mixing is completed, the proportions of the mixture shall be in accordance with the approved mix design. When application of water and mixing are completed, on the basis of dry weight, moisture shall not be below the optimum moisture content of the mixture, nor shall it be more than 2% above the optimum moisture content. 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 sweepers 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 areas to be stabilized, or on pulverized, mixed, or partially

mixed material. Provide line and grade stakes as necessary for control. Place grade stakes in lines parallel to the centerline of the area under construction and suitably spaced for string lining.

230.5.2. Preparation of Area to be Stabilized. Clean debris from area to be stabilized, and inspect the area for adequate compaction. The area shall be capable of withstanding, without displacement, the compaction specified for the soil-cement mixture. Dispose of debris and removed unsatisfactory in-place material as specified.

Note: The subgrade shall be exposed to compact the top 150 millimeters [6 inches] and to provide a surface for compacting the surface course against. If the stabilized section will 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 shall be removed so the underlying layer can be compacted.

230.5.3. In-place Material to be Stabilized. Grade and shape the entire area to be stabilized to conform to the lines, grades, and cross sections shown in the plans prior to processing the area. Stabilize soft or yielding areas by undercut and backfill or drying before stabilized layer construction begins.

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.

230.5.4. In-place Materials to Receive Stabilized Course. Correct soft, yielding areas and ruts or other irregularities in the surface. Loosen material in the affected areas and remove unsatisfactory material. Add approved select material where directed. Reshape the area to line, grade, and cross section, and compact to the specified density.

230.5.5. Select Material. Use sufficient select material to provide the required thickness of the stabilized layer after compaction, and process to meet the requirements specified before cement stabilization is undertaken.

230.6. Installation.

230.6.1. Edges of Stabilized Course. Place approved material 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 [12-inch] width of the shoulder to be rolled and compacted simultaneously with the rolling and compacting of each layer of the stabilized course.

230.6.2. Scarifying and Pulverizing Soil. Prior to the application of cement, scarify and pulverize the soil. Control scarification carefully so that the layer beneath the layer to be stabilized is not disturbed. The depth of pulverizing shall not exceed the depth of scarification. Unless otherwise permitted, the area scarified and pulverized shall not exceed the area that can be completed in 2 working days.

230.6.3. Application of Cement. Shape pulverized material approximately to the cross section indicated. Apply cement so that when uniformly mixed with the soil, the specified cement content is obtained and a sufficient quantity of stabilized soil is produced to construct a compacted stabilized course conforming to the lines, grades, and cross section indicated. Equipment, except that used in spreading and mixing operations, shall not pass over the freshly spread stabilized layer.

230.6.4. Dry Mixing. Immediately after the cement has been distributed, mix it with the soil. Do not mix the cement below the required depth. Continue mixing until the cement has been sufficiently blended with the soil to prevent the formation of cement balls when water is applied.

230.6.5. Water Application and Moist Mixing. Determine the moisture content of the mixture immediately after completion of mixing the soil and cement. Provide water-supply and pressure-distributing equipment that will permit the continuous application within 3 hours of all water required on the section being processed. Incorporate water in the mix so that concentration of water near the surface does not occur. After all the mixing water has been added, continue mixing 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. Dispose of any portion of the mixture remaining undisturbed more than 30 minutes during mixing as specified. Ensure that satisfactory moisture distribution occurs along the edges of the section.

230.6.6. Layer Thickness.

230.6.6.1. The compacted thickness of the stabilized course shall be 150 millimeters [6 inches]. No layer shall be in excess of 200 millimeters [8 inches], nor less than 100 millimeters [4 inches] in compacted thickness.

230.6.6.2. Following compaction of the subgrade, place the first lift of material to be stabilized 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, monitor the amount of reduction in thickness so that pre-compaction layer thickness can be adjusted to result in the final desired thickness. The grades shall not change significantly after the addition of the cement. 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.

230.6.7. Compaction.

230.6.7.1. Stabilized Course. Density is based on the material being stabilized. Before compaction operations are started, and as a continuation of the mixing operation, loosen the mixture thoroughly to the full depth. At the beginning of compaction, at least 80% of the soil shall pass a 4.75-millimeter [No. 4] sieve, and 100% shall pass a 50-millimeter [2-inch] sieve for surface courses, or a 75-millimeter [3-inch] sieve for base or subbase courses. Start compaction immediately after mixing is completed. Compact the cement-stabilized material as soon as possible after addition of the cement. In no case shall the compaction be completed more than 4 hours after the initial introduction of the cement to the material to be stabilized. The density of the compacted soil-cement mixture shall be at least 100% of the maximum density obtained from the laboratory-prepared samples. Compact the loose mixture uniformly and continuously until the entire depth and width of the area is compacted to the density specified. Maintain the moisture content at the surface near optimum at all times through the rolling, but drier than the moisture content that will cause the soil-cement mixture to become unstable during compaction. 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 shall be slightly different lengths. Displacement of the mixture shall not occur due to the speed of the roller. Use mechanical tampers to compact areas inaccessible to rollers.

230.6.7.2. Subgrade. As necessary, expose and compact the subgrade with a sheepsfoot roller or a large (preferably a 36-metric-ton [40-ton]), rubber-tired roller. Remove and replace any soft, shoving, or yielding areas of the subgrade with select fill. Compact the select fill similarly to the existing subgrade material that did not yield.

230.6.8. Finishing. Moisten the surface, if necessary, and shape to the required lines, grades, and cross section. If necessary, lightly scarify the surface to eliminate any imprints made by the compacting or shaping equipment. Thoroughly compact the surface 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. Complete these finishing operations within 2 hours after completion of mixing operations. In places not accessible to finishing and shaping equipment, compact the mixtures with mechanical tampers to the density specified and shape and finish by hand methods. Correct any portion of the compacted mix that has a density less than that specified, that has not properly hardened, or that is improperly finished.

230.6.9. Construction Joints. At the end of each day's 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 and replace material along construction joints not properly compacted with material that is mixed, moistened, and compacted as specified.

230.6.10. Curing and Protection. Protect the finished surface against rapid drying for 7 days by covering with bituminous material. Bituminous material (RC-70 or MC-70)

shall be uniformly applied by means of a bituminous distributor within a temperature range of 50 to 85 °C [120 to 185 °F], as directed. Bituminous material for curing shall be uniformly applied at the rate of 0.91 to 1.13 liter per square meter [0.2 to 0.25 gallon per square yard]. Areas inaccessible to or missed by the distributor shall be properly treated using the manually operated hose attachment. Bituminous material shall be applied only to the top layer. At the time the bituminous material is applied, the surface shall be free of loose or foreign matter and shall contain sufficient moisture to prevent excessive penetration of the bituminous material. When necessary, water in sufficient quantity to fill the surface voids shall be applied immediately before the bituminous material is applied. The treated surface shall be sanded or dusted to prevent the bituminous material from being picked up by traffic.

230.6.11. Maintenance. Maintain the stabilized area in a satisfactory condition until the completed work is accepted. Maintenance includes immediate repairs to any defects. Repeat maintenance as often as necessary to keep the area intact.

230.6.12. Traffic. Completed portions of the stabilized area may be opened immediately to light traffic provided that 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. Protect finished portions of cement-stabilized soil that are traveled on by equipment used in constructing an adjoining section in a manner that prevents equipment from marring or damaging the completed work.

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

230.7. Quality Control (QC) Testing.

230.7.1. Grade Control. Excavate underlying material to a sufficient depth for the required stabilized course thickness. The finished stabilized course, with the subsequent surface course, shall meet the fixed grade. The finished and completed stabilized area shall conform to the lines, grades, cross section, and dimensions indicated.

230.7.2. Smoothness Test. The surface of a stabilized layer shall show no deviations in excess of 12 millimeters [1/2 inch] when tested with a 3.6-meter [12-foot] straightedge. Correct deviations exceeding this amount by removing material and with replacing new material, or by reworking existing material and compacting. Take measurements for deviation from grade and cross section shown in the drawings in successive positions parallel to the runway centerline with a straightedge. Also take measurements perpendicular to the runway centerline at 15-meter [50-foot] intervals.

230.7.3. Thickness Control. The completed thickness of the stabilized course shall be within 25 millimeters [1 inch] of the thickness indicated. Where the measured thickness is deficient by more than 25 millimeters [1 inch], correct such areas by scarifying, adding mixture of proper gradation, reblading, and recompacting. Where the measured thickness is more than 25 millimeters [1 inch] thicker than indicated, the course shall be considered as conforming with the specified thickness requirements, unless the surface course thickness is impacted. The average job thickness shall be the average of all thickness measurements taken for the job, but shall be within 12 millimeters [1/2 inch] of the thickness indicated. Measure the thickness of the stabilized course at intervals that ensure one measurement for each 4100 square meters [5000 square yards] of stabilized course. Take measurements in 75-millimeter [3-inch] diameter test holes penetrating the stabilized course.

230.7.4. Field Density.

230.7.4.1. Conduct field density tests in accordance with ASTM D 1556, *Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method*, or ASTM D 6938, *Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depths)*. When ASTM D 6938 is used, check and adjust, if necessary, the calibration curves or tables using the methods describe in the Annexes. Make calibration checks of the density gauge at the beginning of a job on each type of material encountered. If ASTM D 6938 is used, check in-place densities by ASTM D 1556 at least once per lift for each 836 square meters [1000 square yards] of stabilized material. Provide the calibration curves and calibration test results within 24 hours of conclusion of the tests. Perform at least one field density test for each 209 square meters [250 square yards] of each layer of base material.

230.7.4.2. Make test cylinders during construction, or take core samples to check strength gain. When the cores/test cylinders reach the design strength, limited traffic may begin. The airfield shall be fully capable within approximately 28 days of construction of the final lift of the cement-stabilized layer.

230.7.5. Sieve Analysis. Complete a minimum of one analysis for each 1000 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 or deficiencies are found, repeat the analysis and/or retest the material already placed to determine the extent of unacceptable material. Replace all in-place unacceptable material.

230.8. Unit Prices.

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NOTE: Delete unit price paragraphs when lump sum bidding is used. Edit the pay item descriptions to suit the project.

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230.8.1. Measurement.

230.8.1.1. Portland Cement. The quantity of portland cement to be paid for shall be the number of metric tons [tons] of material placed, blended, and accepted in the completed subbase, but not in excess of 105% of the amount specified. The portland cement shall be weighed either at the place of loading the trucks, at the place of unloading the trucks, or at such other point as the engineer may designate. The Contractor shall furnish approved duplicate load tickets upon which is recorded the net weight of the portland cement in each truck.

230.8.1.2. Soil Processing. The quantity of soil processing to be paid for shall be the number of square meters [yards] placed and accepted, for the depth specified.

230.8.2. Payment.

230.8.2.1. The quantities of pay items, determined as specified above, will be paid for at the respective contract unit prices. Payment shall constitute full compensation for all operations necessary to complete the work as specified herein.

230.8.2.2. Payment will be made under:

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NOTE: Edit the pay item list to suit the project.

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Item 230-1	Portland Cement	per metric ton [ton]
Item 230-2	Soil Processing, [__] Depth	per SM [SY]

AF 240
DRAINAGE LAYER

240.1. General. This specification covers the requirements for a drainage layer under airfield pavements. Paragraphs 240.1.1 through 240.1.3 define various types of drainage layers:

240.1.1. 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 240-1

240.1.2. Bituminous-stabilized Drainage Layer: A drainage layer consisting of OGM stabilized with asphalt cement.

240.1.3. Cement-stabilized Drainage Layer: A drainage layer consisting of OGM stabilized with portland cement.

240.2. Material.

240.2.1. Aggregates. Aggregates shall consist of clean, sound, hard, durable, angular particles of crushed stone, crushed slag, or crushed gravel that meet the specification requirements. Slag shall 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 American Society for Testing and Materials (ASTM) C 29/C 29M, *Standard Test Method for Bulk Density (Unit Weight) and Voids in Aggregate*. The aggregates shall 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.

240.2.1.1. Aggregate Quality.

240.2.1.1.1. The aggregate shall 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*.

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NOTE: 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.

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240.2.1.1.2. The aggregate shall 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*.

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NOTE: Loss on abrasion of 40% is normally used, except that a value up to 50% may be used where experience with local materials indicates that such an increase is justified.

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240.2.1.1.3. The percentage of flat and/or elongated particles shall be determined by ASTM D 4791, *Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate*, with these modifications: the aggregates shall be separated into 2 size fractions—particles greater than the 12.5-millimeter [1/2-inch] sieve, and particles passing the 12.5-millimeter [1/2-inch] sieve and retained on the 4.75-millimeter [No. 4] sieve.

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

240.2.1.1.5. When the aggregate is supplied from more than one source, aggregate from each source shall meet the specified requirements.

240.2.1.1.6. When the aggregate is supplied from crushed gravel, it shall be manufactured from gravel particles, 90% of which by weight are retained on the maximum-size sieve listed in Table 240-1. In the portion retained on each sieve specified, the crushed gravel shall contain at least 90% by weight of crushed pieces having 2 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 2 fractures are contiguous, the angle between planes of the fractures must be at least 30° in order to count as 2 fractured faces.

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NOTE: Fractured faces may be reduced to 75% if the required California Bearing Ratio (CBR) is 50 or less.

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240.2.1.2. Gradation Requirements.

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NOTE: 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 (5000 feet) 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 240-1 provides gradation limits for the drainage layer:

Table 240-1. Gradation of Drainage Layer Material

Sieve Designation	Percentage by Weight Passing Square-Mesh Sieve			
	RDM	OGM	OGM Stabilized	Choke Stone
37.50 mm [1.5 in]	100	100	100	100
25.00 mm [1 in]	70-100	95-100	95-100	100
19.00 mm [0.75 in]	55-100			100
12.50 mm [0.5 in]	40-80	25-80	25-80	100
9.50 mm [0.375 in]	30-65			80-100
4.75 mm [No. 4]	10-50	0-10	0-10	10-100
2.36 mm [No. 8]	0-25	0-5	0-5	5-40
1.18 mm [No. 16]	0-5			0-10

Notes:

1. Particles having diameters less than 0.02 millimeter (0.0008 inch) shall 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 unless the Contractor can demonstrate in a test section that the drainage layer can be constructed without use of these materials. Choke stone shall be made up of hard, durable, crushed aggregate having 90% of the stone with fractured faces. The gradation for the choke stone shall be based on these 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 shall be less than 5.
   b. The ratio of the D50 of the OGM to the D50 of the choke stone shall be greater than 2.
4. For RDM, the coefficient of uniformity (CU) shall be greater than 3.5. (CU = D60/D10).

240.2.2. Bituminous Materials. Refer to Unified Facilities Criteria (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 shall conform to either American Association of State Highway and Transportation Officials (AASHTO) M 320, *Standard Specification for Performance-Graded Asphalt Binder,* 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 shall show a negative spot when subjected to the spot test in accordance with AASHTO T 102, *Standard Method of Test for Spot Test of Asphaltic Materials*, using the standard naphtha specified.

240.2.3. Cementitious Materials. Refer to UFC 3-250-04FA, *Standard Practice for Concrete Pavements*, for information on choosing the appropriate type and grade of cementitious material. Portland cement to be mixed with aggregates shall conform to either ASTM C 150, *Standard Specification for Portland Cement*, Type I, IA, II, or IIA, or ASTM C 595, *Standard Specification for Blended Hydraulic Cements*, Type IS or IS.

240.2.4. Bituminous- or Cement-stabilized Job-Mix Formula (JMF). The bituminous-stabilized mix shall consist of a mixture of OGM and a minimum of 2% asphalt cement by weight. Tolerances for bituminous-stabilized material shall 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 that the stabilized drainage layer will not rut or be disturbed by the paving method in the project.

240.2.5. 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 240.2.6).

240.2.6. 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 helps determine 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 quality assurance (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.

240.2.6.1. Constructing the Test Section. For construction of the test section, the compaction equipment speed shall 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 [2-inch] intervals of depth down for the total layer thickness, in accordance with ASTM D 6938, *Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate 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 12 millimeters [1/2 inch] and work into the surface of the OGM using 2 passes of a vibratory roller and moisten the surface. 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.

240.2.6.2. Testing Bituminous- or Cement-stabilized Drainage Layer. For a bituminous- or cement-stabilized drainage layer, conduct density tests at the surface and at intervals of 50 millimeters [2 inches] of depth for the total layer thickness in accordance with ASTM D 6938. 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 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 [0.5 pound per cubic foot].

240.2.6.3. 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 shall 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 3 and 6 passes, only slight increases in dry density (16 kilograms per cubic meter) [1.0 pound per cubic foot] 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 shall 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 shall be examined 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 shall take precedence.

240.3. Construction.

240.3.1. Equipment.

240.3.1.1. Placement Equipment. An asphalt paving machine shall 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.

240.3.1.2. Compaction Equipment. A dual or single smooth drum roller that provides a maximum compactive effort without crushing the drainage layer aggregate shall be used to compact drainage layer material.

240.3.1.3. Bituminous Mixing Plant. The bituminous mixing plant shall be an automatic or semiautomatic controlled, commercially manufactured unit capable of producing a bituminous-stabilized aggregate mixture consistent with the JMF. Drum mixers shall 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 from Bituminous Paving Mixtures*, and recovery of the asphalt cement in accordance with ASTM D 1856, *Standard Test Method for Recovery of Asphalt from Solution by Abson Method*. The penetration of the recovered asphalt binder shall not be less than 60% of the original penetration in accordance with ASTM D 5, *Standard Test Method for Penetration of Bituminous Materials*.

240.3.1.4. Cementitious Mixing Plant. The cementitious mixing plant shall 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 the dry aggregate and cement to prevent cement balls from forming when water is added.

240.3.2. Weather Limitation. Place drainage layer material when the atmospheric temperature is above 2 °C (35 °F). Correct 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, to meet specified requirements.

240.3.3. 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.

240.3.4. Test Section. Construct the test section as described in paragraph 240.2.6.1.

240.3.5. Preparation of Underlying Course. Prior to constructing the drainage layer, clean the underlying course of all foreign materials. During construction, the underlying course shall contain no frozen material. The underlying course shall 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 the specified density. Do not disturb the finished underlying course by traffic or other operations, and maintain the finished underlying course in a satisfactory condition until the drainage layer is placed.

240.3.6. Transporting Material. The aggregate drainage layer material shall be transported to the site in a manner that prevents segregation and contamination of materials. Bituminous-stabilized material shall be transported from the mixing plant to the site in trucks having tight, clean, smooth beds that are 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.

240.3.7. Placing.

240.3.7.1. General Requirements. Place drainage layer material on the underlying course in lifts of uniform thickness using equipment meeting the requirements of paragraph 240.3.1. When a compacted layer 150 millimeters [6 inches] or less in thickness is required, place the material in a single lift. When a compacted layer in excess of 150 millimeters [6 inches] is required, place the material in lifts of equal thickness. No lift shall exceed 150 millimeters [6 inches] or be less than 75 millimeters [3 inches] when compacted. The lifts, when compacted after placement, shall 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 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 12 millimeters [1/2 inch].

240.3.7.2. 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 [12 inches]; however, the joint in the top layer shall be at the centerline of the pavement. Offset the transverse joints in one layer by at least 0.6 meter [2 feet] from the transverse joints in the previous layer. Offset the transverse joints in adjacent strips a minimum of 3 meters [10 feet].

240.3.7.3. Placing Adjacent Bituminous-stabilized Strips. Place the bituminous-stabilized material in consecutive adjacent strips having a minimum width of 3 meters [10 feet], except where edge lanes require strips less than 3 meters [10 feet] 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 [3 to 4 inches]. Ensure that 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.

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

240.3.8. Compaction Requirements. Accomplish compaction using rollers meeting the requirements of paragraph 240.3.1 and operating at a rolling speed of no greater than 2.4 kilometers per hour [1.5 miles per hour]. Compact each lift of drainage material, including shoulders that contain a drainage layer, 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. 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 240.3.12. 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 the bituminous-stabilized material immediately when the material has cooled to 77 °C [170 °F]. No more than 30 minutes shall elapse between the start of moist mixing of the cement-stabilized material and the start of field compaction. Complete field compaction within 60 minutes. In all places not accessible to the rollers, the drainage layer material shall be compacted with mechanical hand-operated tampers.

240.3.9. 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.

240.3.10. 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 until the surface is stable enough to support the water truck without deformation.

240.3.11. 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 [12-inch] width of the shoulder simultaneously with the rolling and compacting of each lift of the drainage layer.

240.3.12. Deficiencies.

240.3.12.1. 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 240.4), trim to grade and finish in accordance with paragraph 240.3.9. If the elevation of the top surface of the drainage layer is 12 millimeters [1/2 inch] or more below the required grade, scarify the surface of the drainage layer to a depth of at least 75 millimeters [3 inches], 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 12 millimeters [1/2 inch], correct by excavating to the required depth and replace with new material to obtain a compacted lift thickness of at least 75 millimeters [3 inches]. Control the depth of the required excavation to keep the final surface elevation within grade requirements and to preserve layer thicknesses of materials below the drainage layer.

240.3.12.2. 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 is determined.

240.3.12.3. 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.

240.4. Quality Control (QC) Testing.

240.4.1. Sampling. Take aggregate samples in accordance with ASTM D 75, *Standard Practice for Sampling Aggregates*. Take bituminous samples in accordance with ASTM D 140, *Standard Practice for Sampling Bituminous Materials*.

240.4.2. Test Methods. Complete sieve analyses in accordance with ASTM C 117, *Standard Test Method for Materials Finer Than 75 µm (No. 200) Sieve in Mineral Aggregates by Washing*, and ASTM C 136, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*. Complete field density tests in accordance with ASTM D 6938. Use this method to determine the moisture content of the aggregate drainage layer material. Check the calibration curves furnished with the moisture gauges along with density calibration checks as described in ASTM D 6938. Complete the calibration checks of both the density and moisture gauges by the prepared containers of material method, as described in paragraph "Calibration" of ASTM D 6938, on each different type of material being tested at the beginning of a job and at intervals as directed herein. Complete soundness tests in accordance with ASTM C 88. Complete Los Angeles abrasion tests in accordance with ASTM C 131. Complete flat and/or elongated particle tests in accordance with ASTM D 4791. When aggregates are supplied from crushed gravel, use the test methods stated herein to assure that the aggregate meets the requirements for fractured faces in paragraph 240.2.1. Complete bitumen extraction tests in accordance with ASTM D 2172.

240.4.3. Testing Frequency.

240.4.3.1. Aggregate Layer. Perform sieve analyses, field density, and moisture content tests at a rate of at least one test for every 1,000 square meters [1,200 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 1 test for every 10 sieve analysis tests.

240.4.3.2. Stabilized Layer. Perform sieve analyses on aggregates prior to adding asphalt or portland cement, at a rate of at least one test for every 1,000 square meters [1,200 square yards] 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 1 test for every 10 sieve analysis tests. Perform field density tests at a rate of at least one test for every 1,000 square meters [1,200 square yards] of completed area and not less than one test for each day’s production.

240.4.4. Smoothness Test. The surface of the top lift shall not deviate more than 12 millimeters [1/2 inch] when tested with a 3.6-meter [12-foot] straightedge applied parallel with and at right angles to the centerline of the area to be paved. Correct deviations exceeding 12 millimeters [1/2 inch] in accordance with paragraph 240.3.12.

240.4.5. Thickness Control. The completed thickness of the drainage layer shall be within 12 millimeters [1/2 inch] of the thickness indicated. Measure the 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 [3 inches] in diameter. Where the measured thickness is deficient by more than 12 millimeters [1/2 inch], correct such areas in accordance with paragraph 240.3.12. Where the measured thickness is 12 millimeters [1/2 inch] more than indicated, it will be considered as conforming to the requirements (if the grades are sufficient). The average job thickness shall be the average of all job measurements as specified above, but within 9.5 millimeters [3/8 inch] of the thickness shown on the drawings.

240.5. Unit Prices.

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NOTE: Delete unit price paragraphs when lump sum bidding is used. Edit the pay item descriptions to suit the project.

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240.5.1. Measurement.

240.5.1.1. Aggregate Drainage Layer. The quantity of drainage layer to be paid for shall be the number of square meters [yards] placed and accepted, for the depth specified. The choke stone shall be considered as part of the drainage layer thickness and shall not be measured separately.

240.5.1.2. Bituminous or Cement Stabilized Drainage Layer. The quantity of bituminous or cement-stabilized drainage layer to be paid for shall be the number of square meters [yards] placed and accepted, for the depth specified. The bituminous or cement stabilizing material shall not be measured separately for payment and shall be considered incidental to the pay item.

240.5.2. Payment.

240.5.2.1. The quantities of pay items, determined as specified above, will be paid for at the respective contract unit prices. Payment shall constitute full compensation for all operations necessary to complete the work as specified herein.

240.5.2.2. Payment will be made under:

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NOTE: Edit the pay item list to suit the project.

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Item 240-1	Aggregate Drainage Layer	per SM [SY]
Item 240-2	Bituminous Stabilized Drainage Layer	per SM [SY]
Item 240-3	Cement Stabilized Drainage Layer	per SM [SY]

240.6. Additional Reference. See ASTM D 1250, *Standard Guide for Use of the Petroleum Measurement Tables*.

AF 250
BASE AND SUBBASE COURSE

250.1. 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 250.2 for guidance on selecting materials suitable to meet a given minimum CBR base on gradation and particle shape.

250.2. Material. The Table 250-1 shall be used as guidance for selecting materials to meet given minimum CBR requirements. Materials meeting the requirements given in Table 250-1 can be assumed to provide the minimum CBR stated. For materials that do not meet all requirements, expedient field tests (dynamic cone penetrometer (DCP) or field CBR on compacted test fills) shall be performed on the material to determine the CBR. All base and subbase materials shall be comprised of sound, durable, and unweathered materials. Materials that are soft (break down under compaction or handling) shall not be used.

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NOTE: Designers should edit Table 250-1 to suit the project and eliminate unnecessary gradations.

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Table 250-1. Base and Subbase 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

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. 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 plasticity 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 crushed pit-run gravel where only a percentage of the material is crushed, these requirements shall 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, the CBR must be tested.

***This material gradation is provided for a base course under rigid pavement. The key point for 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.

250.3. Construction.

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

250.3.2. 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. Correct ruts or soft yielding spots in the underlying course by removing, replacing, and recompacting the unsatisfactory material. Do not place material in snow or on a soft, muddy, or frozen underlying course.

250.3.3. Placement. Place the material 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 shall be placed in no more than 152 millimeters [6 inches] and no less than 76 millimeters [3 inches] of compacted lift thickness. If the base or

subbase course is to be a mixture of different gradations, the gradations will be blended prior to placement, with no in-place proportioning.

250.3.3.1. 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 materials.

250.3.3.2. 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.

250.3.4. Moisture Content. The moisture content shall be adjusted to ±3% of optimum to facilitate compaction.

250.3.5. Density. Each layer will be compacted to 100% maximum density using the modified effort as determined by American Society for Testing and Materials (ASTM) D 1557, *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft–lbf/ft^3 (2,700 kN-m/m^3))*.

250.3.6. Surface Smoothness. The surface layer will not show deviations in excess of 9.5 millimeters [3/8 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.

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

250.4. Quality Control (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 the statistical procedures in ASTM D 3665, *Standard Practice for Random Sampling of Construction Materials*.

250.4.1. Density. Take one density test from each sublot. The density will be at least 100% of the maximum density of the laboratory specimens prepared from samples of the material delivered to the job site. 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-Cone Method*, or ASTM D 2167*, Standard Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method*. ASTM D 6938,

Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate 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.

250.4.2. Surface Smoothness. Tests for surface smoothness will be a 3.6-meter [12-foot] straightedge applied with and at right angles to the centerline of the area to ensure that the surface layer will not show deviations in excess of 9.5 millimeters [3/8 inch]. Tests will be taken randomly, at least one test for each sublot.

250.4.3. 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 [1 inch] deficient will be reworked by scarifying the surface, adding material to the surface, and recompacting. Areas greater than 25 millimeters [1 inch] in required layer thickness will be considered acceptable as long as surface smoothness requirements are met.

250.4.4. Gradation. Gradation tests will be taken every 4180 square meters [5000 square yards] of base or subbase placement.

250.5. Quality Assurance (QA). Testing requirements stated above are for QC. QA testing shall be accomplished at the rate of 1 QA test for every 10 QC tests.

250.6. Unit Prices.

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NOTE: Delete unit price paragraphs when lump sum bidding is used. Edit the pay item descriptions to suit the project.

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250.6.1. Measurement.

250.6.1.1. Aggregate Base Course (by area). The quantity of aggregate base course to be paid for shall be the number of square meters [yards] completed and accepted, for the depth specified.

250.6.1.2. Aggregate Base Course (by volume). The quantity of aggregate base course to be paid for shall be the number of cubic meters [yards] completed and accepted. The volume of material in-place and accepted shall be determined by the average job thickness and the dimensions shown in the drawings.

250.6.1.3. Aggregate Base Course (by weight). The quantity of aggregate base course to be paid for shall be the number of metric tons [tons] completed and accepted. Deductions shall be made for any material wasted, unused, rejected, or used for the convenience of the Contractor, and for water exceeding the specified amount at the time of weighing.

250.6.1.4. Subbase Course (by area). The quantity of subbase course to be paid for shall be the number of square meters [yards] completed and accepted, for the depth specified.

250.6.1.5. Subbase Course (by volume). The quantity of subbase course to be paid for shall be the number of cubic meters [yards] completed and accepted. The volume of material in-place and accepted shall be determined by the average job thickness and the dimensions shown in the drawings.

250.6.1.6. Subbase Course (by weight). The quantity of subbase course to be paid for shall be the number of metric tons [tons] completed and accepted. Deductions shall be made for any material wasted, unused, rejected, or used for the convenience of the Contractor, and for water exceeding the specified amount at the time of weighing.

250.6.2. Payment.

250.6.2.1. The quantities of pay items, determined as specified above, will be paid for at the respective contract unit prices. Payment shall constitute full compensation for all operations necessary to complete the work as specified herein.

250.6.2.2. Payment will be made under:

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NOTE: Edit the pay item list to suit the project.

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Item 250-1	Aggregate Base Course, [__] Depth	per SM [SY]
Item 250-2	Aggregate Base Course	per CM [CY]
Item 250-3	Aggregate Base Course	per metric ton [ton]
Item 250-4	Subbase Course, [__] Depth	per SM [SY]
Item 250-2	Subbase Course	per CM [CY]
Item 250-3	Subbase Course	per metric ton [ton]

AF 400
ASPHALT PRIME AND TACK COAT

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

400.2. Materials. The selection of a prime or tack coat material will be based on material availability. Paragraphs 400.2.1 through 400.2.2.3 give guidance on material selection.

400.2.1. Tack Coat Material.

400.2.1.1. Cutback asphalt shall conform to American Society for Testing and Materials (ASTM) D 2028, *Standard Specification for Cutback Asphalt (Rapid-Curing Type)*, cutback grades RC-70 or RC-250. These materials perform better than emulsions in cool weather construction.

400.2.1.2. Paving grade asphalt shall conform to Table 400-1. The harder grades, penetration grade 85-100 and viscosity grades AC 10 or AR 4000, are recommended for airfield pavements.

Table 400-1. Paving Grade Asphalt Standards

ASTM Standard	Grade
ASTM D 946, *Standard Specification for Penetration-Graded Asphalt Cement for Use in Pavement Construction*	Penetration grade 200-300, 120-150, or 85-100
ASTM D 3381, *Standard Specification for Viscosity-Graded Asphalt Cement for Use in Pavement Construction*	Viscosity grade AC 2.5, AC 5, or AC 10
ASTM D 3381	Aged residue viscosity grades AR 1000, AR 2000, or AR 4000

400.2.1.3. Emulsions, either anionic or cationic, can be used for tack coats. Anionic emulsion shall conform to ASTM D 977*, Standard Specification for Emulsified Asphalt*, grades RS-1, MS-1, HFMS-1, SS-1 or SS-1h. Cationic emulsions shall conform to 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.

400.2.2. Prime Coat Material.

400.2.2.1. Cutback asphalt shall conform to Table 400-2.

Table 400-2. Cutback Asphalt Standards

ASTM Standard	Cure	Type
ASTM D 2026, *Standard Specification for Cutback Asphalt (Slow-Curing Type)*	Slow cure	Type SC-70 or SC-250
ASTM D 2027, *Standard Specification for Cutback Asphalt (Medium-Curing Type)*	Medium cure	Type MC-30, MC-70, or MC-250
ASTM D 2028, *Standard Specification for Cutback Asphalt (Rapid-Curing Type)*	Rapid cure	Type RC-70 or RC-250

400.2.2.2. Selection of a particular type and grade shall consider the nature of the surface to be treated. An open base course material will be penetrated readily, and all of the types and grades in Table 400-2 can be considered except for the low-viscosity MC-30. A tight surface will not be penetrated as readily; therefore, the less viscous materials are recommended, such as RC-70, MC-30, MC-70, and SC-70. Use caution when 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.

400.2.2.3. Emulsions, either anionic or cationic, can be used. Anionic emulsion shall conform to ASTM D 977, grades SS-1 or SS-1h. Cationic emulsions shall conform to 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.

400.3. Construction.

400.3.1. 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 shall be damp.

400.3.2. 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 the Contractor carries out repairs, those repairs will be at no additional cost to the Government).

400.3.3. Application Rate. The application rates specified in this paragraph are the rates for the asphalt residue content and do not account for the water or solvent if an emulsion or cutback is used. Prime coats shall be applied at the rate of 0.7 to 1.8 liters

per square meter [0.15 to 0.40 gallon per square yard]. Tack coats shall be applied at the rate of 0.2 to 0.7 liter per square meter [0.05 to 0.15 gallon per square yard]. If, at the prescribed application rate, the material flows off the surface, the application rate shall be reduced to one-half the total amount and applied in two separate applications, 24 hours apart.

400.3.4. 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 gauges, 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.

400.3.5. Application Temperature. The 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 400-3 shows the normal application temperatures for each material type.

Table 400-3. Application Temperatures

Liquid Asphalt	
SC-70	50-107 °C [120-225 °F]
SC-250	75-132 °C [165-270 °F]
MC-30	29-87 °C [85-190 °F]
MC-70	50-107 °C [120-225 °F]
MC-250	75-132 °C [165-270 °F]
RC-70	50-90 °C [120-200 °F]
RC-250	75-120 °C [165-250 °F]
Viscosity Grade Asphalt	
AC 2.5	+132 °C [+270 °F]
AC 5	+137 °C [+280 °F]
AC 10	+137 °C [+280 °F]
AR 1000	+135 °C [+275 °F]
AR 2000	+140 °C [+285 °F]
AR 4000	+143 °C [+290 °F]

Penetration Grade Asphalt	
200-300	+130 °C [+265 °F]
120-150	+132 °C [+270 °F]
85-100	+137 °C [+280 °F]
Emulsions	
RS-1	20-60 °C [70-140 °F]
MS-1	20-70 °C [70-160 °F]
HFMS-1	20-70 °C [70-160 °F]
SS-1	20-70 °C [70-160 °F]
SS-1h	20-70 °C [70-160 °F]
CRS-1	52-85 °C [125-185 °F]
CSS-1	20-70 °C [70-160 °F]
CSS-1h	20-70 °C [70-160 °F]

400.3.6. Application. Asphalt material shall 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.

400.3.7. Curing Period. Following application of the asphalt material and prior to application of the succeeding layer of pavement, the asphalt coat shall 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.

400.4. Quality Control (QC) Testing.

400.4.1. The application rate and application temperature shall be checked periodically to ensure that 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 the 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 the check the application rate is by comparing weigh bills to the amount of area covered.

400.4.2. Quality assurance (QA) shall consist of checking computations on calibration and observing surfaces to see that uniform applications are being obtained.

400.5. Unit Prices.

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NOTE: Delete unit price paragraphs when lump sum bidding is used. Edit the pay item descriptions to suit the project.

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400.5.1. Measurement.

400.5.1.1. Bituminous Material. The quantity of bituminous material to be paid for shall be the number of liters [gallons] applied and accepted, provided that the measured quantities are not 10% over the specified application rate. Measured quantities shall be expressed in liters at 15.6 °C [gallons at 60 °F]. Volumes measured at temperatures other than 15.6 °C [60 °F] shall be corrected in accordance with ASTM D 1250, *Standard Guide for Use of the Petroleum Measurement Tables*. Water added to emulsified asphalt shall not be measured for payment.

400.5.2. Payment.

400.5.2.1. The quantities of pay items, determined as specified above, will be paid for at the respective contract unit prices. Payment shall constitute full compensation for all operations necessary to complete the work as specified herein.

400.5.2.2. Payment will be made under:

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NOTE: Edit the pay item list to suit the project.

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Item 400-1	Bituminous Tack Coat	per liter [gallon]
Item 400-2	Bituminous Prime Coat	per liter [gallon]

AF 410
HOT-MIX ASPHALT (HMA) FOR AIRFIELDS

410.1. General. This specification covers the requirements for the construction of hot-mix asphalt (HMA) for airfields. This specification is intended to stand alone for construction of HMA pavement; however, where the construction covered herein interfaces with other specifications, the construction at each interface shall conform to the requirements of both this specification and the other specification, including tolerances for both.

410.2. Material.

410.2.1. Aggregates. Aggregates shall 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.

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

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

410.2.1.1.2. The sodium sulfate soundness loss shall not exceed 12%, or the magnesium sulfate soundness loss shall not exceed 18% after five cycles when tested in accordance with ASTM C 88, *Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate*.

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

410.2.1.1.3. At least 75% by weight of coarse aggregate retained on the 4.75-millimeter [No. 4] sieve and each coarser size shall have at least two or more fractured faces when tested in accordance with U.S. Army Corps of Engineers (COE) CRD-C 171, *Standard Test Method for Determining Percentage of Crushed Particles in Aggregate*. Fractured faces shall be produced by crushing.

410.2.1.1.4. The particle shape shall be essentially cubical and the aggregate contain no more than 20% by weight of flat and elongated particles (3:1 ratio of maximum to minimum) when tested in accordance with ASTM D 4791, *Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate*.

410.2.1.1.5. Slag shall 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, *Standard Test Method for Bulk Density (Unit Weight) and Voids in Aggregate*.

410.2.1.1.6. Clay lumps and friable particles shall not exceed 0.3% by weight when tested in accordance with ASTM C 142, *Standard Test Method for Clay Lumps and Friable Particles in Aggregates*.

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

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

410.2.1.2.2. The fine aggregate shall have a sand equivalent value greater than 45 when tested in accordance with ASTM D 2419, *Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate*.

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

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

410.2.1.3. Mineral Filler. Mineral filler shall be nonplastic material meeting the requirements of ASTM D 242, *Standard Specification for Mineral Filler for Bituminous Paving Mixtures*.

410.2.1.4. Aggregate Gradation. The combined aggregate gradation shall conform to gradations specified in Table 410-1 when tested in accordance with ASTM C 136, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*, and ASTM C 117, *Standard Test Method for Materials Finer Than 75 µm (No. 200) Sieve in Mineral Aggregates by Washing*, 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: Generally the layer thickness shall be at least three times the nominal aggregate size shown in Table 410-1.

Table 410-1. Aggregate Gradations

Sieve Size	Nominal Percent Passing by Mass
	Gradation 2
	12.5 mm [0.5 in]
25 mm [1 in]	100
19 mm [0.75 in]	100
12 mm [0.5 in]	76-96
9.5 mm [0.375 in]	69-89
4.75 mm [No. 4]	53-73
2.36 mm [No. 8]	38-60
1.18 mm [No. 16]	26-48
0.60 mm [No. 30]	18-38
0.30 mm [No. 50]	11-27
0.15 mm [No. 100]	6-18
0.075 mm [No. 200]	3-6

410.2.2. Asphalt Cement Binder. Asphalt cement binder will conform to American Association of State Highway and Transportation Officials (AASHTO) M 320, *Standard Specification for Performance-Graded Asphalt Binder*, PG 70-22; ASTM D 3381, *Standard Specification for Viscosity-Graded Asphalt Cement for Use in Pavement Construction*, Table 2, Viscosity Grade AC-20; or ASTM D 946, *Standard Specification for Penetration-Graded Asphalt Cement for Use in Pavement Construction*, Penetration Grade 60-70.

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

410.2.3. Mix Design. Design the mix in accordance with Asphalt Institute (AI) MS-2, *Mix Design Methods*, and the criteria in Table 410-2. If the tensile strength ratio (TSR) of the composite mixture as determined by ASTM D 4867/D 4867M, *Standard Test Method for Effect of Moisture on Asphalt Concrete Paving Mixtures*, is less than 75, treat the aggregate with an approved antistripping agent. The amount of antistripping agent added shall be sufficient to produce a TSR of not less than 75.

Table 410-2. Marshall Design Criteria

Test Property	75 Blow Mix	50 Blow Mix
Stability (minimum)	9.56 kN [2150 lb]*	6.0 kN [1350 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 410-3	See Table 410-3
Dust Proportion	0.8-1.2%	0.8-1.2%
TSR (minimum)	75%	75%

*This is a minimum requirement. The average during construction shall 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 or overruns. Disregard the mix column (50 blow mix or 75 blow mix) that does not apply, unless the project includes both 75 blow and 50 blow mixes.

Table 410-3. Minimum Percent Voids in Mineral Aggregate (VMA)

Aggregate (See Table 410-1)	Minimum VMA*
Gradation 2	14%

*Calculate VMA in accordance with AI MS-2 and based on the bulk specific gravity for the aggregate according to ASTM D 2726, *Standard Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures*.

Note: Select the appropriate gradation and VMA requirements consistent with the gradation in Table 410-1.

410.2.4. Recycled HMA.

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NOTE: Reclaimed asphalt pavement (RAP) shall not be used for surface mixes, except on shoulders and overruns; however, it can be used very effectively in lower layers, or for shoulders and overrun surfaces. In lower layers, shoulders, and overruns, the Contractor shall be able to use RAP up to 30% as long as the resulting recycled mix meets all requirements that are specified for virgin mixtures. Remove these paragraphs if RAP is not used.

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410.2.4.1. Recycled HMA shall consist of RAP, coarse aggregate, fine aggregate, mineral filler, and asphalt cement. The RAP shall be of a consistent gradation and asphalt content and properties. When RAP is fed into the plant, the maximum RAP chunk size shall not exceed 50 millimeters [2 inches]. The recycled HMA mix shall be designed using procedures contained in AI MS-2. The job mix shall meet the requirements of paragraph 410.2.3. RAP shall be used only for shoulder or overrun surface course mixes and for any intermediate courses. The amount of RAP shall be limited to 30%.

410.2.4.2. RAP Aggregates and Asphalt Cement. The blend of aggregates used in the recycled mix shall meet the requirements of paragraph 410.2.1. The percentage of asphalt in the RAP shall be established for the mixture design according to ASTM D 2172, *Standard Test Method for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures*, using the appropriate duct correction procedure.

410.2.4.3. RAP Mix. The blend of new asphalt cement and the RAP asphalt binder shall meet the dynamic shear rheometer (for PG-grade asphalts), penetration (for penetration-grade asphalts), or viscosity (for viscosity-grade asphalts) requirements in paragraph 410.2.2. The virgin asphalt cement shall not be more than two standard asphalt material grades different than that specified in paragraph 410.2.2.

410.2.5. Bituminous Tack Coat. Bituminous tack coat shall conform to section AF 400 ASPHALT PRIME AND TACK COAT.

410.3. Construction.

410.3.1. Preparation of Asphalt Binder Material. Heat the asphalt cement material 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 unmodified asphalt delivered to the mixer shall be sufficient to provide a suitable viscosity for adequate coating of the aggregate particles, but shall not exceed 160 °C [325 °F]. Modified asphalt shall be no more than 177 °C [350 °F] when added to the aggregates.

410.3.2. Preparation of Mineral Aggregate. Heat and dry the aggregate for the mixture prior to mixing. The maximum temperature and rate of heating shall be such that no damage occurs to the aggregates. The temperature of the aggregate and mineral filler shall not exceed 177 °C [350 °F] when the asphalt cement is added. The temperature shall not be lower than is required to obtain complete coating and uniform distribution on the aggregate particles and to provide a mixture of satisfactory workability.

410.3.3. Rollers. Rollers shall 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 shall be sufficient to compact the mixture to the required density while the mixture is still in a workable condition. Do not use equipment that causes excessive crushing of the aggregate.

410.3.3.1. The following paragraphs outline a good rolling pattern:

410.3.3.1.1. Steel wheel breakdown rolling – two coverages only.

410.3.3.1.2. Rubber tire intermediate rolling – at least eight coverages.

410.3.3.1.3. Steel wheel finish rolling – sufficient coverages to remove roller marks. (Usually three coverages are adequate.)

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

410.3.3.3. These weights are recommended for compacting airfield pavements:

410.3.3.3.1. Steel wheel breakdown roller – 9 metric tons [10 tons].

410.3.3.3.2. Rubber tire intermediate roller – 22.6 to 27.2 metric tons [25 to 30 tons]; tire pressure a minimum of 0.62 megapascal [90 pounds per square inch].

410.3.3.3.3. Steel wheel finish roller – 9 metric tons [10 tons].

410.3.4. Preparation of the Underlying Surface. Immediately before placing the HMA, the underlying course shall be cleaned of all dust and debris. Apply a prime coat and/or tack coat, as required.

Note: If the underlying surface to be paved is an unbound granular layer, apply a prime coat, especially if this layer will be exposed to weather for an extended period prior to covering with an asphalt mixture. Apply the prime coat after the base course is completed, with another coat added just before paving with HMA. A prime coat provides a number of benefits: adding an additional weatherproofing 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, always use a tack coat to ensure an adequate bond between layers. Place the tack coat directly prior to paving with HMA.

410.3.5. Placing of the Asphalt Mix. Place and compact the mix 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]. When the mixture arrives, place it to the full width using an asphalt paver. It shall 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. Regulate the speed of the paver 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 [10 feet]. Offset the longitudinal joint in one course with the longitudinal joint in the course immediately below by at least 0.3 meter [1 foot]; however, the joint in the surface course shall be at the centerline of the pavement. Offset transverse joints in one

course by at least 3 meters [10 feet] from transverse joints in the previous course. Offset transverse joints in adjacent lanes by a minimum of 3 meters [10 feet]. On isolated areas where irregularities or unavoidable obstacles make the use of mechanical spreading and finishing equipment impractical, the mixture may be spread and luted by hand tools.

410.3.6. Compaction of Mixture. After placing the mixture, thoroughly and uniformly compact it by rolling. Compact the surface 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. Do not make more than three passes with a vibratory roller in the vibrating mode.

410.3.6.1. At all times, the speed of the roller shall be sufficiently slow to avoid displacement of the hot mixture and be effective in compaction. Immediately correct any displacement occurring as a result of reversing the direction of the roller, or from any other cause. Make sure there are sufficient rollers to handle the output of the plant. Continue rolling 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.

410.3.6.2. 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, shall be removed full depth and replaced with fresh hot mixture and immediately compacted to conform to the surrounding area. Skin patching is not allowed.

410.3.7. Joints. Form all joints in such a manner as to ensure a continuous bond between the courses and obtain the required density. All joints shall have the same texture as other sections of the course and meet the requirements for smoothness and grade.

410.3.7.1. Transverse Joints. The roller shall not pass over the unprotected end of the freshly laid mixture except when necessary to form a transverse joint. When necessary to form a transverse joint, place a bulkhead or taper the course. Cut back the tapered edge to its full depth and width on a straight line to expose a vertical face prior to placing the adjacent lane. Remove the cutback material from the project. In both methods, apply a light tack coat of asphalt material to all contact surfaces before placing any fresh mixture against the joint.

410.3.7.2. Longitudinal Joints. Cut back longitudinal joints that are irregular, damaged, uncompacted, cold, or otherwise defective, a minimum of 75 millimeters [3 inches] with a cutting wheel to expose a clean, sound surface for the full depth of the course. Remove all cutback material from the project. Apply a light tack coat of asphalt material to all contact surfaces prior to placing any fresh mixture against the joint.

410.3.8. Test Section.

410.3.8.1. If possible, place a test section for each job-mix formula (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 the best results. The test section shall be of the same depth as the course that it represents. The underlying grade or pavement structure upon which the test section is to be constructed shall be the same as the remainder of the course represented by the test section. The equipment used in construction of the test section shall be the same equipment used on the remainder of the course represented by the test section.

410.3.8.2. If the initial test section is unacceptable, make the necessary adjustments to the JMF, plant operation, placing procedures, and/or rolling procedures. Then place a second test section. Additional test sections, as required, shall be constructed and evaluated for conformance to the specifications.

410.3.9. Bituminous Butt Joint. The removal of bituminous pavement may be completed with the use of mill machines or other approved devices. The butt joint shall be constructed as indicated in the plans. Removed material shall be disposed of off Government property. Prior to any surface removal, the bituminous butt joint shall be sawed to the minimum depth indicated in the plans. Construction of the joint shall result in a straight joint perpendicular to the paving direction. Prior to placement of new bituminous material, bituminous tack coat shall be applied to the joint surface and vertical edges. The bituminous tack coat shall be in accordance with section AF 400 ASPHALT PRIME AND TACK COAT.

410.4. Quality Control (QC) Testing.

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

410.4.1. Asphalt Content. A minimum of two tests to determine asphalt content will be performed per lot by 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 each method is calibrated for the specific mix being used. For the extraction method, determine the weight of ash, as described in ASTM D 2172, as part of the first extraction test performed at the beginning of plant production and as part of every tenth extraction test performed thereafter, for the duration of plant production. The last weight of ash value obtained shall be used in the calculation of the asphalt content for the mixture.

410.4.2. Gradation. Determine aggregate gradations at least twice per lot from mechanical analysis of recovered aggregate in accordance with ASTM D 5444, *Standard Test Method for Mechanical Size Analysis of Extracted Aggregate*. When asphalt content is determined by the nuclear method, determine aggregate gradation from hot bin samples on batch plants, or from the cold feed on drum mix plants. For

batch plants, test aggregates in accordance with ASTM C 136, using actual batch weights to determine the combined aggregate gradation of the mixture.

410.4.3. 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.

410.4.4. Aggregate Moisture. Determine the moisture content of aggregate used for production at least once per lot in accordance with ASTM C 566, *Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying.*

410.4.5. Moisture Content of Mixture. Determine the moisture content of the mixture 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.

410.4.6. Laboratory Air Voids and Density. For air void and density testing, divide each lot into four equal sublots. Take one random mixture sample for determining laboratory air voids and theoretical maximum density (TMD) from a loaded truck delivering the mixture to each sublot, or other appropriate location for each sublot. Select all samples randomly, using commonly recognized methods of assuring randomness (ASTM D 3665, *Standard Practice for Random Sampling of Construction Materials*) and employing tables of random numbers or computer programs. Determine laboratory air voids from three laboratory-compacted specimens of each sublot sample in accordance with AASHTO T 245, *Standard Method of Test for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus*. Compact the specimens within 2 hours of the time the mixture was loaded into trucks at the asphalt plant. Do not reheat samples prior to compaction, and use insulated containers as necessary to maintain the temperature. Calculate laboratory air voids 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.* Determine the TMD 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 shall use the latest TMD values obtained, either for that sublot or the previous sublot. Determine the mean absolute deviation of the four laboratory air void contents (one from each sublot) from the JMF air void content. The Government will complete all laboratory air void tests within 24 hours after completion of construction of each lot.

410.4.6.1. Air Voids. The mean absolute deviation of the laboratory air voids from the JMF shall be 0.60 or less for full payment. If the mean absolute deviation is greater than 0.60 but less than 1.20, the lot shall be paid at 90% of the unit price. If the mean absolute deviation is greater than 1.20, the lot shall be removed and replaced at no additional cost to the Government.

410.4.7. In-place Density. For determining in-place density, one random core will be taken from the mat (interior of the lane) of each sublot, and one random core will be

taken from the joint of each sublot. (The core shall be centered over the joint with approximately 50% of the material from the mat on each side of the joint.) Each random core will be the full thickness of the layer being placed. When the random core is less than 25 millimeters [1 inch] thick, it will not be included in the analysis; in this case, another random core will be taken. After air drying the cores to a constant weight, use cores obtained from the mat and from the joints 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). Determine both the average in-place mat density and joint density for each lot. 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. Complete and report all density results for a lot within 24 hours after the construction of that lot.

410.4.7.1. Mat Density. The average mat density for each lot shall be greater than or equal to 94.0% but less than or equal to 96.0% of the TMD. Lots with an average mat density greater than 92.0% and less than 94.0% or greater than 96.0% and less than or equal to 97.0% of the TMD shall be paid at 75% of the unit price. Lots with an average mat density less than 92.0% or greater than 97.0% of the TMD shall be removed and replaced at no additional cost to the Government.

410.4.7.2. Joint Density. The average joint density for each lot shall be greater than 92.5% of the TMD. Lots with an average joint density greater than 90.5% and less than or equal to 92.5% of the TMD shall be paid at 75% of the unit price. Lots with an average joint density less than or equal to 90.5% of the TMD shall be removed and replaced at no additional cost to the Government.

410.4.8. Grade. Test the final wearing surface of the pavement for conformance with the grades shown in the plans. 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.

410.4.9. Smoothness. After completion of the final rolling of a lot, the inspector will test the final wearing surface with a 3.6-meter [12-foot] straightedge. Take measurements parallel to and across all joints at equal distances along the joint not to exceed 7.6 meters [25 feet]. Record locations that fail the straightedge test. Use the tolerance criteria in Table 410-4.

Table 410-4. Surface Smoothness Tolerance

Pavement Category	Direction of Testing	Tolerance
Runways and taxiways	Longitudinal transverse	3 mm [0.125 in]
		6 mm [0.25 in]
All other airfields and helicopter paved areas	Longitudinal transverse	6 mm [0.25 in]
		6 mm [0.25 in]

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

410.4.10.1. As an example, the criteria in Table 410-5 and Table 410-6 were specified for an airfield project.

Table 410-5. Sample Aggregate Gradation Criteria

Sieve Size	Percentage Passing
25 mm [1 in]	100
19 mm [0.75 in]	100
12.5 mm [0.5 in]	76-96
9.5 mm [0.375 in]	69-89
4.75 mm [No. 4]	53-73
2.36 mm [No. 8]	38-60
1.18 mm [No. 16]	26-48
0.6 mm [No. 30]	18-38
0.3 mm [No. 50]	11-27
0.15 mm [No. 100]	6-18
0.075 mm [No. 200]	3-6

Table 410-6. 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

410.4.10.2. The aggregates from the three stockpiles shown in Table 410-7 were combined to meet the specification.

Table 410-7. Sample Stockpile Aggregates

Sieve Size	Percentage From Each Stockpile			Combined Gradation
	Stockpile 1 55%	Stockpile 2 25%	Stockpile 3 20%	
25 mm [1 in]	100	100	100	100.00
19 mm [0.75 in]	100	100	100	100.00
12.5 mm [0.5 in]	70	100	100	83.50
9.5 mm [0.375 in]	55	90	100	72.75
4.75 mm [No. 4]	30	85	98	57.35
2.36 mm [No. 8]	20	70	94	47.30
1.18 mm [No. 16]	8	42	85	31.90
0.6 mm [No. 30]	6	25	67	22.95
0.3 mm [No. 50]	5	15	50	16.50
0.15 mm [No. 100]	4	10	25	9.70
0.075 mm [No. 200]	2	6	10	4.60

410.4.10.3. The mix was designed in accordance with AI MS-2 and obtained these mix properties:

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

410.4.10.4. A plot of the proposed gradation (Figure 410-1) indicates that it is well graded and falls within the gradation band in the specification. Since all other mix properties meet the specification, the JMF is acceptable. If the test results exceed tolerances, adjustments shall 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 the test results and trends.

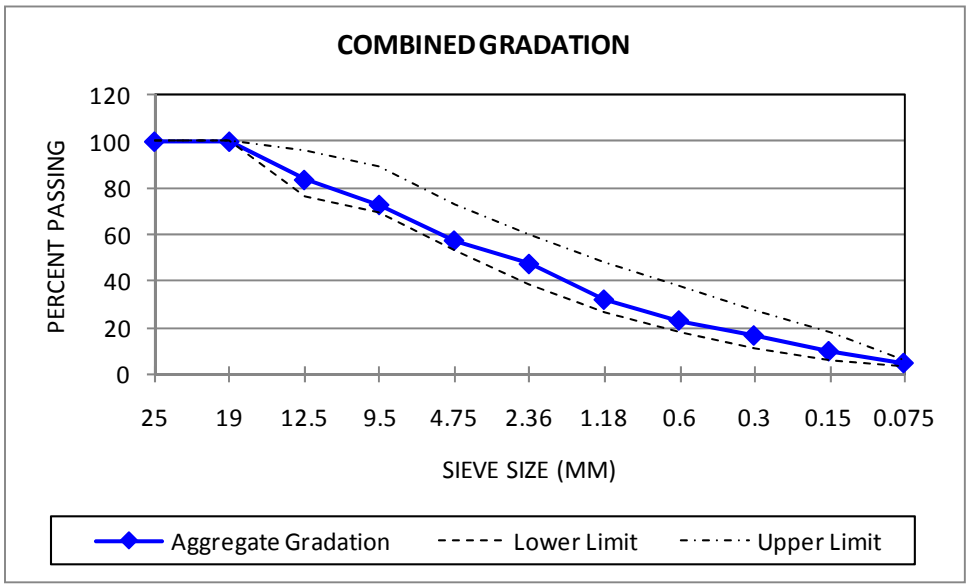

Figure 410-1. Proposed Gradation Plot

410.4.11. Additional Tests. These tests are also required for QC:

410.4.11.1. Aggregate Tests.

410.4.11.1.1. Aggregate Gradation (ASTM C 136). Ensure that gradation meets the requirements of the JMF.

410.4.11.1.2. Los Angeles Abrasion Test (ASTM C 131). This test is a measure of abrasion resistance.

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

410.4.11.1.4. Fractured Faces (COE CRD-C 171). This test is very important. Compare to the specification. Mixes with improperly crushed aggregate may be difficult to compact, lack stability, provide low skid resistance, and tend to strip.

410.4.11.1.5. 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%.

410.4.11.2. Asphalt Concrete Tests (AI MS-2):

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

410.4.11.2.2. Marshall Flow. Compare to the 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.

410.4.11.2.3. 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.

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

410.4.11.2.5. VMA. This is intergranular void space between aggregate particles—essentially, the sum of air voids plus effective asphalt cement content (not counting asphalt cement absorbed by aggregates) expressed as a percentage of bulk volume of compacted mix.

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

410.4.12. Control Charts. Use control charts for process control. Linear control charts on both individual samples and the running average of the last four samples for the parameters listed in Table 410-8 are recommended (to be plotted on individual and running average control charts). These control charts are to be posted in a satisfactory location and shall 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, and the test results. Also show target values from the JMF on the control charts as indicators of the central tendency for the cumulative percentage passing, asphalt content, and laboratory air void parameters. When the test results exceed the applicable action limit in Table 410-8 for either the individual samples or the running average of the last four samples, 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 410-8. 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 (75-blow mix)	7830 N [1760 lb]	7290 N [1640 lb]	9560 N [2150 lb]	9030 N [2030 lb]
Stability, minimum (50-blow mix)	4230 N [950 lb]	3690 N [830 lb]	6000 N [1350 lb]	5470 N [1230 lb]
Flow, 0.25 mm [0.01 in] (75-blow mix)	8-16	7-17	9-15	8-16
Flow, 0.25 mm [0.01 in] (50-blow mix)	8-18	7-19	9-17	8-18
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			

410.4.13. Inspector Checklist for Asphalt Concrete Pavement. Table 410-9 is a partial checklist to assist the inspector.

Table 410-9. Asphalt Concrete Pavement Checklist

Task	Yes	No
Crushed face results meet specification requirement?		
Natural sand within specification limits?		
Aggregate gradation complies with JMF?		
Asphalt cement has been tested and meets specification?		
Mix design conducted in accordance with AI 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 because 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?		
Tack coat used to bond overlays?		
Stringline used for grade control?		
Grade and smoothness checked and results reported?		
Cores obtained and tested for QA densities? (A nuclear density gauge can be used to control density but shall not be used for acceptance.)		
Asphalt content compared to JMF?		
All deficiencies noted in diary and corrected?		
Joints cut back to obtain required density?		
Control charts reviewed daily?		

Table 410-10. 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

Problem	Symptom	Test	Potential Cause
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

Problem	Symptom	Test	Potential Cause
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

410.5. Unit Prices.

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NOTE: Delete unit price paragraphs when lump sum bidding is used. Edit the pay item descriptions to suit the project.

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410.5.1. Measurement.

410.5.1.1. HMA for Airfields (by area). The quantity of HMA for airfields to be paid for shall be the number of square meters [yards] completed and accepted, for the depth specified.

410.5.1.2. HMA for Airfields (by weight). The quantity of HMA for airfields to be paid for shall be the number of metric tons [tons] completed and accepted. Deductions shall be made for any material wasted, unused, rejected, or used for convenience of the Contractor.

410.5.1.3. Bituminous Butt Joint. The quantity of bituminous butt joint construction to be paid for shall be the number of square meters [square yards] measured, completed, and accepted.

410.5.2. Payment.

410.5.2.1. The quantities of pay items, determined as specified above, will be paid for at the respective contract unit prices. Payment shall constitute full compensation for all operations necessary to complete the work as specified herein.

410.5.2.2. Payment will be made under:

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NOTE: Edit the pay item list to suit the project.

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Item 410-1	HMA for Airfields, [__] Depth	per SM [SY]
Item 410-2	HMA for Airfields	per metric ton [ton]
Item 410-3	Bituminous Butt Joint Construction	per SM [SY]

AF 420
ASPHALT PAVEMENT REPAIR

420.1. General. This specification covers the requirements for repairing distressed bituminous pavements.

420.2. Materials.

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NOTE: Choose American Society for Testing and Materials (ASTM) D 6690, Standard Specification for Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavements*, Type II sealant for areas that will experience pedestrian traffic, such as aprons, because it has a high modulus of elasticity and therefore should not adhere to pedestrians' shoes.*

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420.2.1. Sealants shall conform to ASTM D 6690, Type II, or ASTM D 6690, Type I.

420.2.2. Backup materials (backer rod) shall be compressible, nonshrinking, nonstaining, nonabsorptive, and nonreactive with the crack sealant. The melting point of the backup material shall be at least 2 ºC [5 ºF] greater than the maximum pouring temperature of the sealant being used, when tested in accordance with ASTM D 789, *Standard Test Methods for Determination of Solution Viscosities of Polyamide (PA)*. The material shall have water absorption of not more than 5% by weight when tested in accordance with ASTM C 509, *Standard Specification for Elastomeric Cellular Preformed Gasket and Sealing Material*. The backup material shall be 25% (plus or minus 5%) larger in diameter than the nominal width of the crack.

420.2.3. Crack/Joint Filler. Bituminous sand mix shall conform to the requirements listed in Table 420-1. The ingredients shall be heated and combined in such a manner as to produce a bituminous mixture that, when discharged from the mixer, shall not be more than 177 ºC [350 ºF].

Table 420-1. Sand Mix for Crack Filler Requirements

Sieve	% Passing
9.5 mm [3/8 in]	100
4.75 mm [No. 4]	94-100
1.18 mm [No. 16]	45-85
0.30 mm [No. 50]	10-30
0.15 mm [No. 100]	0-10
Asphalt	**% by Weight**
PG 64-22	4-7

420.3. Equipment.

420.3.1. Routing Equipment. The routing equipment shall be a self-powered machine operating a power driven tool or bit specifically designed for routing bituminous pavements. The bit shall rotate about a vertical axis at sufficient speed to cut a smooth vertical-walled reservoir in the pavement surface and shall maintain accurate cutting without damaging the sides or top edges of the reservoir. The router shall be capable of following the trace of the crack without deviation.

420.3.2. Concrete Saw. A self-propelled power saw with small diameter (150 millimeters [6 inches] or less) water-cooled diamond or abrasive saw blades shall be provided for cutting cracks to the depths and widths indicated in the plans, and for removing filler that is embedded in the cracks or adhered to the crack faces. The diameter of the saw blade shall be small enough to allow the saw to closely follow the trace of the crack.

420.3.3. Crack Sealing Equipment. The unit applicators used for heating and installing the hot-poured crack sealant materials shall be mobile and shall be equipped with a double-boiler, agitator-type kettle with an oil medium in the outer space for heat transfer; a direct connected pressure-type extruding device with a nozzle shaped for inserting in the crack to be filled; and positive temperature devices for controlling the temperature of the sealant. The applicator unit design shall allow the sealant to circulate through the delivery hose and return to the inner kettle when not in use.

420.3.4. Bituminous Pavement Milling Equipment. The bituminous pavement milling equipment shall be subject to approval by the Government. All equipment used shall comply with the requirements in paragraph 420.3.4.1.

420.3.4.1. Surface removal equipment shall be a power operated mechanical scarifier, roto-mill, planing machine, grinder, or other device capable of removing the surface to the depth shown in the plans and leaving a sound, bondable surface. The equipment shall be in good working condition, free from oil or fuel leaks. Power brooms and sweepers, vacuum sweepers, and air compressors shall be used sufficiently to remove dust and debris from the final milled surface.

420.4. Construction.

420.4.1. Preparation of Cracks. Immediately before the installation of crack sealant, thoroughly clean the cracks to remove oxidized pavement, loose aggregate, and foreign debris.

420.4.1.1. Hairline Cracks. Cracks that are less than 6 millimeters [0.25 inch] wide shall be blown clean and sealed in accordance with paragraph 420.4.3.

420.4.1.2. Small Cracks. Cracks that are 6 to 20 millimeters [0.25 to 0.75 inch] wide shall be routed or saw-cut to a nominal width 3 millimeters [0.125 inch] greater than the existing nominal width and to a depth not less than 20 millimeters [0.75 inch], wire brushed, and cleaned using compressed air.

420.4.1.3. Medium Cracks. Cracks that are 20 to 50 millimeters [0.75 to 2 inches] wide shall be wire brushed and cleaned using compressed air.

420.4.1.4. Large Cracks. Cracks that are greater than 50 millimeters [2 inches] wide shall be filled with crack/joint sand mix filler in accordance with paragraph 420.4.2.

420.4.2. Sand Mix Crack Repair. Prior to filling large cracks, they shall be wire brushed and cleaned using compressed air. Apply tack coat to the cleaned crack prior to filling the crack. Fill the crack with bituminous mixture in maximum 75-millimeter [3-inch] lifts. Compact lower lifts with hand tools to the satisfaction of the Government. Compact the top lift with a self-propelled “pup” roller or other means approved by the Government. Do not use mixture delivered to the work site that has cooled below 93 ºC [200º F].

420.4.3. Existing Sealant Removal. If cracks have been previously sealed, the in-place sealant shall be cut loose from both crack faces and to a depth shown in the drawings using a concrete saw or hand tools. The depth shall be sufficient to accommodate any backup material that is required to maintain the depth of the new sealant to be installed. Prior to further cleaning operations, all old loose sealant remaining in the crack opening shall be removed by blowing with compressed air.

420.4.4. Backup Material. Install backer material on all cracks that are deeper than 19 millimeters [0.75 inch]. The backup material shall be inserted in to the lower portion of the crack as shown in the drawings. Ensure that the backup material is placed at the specified depth and is not stretched or twisted during installation.

420.4.5. Seal cracks immediately following the final cleaning of the crack walls and following placement of the backup material (when required). Cracks that cannot be sealed under the conditions specified, or when rain interrupts sealing operations, shall be recleaned and allowed to dry prior to sealant installation.

420.4.6. Fill cracks from the bottom up to 3 millimeters [1/8 inch] below the pavement surface. Remove and discard excess or spilled sealant from the pavement by approved methods. Install the sealant in a manner that prevents the formation of voids or entrapped air. Several passes of the applicator wand may be necessary to obtain the specified sealant depth from the pavement surface.

420.4.7. Traffic shall not be permitted over newly sealed pavement until authorized by the Government. Check cracks frequently to ensure that the newly installed sealant is cured to tack-free condition within 3 hours.

420.4.8. Bituminous Pavement Milling. The pavement surface shall be removed to the limits indicated in the plans and shall be disposed of off Government property. Prior to subsequent paving, the roughened surface shall be cleaned to ensure that it is free from dirt and loose materials. If cleaning with power brooms or sweepers, high-pressure air shall be used to remove the dust and debris left behind. The temperature, condition of equipment, and actual construction shall be such that the milled surface is not injured during operation, whether it be torn, gouged, shoved, or otherwise injured. Multiple

cutting passes may be necessary to eliminate all irregularities or high points to the satisfaction of the Government.

420.5. Unit Prices.

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NOTE: Delete unit price paragraphs when lump sum bidding is used. Edit the pay item descriptions to suit the project. If the only joint sealant used in the project is associated with new portland cement concrete (PCC) construction, then joint sealant installation should be incidental to the pavement pay item.

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420.5.1. Measurement.

420.5.1.1. Clean and Seal Bituminous Cracks. The quantity of clean and seal bituminous cracks shall be measured by the linear meter [foot] of each crack or joint routed, cleaned, sealed and accepted as complete.

420.5.1.2. Sand Mix Crack Repair. The quantity of sand mix crack repair shall be measured by the linear meter [foot] of each crack or joint routed, cleaned, filled, compacted, and accepted as complete.

420.5.1.3. Hot-Mix Asphalt (HMA) Patch, [__] Depth. The quantity of HMA patch shall be measured by the square meter [square yard] as measured in the field, completed, and accepted. Pavement saw cuts, removal, and replacement are included in the work item. Pavement milling for patches shall not be paid separately.

420.5.1.4. Bituminous Pavement Milling. The quantity of bituminous pavement milling shall be measured by the square meter [square yard] as measured in the field, completed, and accepted. Pavement milling required for butt joint construction shall be measured for payment under Item 410-3.

420.5.2. Payment.

420.5.2.1. The quantities of pay items, determined as specified above, will be paid for at the respective contract unit prices. Payment shall constitute full compensation for all operations necessary to complete the work as specified herein.

420.5.2.2. Payment will be made under:

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NOTE: Edit the pay item list to suit the project.

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Item 420-1	Sand Mix Crack Repair	per LM [LF]
Item 420-2	Clean and Seal Bituminous Cracks	per LM [LF]
Item 420-3	Hot-Mix Asphalt Patch, [__] Depth	per SM [SY]
Item 420-4	Bituminous Pavement Milling	per SM [SY]

AF 430
BITUMINOUS SEAL COAT - SPRAY APPLICATION

430.1. General. This specification covers the requirements for bituminous seal coating for airfields. Refer to Unified Facilities Criteria (UFC) 3-250-03, *Standard Practice Manual for Flexible Pavements*.

430.2. Material.

430.2.1. Bituminous Material.

****

NOTE: Specify the type of bituminous material most suited to the project. RC-800 is commonly recommended for surface treatments. Where cooler temperatures are anticipated, use of RC-250 may be desirable. The type of cutback or emulsion to be used will depend on local conditions and temperatures, and these factors must be considered carefully in making the selection for surface treatments. Where cooler temperatures are anticipated, preference should be given to the use of 200-300 grade asphalt cement.

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.*

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%. These considerations should be included in the evaluation of alternate grades to be specified for the project:*

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

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

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

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

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.*

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.*

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430.2.1.1. Cutback Asphalt. Rapid-curing cutback asphalt shall conform to American Society for Testing and Materials (ASTM) D 2028, *Standard Specification for Cutback Asphalt (Rapid-Curing Type)*, Grade [RC-250] [RC-800] [RC-3000].

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

430.2.1.2. Emulsified Asphalt. Rapid-setting emulsified asphalt shall conform to ASTM D 977, *Standard Specification for Emulsified Asphalt*, Grade RS-1 or RS-2, or ASTM D 2397, *Standard Specification for Cationic Emulsified Asphalt*, Grade CRS-1 or CRS-2.

430.2.1.3. Asphalt Cement. Asphalt cement shall conform to ASTM D 946, *Standard Specification for Penetration-Graded Asphalt Cement for Use in Pavement Construction*, Penetration Grade [120-150] [200-300] or ASTM D 3381, Viscosity Grade [AC-2.5] [AC-5] [AC-10] [AC-20] [AR2000].

430.2.1.4. Tar. Tar shall conform to ASTM D 490, *Standard Specification for Road Tar*, Grade [RT-8 or RT-9] [RT-6 or RT-7].

430.2.2. Mineral Aggregate. The desired gradation to be used for the projects will be specified. For single surface treatment, select the required gradation from Table 430-1. For double surface treatment, select the required gradation (either No. 1 and No. 2 or No. 3 and No. 4) from Table 430-2. Aggregate shall conform to the gradations shown in Table 430-1 or 430-2. Aggregate will consist of crushed stone, crushed gravel, crushed slag, sand, and screenings. The moisture content of the aggregate shall be not greater than 1 to 3%, such that the aggregate will readily bond with the bituminous material. Drying may be required. The aggregate gradation shall be allowed the tolerances provided in Table 430-3.

Table 430-1. Aggregate Gradations for Single Bituminous Surface Treatment

Sieve Size	Percent by Weight Passing Square-Mesh Sieves		
	Gradation No. 1	Gradation No. 2	Gradation No. 3
25.0 mm [1 in]	100	--	--
19.0 mm [3/4 in]	90-100	100	--
12.5 mm [0.5 in]	20-55	90-100	100
9.5 mm [0.375 in]	0-15	40-70	85-100
4.75 mm [No. 4]	0-5	0-15	10-30
2.36 mm [No. 8]	--	0-5	0-10
1.18 mm [No. 16]	--	--	0-5

Table 430-2. Aggregate Gradations for Double Bituminous Surface Treatment

Sieve Size	Percent by Weight Passing Square-Mesh Sieves			
	Gradation No. 1	Gradation No. 2	Gradation No. 3	Gradation No. 4
25.0 mm [1 in]	100	--	--	--
19.0 mm [3/4 in]	90-100	--	100	--
12.5 mm [0.5 in]	20-55	100	90-100	--
9.5 mm [0.375 in]	0-15	85-100	40-70	100
4.75 mm [No. 4]	0-5	10-30	0-15	85-100
2.36 mm [No. 8]	--	0-10	0-5	10-30
1.18 mm [No. 16]	--	0-5	--	0-10
0.30 mm [No. 32]	--	--	--	0-5

Table 430-3. 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%

430.2.2.1. Crushed Stone. Crushed stone shall consist of clean, sound, durable particles, free of soft or disintegrated pieces, duct, or foreign matter.

430.2.2.2. Crushed Gravel. Crushed gravel shall consist of clean, sound, durable particles, free of soft or disintegrated pieces, duct, or foreign matter. At least 90% by weight of the particles shall have at least two fractured faces.

430.2.2.3. Crushed Slag. Crushed slag shall be an air-cooled blast-furnace product having a dry weight of not less than 1120 kilograms per cubic meter [70 pounds per cubic foot], and shall consist of angular particles that are uniform in density and quality and free of dust and foreign matter. The weight of a cubic meter [foot] of slab aggregate shall be determined by ASTM C 29/C 29M, *Standard Test Method for Bulk Density (Unit Weight) and Voids in Aggregate*.

430.2.3. Fine Aggregate. Fine aggregate shall consist of clean, sound, durable particles of crushed stone, slag, or gravel. The aggregate shall meet the same requirements for stripping, abrasion resistance, and percentage of friable particles as specified for coarse aggregate.

430.3. Construction.

430.3.1. Equipment.

430.3.1.1. Bituminous Distributors. The distributor shall have pneumatic tires of sufficient size and number to prevent rutting, shoving, or otherwise damaging any part of the pavement structure. The distributor shall 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 shall include a separate power unit for the bitumen pump, full-circulation spray bars, a tachometer, pressure gauges, volume-measuring devices, adequate heaters for heating 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 shall be equipped to circulate and agitate the bituminous material during the heating process.

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

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

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

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

430.3.2. Weather Limitations. Apply the seal coat when the existing surface is dry, and when the weather is not foggy or rainy. Do not apply the seal coat when the atmospheric temperature is below 15 °C [60 °F] in the shade, when the pavement surface temperature is below 10 °C [50 °F], or when the wind velocity will prevent the uniform application of the bitumen or aggregates.

430.3.3. Preparation of Surface. Prior to applying the seal coat, repair damaged pavement and fill cracks. Immediately before applying the seal coat, remove all loose material, dirt, clay, or other objectionable material from the surface to be sealed. Do not mix material removed from the surface with the cover aggregate.

430.3.4. Bituminous Material Application. Spread the bituminous material in the quantities shown in Table 430-3. The exact quantities within the range specified may be varied to suit field conditions.

Table 430-3. 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]

430.3.4.1. Temperature. Using the correct 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, the tar application temperature shall be within these ranges:

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

430.3.4.2. Application of Bituminous Material. Following the preparation and inspection of the pavement surface, apply the seal coat material at the specified rates. Uniformly apply the bituminous material in a single pass of the distributor and with either a double or triple lap spray over the surface to be sealed. Spread building paper 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 are operating at the proper pressure on the surface to be sealed. Immediately after the application, remove the building paper. Properly treat spots missed by the distributor with bituminous material applied by hand. No smoking, fires, or flames other than the heaters that are a part of the equipment shall be permitted within 8 meters [25 feet] 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 shall be used by personnel exposed to fumes. Protective creams shall not be used as a substitute for cover clothing.

430.3.5. Aggregate Application.

430.3.5.1. Spread the aggregate at the rates shown in Table 430-3. The exact quantities within the range specified may be varied to suit field conditions. The aggregate weights shown in Table 430-3 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.

430.3.5.2. Spread the specified quantity of cover aggregate uniformly over the bituminous material. Before the bituminous material is applied, sufficient aggregate to cover the distributor load of bituminous material shall be on trucks at the site of the work. No bituminous material shall be down more than 3 minutes before it is covered with aggregate. Spreading shall be done uniformly with aggregate-spreading equipment. Operate trucks spreading aggregate 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.

430.3.6. Rolling and Brooming. Immediately following the application of cover aggregate, begin rolling operations. Accomplish rolling with pneumatic-tired rollers. Operate the rollers at a speed that will not displace the aggregate. Continue rolling until the aggregate is uniformly distributed and keyed into the bituminous material. Sweep all surplus aggregate off the surface and remove surplus not less than 24 hours, nor more than 4 days, after rolling is completed.

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

430.4. Quality Control (QC) Testing. Perform field tests in sufficient numbers to assure that the specifications are being met. Perform testing 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:

430.4.1. Aggregates. Initial tests for determining the suitability of aggregate will include: gradation in accordance with ASTM C 136, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*; abrasion resistance in accordance with ASTM C 131, *Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine*; clay lumps and friable particles in accordance with ASTM C 142, *Standard Test Method for Clay Lumps and Friable Particles in Aggregates*; unit weight and voids in accordance with ASTM C 29/C 29M; and flat and elongated particles in accordance with ASTM D 4791, *Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate*. Aggregate samples for laboratory tests will be taken in accordance with ASTM D 75, *Standard Practice for Sampling Aggregates*.

430.4.1.1. Gradation. Complete gradation tests 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, repeat the gradation test and retest the material already placed to determine the extent of the unacceptable material. Replace all in-place unacceptable material.

430.4.1.2. Abrasion Resistance. Complete abrasion resistance tests in accordance with ASTM C 131. Complete one test for every 1000 cubic meters [1300 cubic yards] of aggregate placed.

430.4.2. Bituminous Material. Take samples of bituminous material in accordance with American Association of State Highway and Transportation Officials (AASHTO) T 40, *Sampling Bituminous Materials*, or ASTM D 140, *Standard Practice for Sampling Bituminous Materials*.

430.4.2.1. Initial Tests. Calibrate the bituminous distributor in accordance with ASTM D 2995, *Standard Practice for Estimating Application Rate of Bituminous Distributors*. Prior to applying the seal coat, place a test section at least 30 meters [100 feet] long by 6 meters [20 feet] wide using the materials chosen for the project. Place and roll the materials in accordance with the specified requirements. Complete tests to determine the application rates of the bitumen and aggregate. If the tests indicate that the seal

coat test section does not conform to the specification requirements, make necessary adjustments to the application equipment and to the spreading and rolling procedures, and construct additional test sections to check conformance with the specifications. Where test sections do not conform to specification requirements, remove the seal coat.

430.4.2.2. 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.

430.5. Unit Prices.

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NOTE: Delete unit price paragraphs when lump sum bidding is used. Edit the pay item descriptions to suit the project.

****

430.5.1. Measurement.

430.5.1.1. Bituminous Seal Coat (by area). The quantity of seal coat to be paid for shall be the number of square meters [yards] repaired, placed, cured and accepted at the specified application rate. No additional payment shall be made for overlaps or outside the boundaries shown in the plans.

430.5.1.2. Unclassified Excavation. The quantity of unclassified excavation to be paid for shall be the number of cubic meters [yards] measured in its original position. All excavation required to finish the compacted subgrade to plan elevation regardless of its classification shall be measured and paid for as unclassified excavation. Any over excavation, including rock removal required to finish the compacted subgrade to plan elevation, shall not be measured for payment.

430.5.2. Payment.

430.5.2.1. The quantities of pay items, determined as specified above, will be paid for at the respective contract unit prices. Payment shall constitute full compensation for all operations necessary to complete the work as specified herein.

430.5.2.2. Payment will be made under:

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NOTE: Edit the pay item list to suit the project.

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Item 430-1	Bituminous Seal Coat	per SM [SY]
Item 430-2	Bituminous Material	per liter [gallon]
Item 430-3	Aggregate Material	per metric ton [ton]

430.6. Additional References:

- ASTM D 633, *Standard Volume Correction Table for Road Tar*
- ASTM D 1250, *Standard Guide for Use of the Petroleum Measurement Tables*

AF 510
PORTLAND CEMENT CONCRETE (PCC) FOR AIRFIELDS

510.1. 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 shall conform to the requirements of both this specification and the other specification, including tolerances for both.

510.2. Material.

510.2.1. Cementitious Materials. Cementitious materials shall be portland cement, blended cement, or only portland cement in combination with supplementary cementitious materials (SCM).

510.2.1.1. Portland cement shall conform to American Society for Testing and Materials (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 shall conform to ASTM C 150, Type III, with C3A limited to 5% (low-alkali).

510.2.1.2. Blended cement shall conform to ASTM C 595, *Standard Specification for Blended Hydraulic Cements*, Type IP or IS, including the optional requirement for mortar expansion and sulfate soundness. The percentage and type of mineral admixture used in the blend shall not change from that submitted for the aggregate evaluation and mixture proportioning.

510.2.1.3. Ground granulated blast-furnace (GGBF) slag shall conform to ASTM C 989, *Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars*, Grade 100 or Grade 120.

510.2.1.4. Class F fly ash shall conform to ASTM C 618, *Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete*, Class F, including the optional requirements for uniformity and effectiveness in controlling alkali-silica reaction, and shall have a loss on ignition not exceeding 6%. Class F fly ash for use in mitigating alkali-silica reactivity shall have a calcium oxide (CaO) content of less than 13% and a total equivalent alkali content less than 3%.

510.2.1.5. Silica fume shall conform to ASTM C 1240, *Standard Specification for Silica Fume Used in Cementitious Mixtures*, including the optional limits on reactivity with cement alkalis. Silica fume may be furnished as a dry, densified material, or as a slurry. Provide at the Contractor's expense the services of a manufacturer's technical representative, experienced in mixing, proportioning, placement procedures, and curing of concrete containing silica fume. This representative must be present on the project prior to and during at least the first 4 days of concrete production and placement using silica fume.

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

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

510.2.2.1.1. 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.

510.2.2.1.2. The materials selected and the proportions used shall be such that when the coarseness factor (CF) and the workability factor (WF) are plotted on a diagram as described in paragraph 510.2.2.1.4, the point thus determined shall fall within the parallelogram described therein.

510.2.2.1.3. CF is determined from this equation:

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

WF is defined as the cumulative percent passing the 2.36-millimeter [No. 8] sieve; however, adjust WF 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].

510.2.2.1.4. Plot a diagram using a rectangular scale with WF 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 these coordinates: (CF-75, WF-28), (CF-75, WF-40), (CF-45, WF-32.5), and (CF-45, WF-41). If the point determined by the intersection of the computed CF and WF does not fall within the above parallelogram, change as necessary the grading of each size of aggregate used and the proportions selected.

510.2.2.1.5. Plot the individual percent retained on each sieve for the combined aggregate grading, on either rectangular or semi-log graph paper. The graph shall show a relatively smooth transition between coarse and fine aggregate and shall have no major valleys or peaks in the area smaller than the 23.6-millimeter [No. 8] sieve. If the plot does not meet these criteria, change as necessary the grading of each size aggregate used and the proportions selected.

510.2.2.2. Coarse Aggregate. Coarse aggregate shall consist of crushed gravel, crushed stone, or a combination thereof. The nominal maximum size of the coarse aggregate shall be 19 millimeters [0.75 inch], 25 millimeters [1 inch], or 38 millimeters [1.5 inches], depending on the thickness of the portland cement concrete (PCC) slab

and the reinforcement. In general, the maximum size of the coarse aggregate shall be such that no areas are too small for a mixture of stone and cement to reside in the finished PCC product. When the nominal maximum size is greater than 25 millimeters [1 inch], the aggregates shall 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 shall not exceed the limits shown in ASTM C 33 Class 1N, 4M, or 4S, depending on the weathering region, and these limits:

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

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

510.2.2.2.3. Total of all deleterious particles: 5% maximum by mass (substances listed in ASTM C 33 and paragraphs 510.2.2.2 through 510.2.2.2.2, exclusive of material finer than a 0.075-millimeter [No. 200] sieve).

510.2.2.2.4. The separation medium for lightweight particles shall have a density of 2 milligrams per cubic meter [specific gravity of 2.0].

510.2.2.3. Fine Aggregate. Fine aggregate shall consist of natural sand, manufactured sand, or a combination of the two, and shall 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 shall not exceed the limits in ASTM C 33, and shall not exceed these limits:

510.2.2.3.1. Lightweight particles (ASTM C 123): 0.5% maximum by mass using a medium with a density of 2 milligrams per cubic meter [specific gravity of 2.0].

510.2.2.3.2. The total of all deleterious material types, listed in ASTM C 33 and paragraphs 510.2.2.3 and 510.2.2.3.1, shall not exceed 3% of the mass of the fine aggregate.

510.2.2.4. Alkali-Silica Reactivity.

510.2.2.4.1. Fine and coarse aggregates to be used in all concrete shall be evaluated and tested for alkali-aggregate reactivity. Both coarse aggregate size groups shall be tested if from different sources.

510.2.2.4.2. The fine and coarse aggregates shall be evaluated separately, using ASTM C 1260, *Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)*. The test results of the individual aggregates shall have a measured expansion equal to or less than 0.08% after 28 days of immersion in a 1N NaOH solution. Should the test data indicate an expansion of greater than 0.08%, the aggregate(s) shall be rejected or additional testing shall be performed using ASTM C 1567, *Standard Test*

Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method), as follows: use the Contractor's proposed low-alkali portland cement [blended cement] and SCM in combination with the proposed aggregate for the test proportioning. Determine the quantity that will meet all the requirements of these specifications and that will lower the expansion equal to or less than 0.08% after 28 days of immersion in a 1N NaOH solution.

510.2.2.4.3. If none of the above options lower the expansion to less than 0.08% after 28 days of immersion in a 1N NaOH solution, the aggregate(s) shall be rejected and the Contractor shall submit new aggregate sources for retesting. The results of testing shall be submitted to the Contracting Officer for evaluation and acceptance.

510.2.3. Chemical Admixtures. Air-entraining admixture shall conform to ASTM C 260, *Standard Specification for Air-Entraining Admixtures for Concrete*. Calcium chloride and admixtures containing calcium chloride shall not be used. A water-reducing or retarding admixture shall meet the requirements of ASTM C 494/C 494M. Type F and G high-range water-reducing admixtures are not allowed.

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

510.2.5. Water. Water for mixing and curing shall be clean, potable, and free of injurious amounts of oil, acid, salt, or alkali.

510.2.6. Joint Materials.

510.2.6.1. Expansion Joint Material. Expansion joint filler shall 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, *Standard Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction* (Types I, II, or III). Expansion joint filler shall be 19 millimeters [0.75 inch] thick.

510.2.6.2. Slip Joint Material. Slip joint material shall be 6-millimeter-thick [0.25 inch-thick] expansion joint filler conforming to ASTM D 1751 or ASTM D 1752.

510.3. Reinforcing.

510.3.1. General. Reinforcing bars shall conform to ASTM A 615/A 615M, *Standard Specification for Deformed or Plain Carbon-Steel Bars for Concrete Reinforcement*, for the specified yield strength of steel. Bar mats shall conform to ASTM A 184/A 184M, *Standard Specification for Fabricated Deformed Steel Bar Mats for Concrete*

Reinforcement. Reinforcement shall be free from loose, flaky rust, loose scale, oil, grease, mud, or other coatings that might reduce the bond with the concrete.

510.3.2. Dowels. Dowels shall be single-piece, plain (non-deformed) steel bars conforming to ASTM A 615/A 615M Grade 40 or 60. Dowels shall be free of loose, flaky rust and loose scale and shall be clean and straight. Grout retention rings shall be fully circular metal or plastic devices capable of supporting the dowel until the epoxy hardens.

510.3.3. Tie Bars. Tie bars shall 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.

510.3.4. Epoxy Resin. All epoxy. resin materials shall be two-component materials conforming to ASTM C 881/C 881M, *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 shall meet these requirements:

510.3.4.1. Material for use for embedding dowels and anchor bolts shall be Type IV, Grade 3.

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

510.3.4.3. Material for injecting cracks shall be Type IV, Grade 1.

510.3.4.4. Material for bonding freshly mixed PCC, mortar, or freshly mixed epoxy resin concrete to hardened concrete shall be Type V, grade as approved.

510.3.5. Specified Concrete Strength and Other Properties. The specified compressive strength (f'_c), for concrete is 34.4 megapascals [5000 pounds per square inch] at 28 days. The 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 American Concrete Institute (ACI) 211.1, *Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete*. The concrete shall be air-entrained with a total air content of 6±1%. The maximum allowable slump of the concrete shall be 50 millimeters [2 inches] for pavement constructed with fixed forms.

510.3.6. Mixture Proportions.

510.3.6.1. Composition. Concrete shall be composed of cementitious material, water, fine and coarse aggregates, and admixtures. The total cementitious material content shall be at least 310 kilograms per cubic meter [517 pounds per cubic yard]. Admixtures shall 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.

510.3.6.2. Concrete Mixture Proportioning Studies. All materials used in mixture proportioning studies shall be representative of those proposed for use on the project. If materials change, perform additional mixture design studies using the new materials. Trial mixtures having proportions, slumps, and air content suitable for the work shall be based on the methodology described in ACI 211.1. Use at least three different water-cement ratios that 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 shall be 40% of the total aggregate saturated surface dry (SSD) weight. Aggregate quantities shall be based on the mass in a SSD condition.

510.3.6.3. Mixture Proportioning Procedure. The procedure shall consist of these steps:

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

510.3.6.3.2. 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.

510.3.6.3.3. From the graphs, select a w/(c+p) that will produce a mixture giving a 28-day strength equal to the required strength determined in accordance with paragraph 510.3.6.4.

510.3.6.4. Average Strength Required for Mixtures. To ensure meeting the strength requirements during production, the mixture proportions selected shall produce a required average compressive strength (f'_{cr}) exceeding the specified compressive strength (f'_c) by 15%.

510.3.7. Equipment.

Note: Disregard the equipment portion of this specification for RED HORSE (Rapid Engineer Deployable, Heavy Operational Repair Squadron) or other military unit construction.

510.3.7.1. Batching and Mixing. The batching plant shall 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 this section. Water shall not be weighed or measured cumulatively with another ingredient. All concrete materials batching shall meet ASTM C 94/C 94M requirements. Mixers shall be stationary mixers or truck mixers. Batching, mixers, mixing time, permitted reduction of mixing time, and concrete uniformity shall meet the requirements of ASTM C 94/C 94M.

510.3.7.2. Transporting Equipment. Transporting equipment shall be in conformance with ASTM C 94/C 94M, and as specified herein. Concrete shall 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 shall not be used for delivery of concrete.

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

510.3.7.4. Paver-finisher. The paver-finisher shall be a heavy-duty, self-propelled machine designed specifically for paving and finishing high-quality pavement. The paver-finisher shall weigh at least 3275 kilograms per meter [2200 pounds per foot] of lane width, and shall be powered by an engine having at least 15,000 watts per meter [6 horsepower per foot] of lane width. The paver-finisher shall spread, consolidate, and shape the plastic concrete to the desired cross section in one pass. The paver-finisher shall 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 shall 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 shall 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 shall be as necessary to properly consolidate the concrete, but the clear distance between vibrators shall not exceed 750 millimeters [30 inches], and the outside vibrators shall not exceed 300 millimeters [12 inches] from the edge of the lane. The paver-finisher shall be equipped with a transversely oscillating screed or an extrusion plate to shape, compact, and smooth the surface.

510.3.7.5. Paver-finisher with Fixed Forms. The paver-finisher shall be equipped with wheels designed to ride the forms, keep it aligned with the forms, and to spread the load to prevent deformation of the forms.

510.3.7.6. Other Types of Finishing Equipment. Bridge deck finishers shall be used only for pavements 250 millimeters [10 inches] or less in thickness and where longitudinal and transverse surface smoothness tolerances are 6.5 millimeters [0.25 inch] or greater. Clary screeds or other rotating tube floats will not be allowed on the project.

510.3.7.7. Texturing Equipment.

510.3.7.7.1. Fabric Drag. A fabric drag shall 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 fabric drag shall be wide enough to provide 600 to 900 millimeters [24 to 36 inches] of material dragging flat on the pavement surface. The fabric material shall be clean, new burlap, kept clean and saturated during use.

510.3.7.7.2. Deep Texturing Equipment. The texturing equipment shall consist of a stiff-bristle broom forming a drag at least 1.2 meters [4 feet] long.

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

510.4. Execution.

510.4.1. Test Section.

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NOTE: Retain this paragraph if slipforming pavements more than 250 millimeters [10 inches] thick. Where desired for other pavements, retain it; otherwise, delete it.

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At least 10 days but not more than 60 days prior to construction of the concrete pavement, a test section shall be constructed [near the job site, but not as part of the production pavement area.] [as part of the production paving area at an outer edge as indicated on the drawings]. Use the test section to develop and demonstrate to the satisfaction of the Contracting Officer the proposed techniques of mixing, hauling, placing, consolidating, finishing, curing, initial saw-cutting, start-up procedures, testing methods, plant operations, and preparation of the construction joints. The test section shall consist of one paving lane at least 122 meters [400 feet] long and shall be constructed to the same thickness as the thickest portion of pavement shown on the drawings. The lane width shall be the same as that required for use in the project. The test section shall contain at least one transverse construction joint. If doweled longitudinal construction joints are required in any of the production pavements, they shall be installed full length along one side of the test strip throughout the test section. Two separate days shall be used for construction of the test section. Variations in mixture proportions other than water shall be made if directed. Vary the water content, as necessary, to arrive at the appropriate content. The mixing plant shall be operated and calibrated prior to the start of placing the test section. Use the same equipment, materials, and construction techniques on the test section as will be used in all subsequent work. Base course preparation, concrete production, placing, consolidating, curing, construction of joints, and all testing shall be in accordance with applicable provisions of this specification. Three days after completion of the test section, provide eight cores at least 150 millimeters [6 inches] in diameter by full depth, cut from points selected in the test section by the Government. The cores will be evaluated for

homogeneity, consolidation, and segregation. Construct the test section, meeting all specification requirements and being acceptable to the Contracting Officer in all aspects, including surface texture. Failure to construct an acceptable test section will necessitate construction of additional test sections at no additional cost to the Government. Test sections allowed to be constructed as part of the production paving that do not meet specification requirements shall be removed at the Contractor's expense. If the Contractor proposes to use slipform paving and is unable to construct an acceptable test section, the slipform paving equipment shall be removed from the job and the construction completed using stationary side forms and equipment compatible with them. Production paving shall not commence until the results on aggregates and concrete, including evaluation of the cores, and all pavement measurements for edge slump, joint face deformation, actual plan grade, surface smoothness, and thickness have been submitted to and approved by the Contracting Officer. Pavement accepted as a production lot will be evaluated and paid in accordance with paragraph 510.5.1.

510.4.2. Condition of Underlying Material. Ensure that 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.

510.4.3. Weather Limitations.

510.4.3.1. Hot Weather Paving. The temperature of concrete shall not exceed 33 °C [90 °F] at the time of delivery to the forms. Cool steel forms, dowels, and reinforcing prior to concrete placement when steel temperatures are greater than 49 °C [120 °F].

510.4.3.2. Cold Weather Paving. The ambient temperature of the air at the placing site and the temperature of surfaces to receive concrete shall be not less than 5 °C [40 °F]. The temperature of the concrete when placed shall be not less than 10 °C [50 °F]. Materials entering the mixer shall 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 [50 °F] 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 510.4.9.

510.4.4. Concrete Production.

510.4.4.1. General Requirements. Deposit concrete 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 [90 ºF], reduce the time to 30 minutes.

510.4.4.2. 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.

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

510.4.5.1. 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 shall 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. Do not use vibrators to transport or spread the concrete.

510.4.5.2. 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 shall overlap the existing pavement the minimum possible, but in no case more than 200 millimeters [8 inches].

510.4.5.3. Required Results. The paver-finisher shall be operated to produce a thoroughly consolidated slab throughout, true to line and grade within specified tolerances. The paver-finishing operation shall produce a surface finish free of irregularities, tears, voids of any kind, and any other discontinuities. It shall produce only a very minimum of paste at the surface. Do not permit multiple passes of the paver-finisher. The equipment and its operation shall 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.

510.4.5.4. Fixed Form Paving. Forms shall 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 shall be not less than eight-tenths of the vertical height of the form, except that forms 200 millimeters [8 inches] or less in vertical height shall have a base width not less than the vertical height of the form. Wood forms for curves and fillets shall 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.

510.4.5.5. 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.

510.4.5.6. Placing Dowels and Tie Bars. Install dowels with error in alignment not greater than 3 millimeters per 300 millimeters [0.125 inch per foot]. Dowels shall be located 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 the dowel 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.

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

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

510.4.5.6.3. Dowels Installed in Hardened Concrete. Installation shall be by bonding the dowels into holes drilled into the hardened concrete. Drill holes into the hardened concrete approximately 3 millimeters [0.125 inch] greater in diameter than the dowels. Bond dowels in the drilled holes, using epoxy resin injected at the back of the hole before installing the dowel and extruded 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 dowel 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 dowel 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.

510.4.5.6.4. Expansion Joints. Install dowels in expansion joints by the bonded-in-place method or by bonding into holes drilled in hardened concrete, using the procedures specified in paragraph 510.4.5.6.3.

510.4.6. Finishing. Do not use clary screeds, "bridge deck" finishers, or other rotating pipe- or tube-type equipment. The sequence of machine operations shall be transverse finishing, longitudinal machine floating (if used), straightedge finishing, texturing, and then edging of joints. Hand finishing shall 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 shall 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.

510.4.6.1. Machine Finishing with Fixed Forms. The machine shall be designed to ride the forms. Do not use machines that cause displacement of the forms. The machine shall 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.

510.4.6.2. 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 [10 to 12 feet] 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.

510.4.6.3. Hand Finishing. Hand-finishing operations shall be used only for those unusual slabs as specified in paragraph 510.4.6. Do not use grate tampers (jitterbugs). As soon as the concrete is 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.

510.4.6.4. Texturing. Before the surface sheen has disappeared and before the concrete hardens, the surface of the pavement shall be given a texture as described herein. After curing is complete, all textured surfaces shall 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 shall be finished to provide a surface of the same texture as the surrounding area.

510.4.6.4.1. 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 shall produce a uniform finished surface having a fine sandy texture without disfiguring marks.

510.4.6.4.2. Broom Texturing. Apply surface texture using a mechanical stiff-bristle broom drag of a type that will uniformly score the surface transverse to the pavement center line. The broom shall 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 shall be overlapped the minimum necessary to obtain a uniformly textured surface. The scores shall be uniform in appearance and approximately 1.5 millimeters [0.0625 inch] in depth,

but not more than 3 millimeters [0.125 inch] in depth. Hand brooming will be permitted only on isolated odd-shaped slabs or slabs where hand finishing is permitted.

510.4.6.5. Edging. After texturing has been completed, carefully finish the edge of the slabs along the forms with an edging tool to form a smooth, rounded surface with a 3-millimeter [0.125-inch] radius. Do not add water to the surface during edging.

510.4.7. 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 305.1, *Specification for Hot Weather Concreting*, contains means of predicting plastic shrinkage cracking and preventative measures. Fill plastic shrinkage cracks by injecting epoxy resin after the concrete hardens. Never trowel over plastic shrinkage cracks or fill with slurry. Accomplish curing by membrane curing or moist curing as specified in paragraphs 510.4.7.1 and 510.4.7.2.

510.4.7.1. 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. Apply curing compound to the finished surfaces with a self-propelled automatic spraying machine equipped with multiple spraying nozzles with wind shields, spanning the newly paved lane. Apply the curing compound 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 shall 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.

510.4.7.2. Moist Curing. Concrete to be moist-cured shall be maintained continuously wet for the entire curing period, commencing immediately after finishing. Cure surfaces 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.

510.4.8. Joints. All joints shall 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].

510.4.8.1. Longitudinal Construction Joints. Install dowels in the longitudinal construction joints or install thickened edges, as indicated in the project drawings. After the end of the curing period, longitudinal construction joints shall be sawed to provide a

groove at the top for sealant conforming to the details and dimensions indicated on the drawings.

510.4.8.2. Transverse Construction Joints. Install transverse construction joints at a planned transverse joint at the end of each day's placing operations and when concrete placement is interrupted. Construct transverse construction joints 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, install dowels using the methods for dowels installed in hardened concrete described in paragraph 510.4.5.6.3. All transverse construction joints shall be dowelled.

510.4.8.3. Expansion Joints. Form expansion joints 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 the plans. Expansion joints shall extend the full slab depth. Finish the edges of the concrete at the joint face with an edger with a radius of 3 millimeters [0.125 inch]. 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.

510.4.8.4. 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. Finish the edges of the joint face with an edger with a radius of 3 millimeters [0.125 inch].

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

510.4.8.6. Sawed Joints. Construct sawed contraction joints by sawing a groove in the concrete with a 3-millimeter [0.125-inch] 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 the exposed edges shall be tightly sealed with cord or backer rod before the concrete in the region of the joint is resprayed with curing compound.

510.4.9. Repair, Removal, and Replacement of Slabs. Remove and replace new pavement slabs that contain full-depth cracks. Determining whether cracks extend the full depth of the pavement may require drilling minimum 150-millimeter-diameter

[6-inch-diameter] cores. 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 510.4.9.1. Spalls along joints shall be repaired as specified in paragraph 510.4.9.2.

510.4.9.1. Removal and Replacement of Full Slabs. Unless keys or dowels are present, all edges of the slab shall be saw-cut full depth. If keys, dowels, or tie bars are present along any edges, these edges shall be sawed full depth 150 millimeters [6 inches] from the edge if only keys are present, or just beyond the end of dowels or tie bars if they are present. These joints shall then be carefully sawed on the joint line to within 25 millimeters [1 inch] of the depth of the dowel or key. The main slab shall be further divided by sawing full depth at appropriate locations, and each piece lifted out and removed. Carefully break up and remove the narrow strips along keyed or doweled edges. 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 [4 inches] 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 them flush with the joint face. All four edges of the new slab shall 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.

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NOTE: Designers should also consult these Air Force engineering technical letters for additional guidance and recommendations for repairing spalls in PCC pavements:

- ETL 07-8, *Spall Repair of Portland Cement Concrete (PCC) Airfield Pavements in Expeditionary Environments*
- ETL 08-2, *Testing Protocol for Rigid Spall Repair Materials*
- ETL 08-4, *Testing Protocol for Polymeric Spall Repair Materials*

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510.4.9.2. Repairing Spalls along Joints. Repair spalls along joints and cracks by first making a vertical saw cut at least 25 millimeters [1 inch] outside the spalled area and to a depth of at least 50 millimeters [2 inches]. Saw cuts shall be straight lines forming

rectangular areas. Chip out the concrete between the saw cut and the joint, or crack, to remove all unsound concrete. Thoroughly clean the cavity with high-pressure water jets supplemented with compressed air to remove all loose material. Immediately before filling the cavity, apply a prime coat to the dry, cleaned surface of all sides and bottom of the cavity, except any joint face. Apply the prime coat in a thin coating and scrub it into the surface with a stiff-bristle brush. The prime coat for portland cement repairs shall be a neat cement grout, and for epoxy resin repairs shall be epoxy resin, Type III, Grade 1. Fill the cavity with low-slump PCC or mortar, or with epoxy resin concrete or mortar. Use PCC for larger spalls, those more than 0.009 cubic meter [0.33 cubic foot] in size after removal operations; use portland cement mortar 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 [0.03 cubic foot] in size after removal operations. Portland cement concretes and mortars shall be very low-slump mixtures, proportioned, mixed, placed, tamped, and cured. Epoxy resin mortars shall be made with Type III, Grade 1 epoxy resin, using the proportions, mixing, placing, tamping, and curing procedures recommended by the manufacturer. Remove any repair material on the surrounding surfaces of the existing concrete before the material 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. Where spalls and popouts are not adjacent to joints and are less than 150 millimeters [6 inches] in maximum dimension, the pavement may be prepared by drilling a core 50 millimeters [2 inches] in diameter greater than the size of the defect, centered over the defect, and 50 millimeters [2 inches] deep or 13 millimeters [0.5 inch] into sound concrete, whichever is greater. Repair the core hole as specified above for other spalls.

510.4.9.3. Areas Defective in Plan Grade or Smoothness. In areas not meeting the specified limits for surface smoothness and plan grade, reduce high areas to attain the required smoothness and grade, except as depth is limited below. Reduce high areas by grinding the hardened concrete with a surface grinding machine after the concrete is at least 14 days old. The depth of grinding shall not exceed 6 millimeters [0.25 inch]. Remove and replace all pavement areas requiring plan grade or surface smoothness corrections in excess of the specified limits.

510.4.10. Existing Concrete Pavement Removal and Repair. Remove existing concrete pavement as indicated and as specified in paragraph 510.4.9.

510.4.11. 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 that is carrying construction traffic or equipment completely clean, continuously. Use special cleaning and care where traffic uses or crosses active airfield pavement.

510.5. Quality Control (QC) Testing. QC 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,* with Change 1, and ETL 97-2*, Maintenance and Repair of Rigid Airfield Pavement Surfaces, Joints, and Cracks,* with Change 1. Major QC 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.

510.5.1. 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. Determine air content measurements in accordance with ASTM C 231, *Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method*. Test for slump in accordance with ASTM C 143/C 143M, *Standard Test Method for Slump of Hydraulic-Cement Concrete*. All test cylinders shall be 150-millimeter [6-inch] by 300-millimeter [12-inch] cylinders and shall 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 shall be the average of the strengths of two cylinders made from the same sample of concrete and tested at 28 days.

510.5.2. 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.

510.5.3. Mixture Proportions. Proportioning shall be accomplished in accordance with the specifications. Guidance and examples for the Air Force specification are contained in ETL 97-5*.* Construct a test section using the approved mixture proportions and ensure that the test section meets requirements, including strength, grade, smoothness, and texture, before recommending approval. If the test section is not acceptable, make adjustments to the mixture proportions and/or construction equipment or techniques, and construct another test section. A test section must be approved before production begins.

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

510.5.4.1. Compressive Strength. Four cylinders from the same batch shall 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 shall 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 [500 cubic yards]. 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 as specified in paragraph 510.3.5. 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 pounds per square inch]. 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.

510.5.4.2. Water/Cement Ratio. The 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.

510.5.4.3. Air Content. The concrete shall be air-entrained with a total air content as specified in paragraph 510.3.5. 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 the air content reaches the specified limits, make an immediate confirmatory test. If the second test also shows the air content at or exceeding the specified limits, immediately adjust the amount of air-entraining admixture batched to bring the air content within the specified limits. If the next adjusted batch of concrete is not within the specified limits, halt concrete placement until concrete air content is within the specified limits. For QA, determine the air content for each 400 cubic meters [500 cubic yards] 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.

510.5.5. Smoothness Requirements. Use a 3.6-meter [12-foot] straightedge to determine if the finished surface meets the specified smoothness requirements. The straightedge shall be constructed of aluminum or magnesium alloy and shall have

blades of box or box-girder cross section with flat bottom adequately reinforced to ensure rigidity and accuracy. Straightedges shall have handles for operation on the pavement. Observe measurements and ensure that the measurement procedure is correct and that all deviations are marked for repair/replacement as outlined in the specifications.

510.5.5.1. Surface Smoothness Requirements. The finished surfaces of the pavements shall have no abrupt change of 3 millimeters [0.125 inch] or more, and all pavements shall be within the tolerances specified in Table 510-1 when checked with the straightedge.

Table 510-1. 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]

510.5.5.2. Surface Smoothness Testing Method. Test the surface of the pavement with the straightedge to identify all surface irregularities exceeding the tolerances specified in Table 510-1. 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.

510.5.6. Plan Grade Testing and Conformance. The finished surface of the pavements shall conform, within the tolerances shown in Table 510-1, to the lines, grades, and cross sections shown on the plans. The finished surface of new abutting pavements shall coincide at their juncture. The finished surface of airfield runway, taxiway, and apron pavements shall vary not more than 13 millimeters [0.5 inch] above or below the plan grade line or elevation indicated on the plans. The surfaces of other pavements shall vary not more than 19 millimeters [0.75 inch] above or below the plan grade line or elevation indicated. Each pavement category shall be checked for conformance with plan grade requirements by running lines of levels at intervals to determine the elevation at each joint intersection.

510.5.7. Slump. The maximum allowable slump of the concrete shall be as specified in paragraph 510.3.5. 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.

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

510.6. Unit Prices.

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NOTE: Delete unit price paragraphs when lump sum bidding is used. Edit the pay item descriptions to suit the project.

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10.6.1. Measurement.

510.6.1.1. PCC Pavement. The quantity of PCC pavement to be paid for shall be the number of square meters [yards] completed and accepted, for the depth specified. Variable-depth pavement (e.g., thickened edge slabs) will be measured at the non-thickened dimension. Dowels, tie bars, reinforcement, and joint sealant shall not be measured separately for payment and shall be considered incidental to the pay item.

510.6.1.2. PCC Test Batch. The test batch shall be measured as a lump sum item. Only one test batch consisting of both low- and high-slump concrete will be paid for per project. Any additional test batches shall be paid for by the Contractor. Should a change in sources be made or admixtures added or deleted from the mix, a new test batch shall be run at the expense of the Contractor.

510.6.2. Payment.

510.6.2.1. The quantities of pay items, determined as specified above, will be paid for at the respective contract unit prices. Payment shall constitute full compensation for all operations necessary to complete the work as specified herein.

510.6.2.2. Payment will be made under:

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NOTE: Edit the pay item list to suit the project.

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Item 510-1	PCC Pavement, [__] Depth	per SM [SY]
Item 510-2	PCC Test Batch	per lump sum

510.7. Additional References:

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

Table 510-2. Checklist for PCC Pavement

Task	Yes	No
Preconstruction		
Have plans and specifications been thoroughly reviewed?		
Has the plant been checked, calibrated, and approved?		
Is the proposed cement appropriate?		
Have cement, pozzolans, and 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, windblown 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 in concrete to adequate depth?		
Is there an automatic cutoff for the vibrators if the paver stops?		
Are adequate backup equipment and materials available 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 in the approved mix design?		
Are adjustments being made for moisture content of the aggregates (particularly the sand)? Is moisture content of the aggregate being checked?		
Is there any sign of segregation, hardened balls of cement, or contaminates in the concrete?		
Is the 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 that water is not added to the concrete after testing and that 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 that water is not sprayed on the fresh surface for finishing.		
Is the 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 510-3. 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 if water has been 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

Problem	Cause or Definition	Action
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

Problem	Cause or Definition	Action
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

AF 520
CONCRETE PAVEMENT REPAIR

520.1. General. This specification covers the requirements for partial-depth repairs of rigid pavements.

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NOTE: Designers should consult Engineering Technical Letter (ETL) 07-8, Spall Repair of Portland Cement Concrete (PCC) Airfield Pavements in Expeditionary Environments*, for important guidance on repair layout details, patch materials, and removal and replacement procedures.*

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520.2. Materials.

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NOTE: Edit the allowed list of repair materials as appropriate for the project.

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520.2.1. Portland Cement Concrete (PCC) Patch Material.

520.2.1.1. Coarse Aggregate.

520.2.1.1.1. Composition and Quality. Coarse aggregate shall consist of gravel, crushed gravel, crushed stone, or a combination thereof. Aggregate, as delivered to the mixers, shall consist of clean, hard, unweathered, and uncoated particles. Dust and other coatings shall be removed from the coarse aggregates by adequate washing. Coarse aggregates shall meet the requirements of American Society for Testing and Materials (ASTM) C 33, *Standard Specification for Concrete Aggregates*, Class 4S for deleterious substances. Particles of the coarse aggregate shall be generally spherical or cubical.

520.2.1.1.2. Grading. The maximum nominal size of the coarse aggregate shall be 12 millimeters [1/2 inch]. The coarse aggregate shall be well graded within the limits specified, and when tested in accordance with ASTM C 136, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*, shall conform to the grading requirements listed in Table 520-1 as delivered to the batching hoppers.

Table 520-1. PCC Patch Material Coarse Aggregate Gradation

Sieve	% Passing
19 mm [3/4 in]	100
12.5 mm [1/2 in]	90-100
9.5 mm [3/8 in]	40-70
4.75 mm [No. 4]	0-15

Sieve	% Passing
2.36 mm [No. 8]	0-5

520.2.1.1.3. Alkali-Silica Reactivity. Coarse aggregates to be used in all concrete shall be evaluated and tested for alkali-silica reactivity in accordance with ASTM C 1260, *Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)*. Test results shall have a measured expansion equal to or less than 0.08% at 28 days. If the test data indicates an expansion greater than 0.08%, the aggregate(s) shall be rejected or additional testing is needed mitigating the alkali-silica reaction using low-alkali cements, ground granulated blast-furnace (GGBF) slag, fly ash, or a combination thereof. Retesting shall be completed to show that the new mixture meets requirements.

520.2.1.2. Fine Aggregate.

520.2.1.2.1. Composition and Quality. Provide fine aggregate consisting of either natural sand, manufactured sand, or a combination of natural and manufactured sand, and composed of clean, hard, durable particles. Particles of the fine aggregate shall be generally spherical or cubical. Fine aggregate shall meet the requirements of ASTM C 33, Table 1, for deleterious substances.

520.2.1.2.2. Grading. Grading of the fine aggregate as delivered to the mixer shall conform to the grading requirements listed in Table 520-2 when tested in accordance with ASTM C 136. In addition, the fine aggregate, as delivered to the mixer, shall have a fineness modulus of not less than 2.40 nor more than 2.90 when calculated in accordance with ASTM C 136.

Table 520-2. PCC Patch Material Fine Aggregate Gradation

Sieve	% Passing
9.5 mm [3/8 in]	100
4.75 mm [No. 4]	95-100
2.36 mm [No. 8]	80-90
1.18 mm [No. 16]	60-80
0.60 mm [No. 30]	30-60
0.30 mm [No. 50]	12-30
0.15 mm [No. 100]	2-10

520.2.1.2.3. Alkali Silica Reactivity. Fine aggregate to be used in all concrete shall be evaluated and tested for alkali-silica reactivity using the procedures described for coarse aggregate.

520.2.1.3. Air-Entraining Admixture. Air-entraining admixture shall conform to ASTM C 260, *Standard Specification for Air-Entraining Admixtures for Concrete*.

520.2.1.4. Cement. Furnish portland cement conforming to ASTM C 150, *Standard Specification for Portland Cement*, Type I or II. Use low-alkali cement if the proposed fine or coarse aggregates are found to have greater than 0.04% expansion when tested in accordance with paragraphs 520.2.1.1.3 and 520.2.1.2.3.

520.2.1.5. Curing Materials.

520.2.1.5.1. Burlap shall conform to American Association of State Highway and Transportation Officials (AASHTO) M 182, *Standard Specification for Burlap Cloth Made From Jute or Kenaf and Cotton Mats*.

520.2.1.5.2. Membrane forming curing compound shall be a pigmented type conforming to U.S. Army Corps of Engineers (COE) CRD-C 300, *Corps of Engineers Specifications for Membrane-Forming Compounds for Curing Concrete*.

520.2.1.5.3. Waterproof blanket materials shall conform to ASTM C 171, *Standard Specification for Sheet Materials for Curing Concrete*, type - optional, color - white.

520.2.1.6. Bonding Agents.

520.2.1.6.1. Epoxy resin shall be a two-component material formulated to meet the requirements of ASTM C 881/C 881M, *Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete*, Type III, grade and class as approved, for use in bond coat applications and as a component of epoxy resin concrete or mortar.

520.2.1.6.2. Latex bonding agent shall meet the requirements of ASTM C 1059/C 1059M, *Standard Specification for Latex Agents for Bonding Fresh to Hardened Concrete*, Type II.

520.2.1.7. Joint-sealing materials shall be in accordance with section AF 600 FIELD-MOLDED JOINT SEALANT FOR RIGID PAVEMENTS.

520.2.1.8. Water shall be clean, fresh, and free from injurious amounts of oil, acid, salt, alkali, organic matter, or other deleterious substances. Water approved by public health authorities for domestic consumption may be accepted for use without being tested. Water that is of questionable quality, in the opinion of the Government, shall be tested in accordance with ASTM C 1602/C 1602M, *Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete*.

520.2.1.9. Proprietary Cementitious Products. A proprietary cementitious product is defined as a rigid material in its hardened state with an elastic modulus greater than 6900 megapascals [1,000,000 pounds per square inch]. The maximum size of

aggregate used to extend the product is 19 millimeters [3/4 inch]. The product shall be tested in accordance with the following test series. Each test shall be replicated on three specimens. All three results shall be reported for each test, and the average value shall be used for comparison with the specification requirements. Report the curing conditions for each test type.

520.2.1.9.1. Compressive Strength. Cast 75- by 150-millimeter [3- by 6-inch] cylinder specimens in accordance with ASTM C 192/C 192M, *Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory*, and test in accordance with ASTM C 39/C 39M, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*, using bonded or unbonded caps, after a 3 hours and 1 day curing period. A minimum compressive strength of 24.1 megapascals [3500 pounds per square inch] is required at 3 hours and 1 day of age.

520.2.1.9.2. Bond Strength. Cast 75- by 150-millimeter [3- by 6-inch] cylinder specimens and test in accordance with ASTM C 882/C 882M, *Standard Test Method for Bond Strength of Epoxy-Resin Systems Used with Concrete by Slant Shear*. Cast the candidate material against a 30-degree wedge specimen consisting of the candidate material itself or an ordinary portland cement mixture. Test specimens, using bonded caps, after a 1-day curing period. For a bond consisting of the candidate material bonded to PCC mortar, a minimum bond strength of 3400 kilopascals [500 pounds per square inch] is required at 1 day of age. For a bond consisting of the candidate material bonded to itself, a minimum bond strength of 6900 kilopascals [1000 pounds per square inch] is required at 1 day of age.

520.2.1.9.3. Modulus of Elasticity. Cast 150- by 300-millimeter [6- by 12-inch] cylinder specimens in accordance with ASTM C 192/C 192M and test in accordance with ASTM C 469, *Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression*, using bonded caps, after a 3-day curing period. A maximum chord modulus of elasticity of 27,600 megapascals [4,000,000 pounds per square inch] is required at 3 days of age.

520.2.1.9.4. Coefficient of Thermal Expansion. Cast 25- by 25- by 250-millimeter [1- by 1- by 10-inch] prismatic bar specimens and test in accordance with ASTM C 531, *Standard Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings, and Polymer Concretes*, after a 3-day curing period. A maximum coefficient of 11.6×10^{-6} millimeter per millimeter per degree C [7×10^{-6} inch per inch per degree F] is required at 3 days of age.

520.2.1.9.5. Shrinkage Potential. Cast 330-millimeter I.D. (inside diameter) by 406-millimeter O.D. (outside diameter) by 150-millimeter [13-inch I.D. by 16-inch O.D. by 6-inch] -tall restrained toroidal specimens and test in accordance with ASTM C 1581, *Standard Test Method for Determining Age at Cracking and Induced Tensile Stress Characteristics of Mortar and Concrete under Restrained Shrinkage*. Start measuring strain after completion of casting. A maximum of 40 microstrain is required at 14 days of age. No cracking is permitted at 28 days of age.

520.2.1.9.6. Freeze-Thaw Resistance. Cast prismatic specimens in accordance with ASTM C 192/C 192M and test in accordance with ASTM C 666/C 666M, *Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing*, Procedure A. Begin freeze-thaw testing after specimens have been immersed in saturated lime-water for 3 days. Report the durability factor (DF) and the number of cycles to failure.

520.2.2. Mix Design.

520.2.2.1. Portland Cement Concrete (PCC). The concrete mixtures shall be designed to produce concrete having an average compressive strength of 34 megapascals [5000 pounds per square inch] at 28 days of age, determined in conformance with ASTM C 39/C 39M, using standard 150- by 300-millimeter [6- by 12-inch] cylinder specimens. The concrete mixtures shall be designed to secure an air content by volume of 6%, plus or minus 1.5%, based on measurements made on concrete immediately after discharge from the mixer in conformance with ASTM C 231, *Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method*. Mix design studies and tests shall be made in accordance with ASTM C 39/C 39M and ASTM C 192/C 192M, and the test results submitted for approval. The maximum slump shall be 50 millimeters [2 inches] when tested in accordance with ASTM C 143/C 143M, *Standard Test Method for Slump of Hydraulic-Cement Concrete*.

520.2.2.2. Neat cement grout shall consist of portland cement and water, thoroughly mixed to yield a thick, creamy mixture.

520.2.2.3. Epoxy Resin Components. Mix epoxy resin grout components in the proportions recommended by the manufacturer. Condition the components to 20 to 30 °C [70 to 85 °F] for 48 hours prior to mixing. Mix the two epoxy components with a power-driven, explosion-proof stirring device in a metal or polyethylene container having a hemispherical bottom. The curing-agent component shall be added gradually to the epoxy resin component with constant stirring until a uniform mixture is obtained. The rate of stirring shall be such that the entrained air is at a minimum.

520.2.2.4. Proprietary cementitious products shall be mixed in accordance with the manufacturer's recommendations. The use of admixtures or the addition of aggregate to extend the product shall be approved in writing by the manufacturer.

520.3. Equipment; Approval, and Maintenance. Dependable and sufficient equipment that is appropriate and adequate to accomplish the work specified shall be assembled at the site of the work a sufficient time before the start of paving to permit thorough inspection, calibration of weighing and measuring devices, adjustment of parts, and any repairs that may be required. The equipment shall be maintained in good working condition.

520.4. Construction.

520.4.1. Preparation of Existing Pavement.

520.4.1.1. Existing Surfaces. In the area to be patched, remove the surface of the existing concrete to a minimum depth of 50 millimeters [2 inches] and to such additional depth where necessary to expose a surface of sound, unweathered concrete that is uncontaminated by oils, greases, or deicing salts or solutions.

520.4.1.1.1. Make a vertical saw cut at least 50 millimeters [2 inches] deep, a minimum of 50 to 75 millimeters [2 to 3 inches] outside of the spalled area. The patch dimensions shall always be square or rectangular, with a length:width ratio less than 2. The largest side dimension shall be 2.4 meters [8 feet] or less.

520.4.1.1.2. After the repair perimeter saw cuts are completed, make interior saw cuts within the bounds of the repair edges using a concrete saw. The cuts shall be in the longitudinal direction and spaced 25 to 64 millimeters [1 to 2.5 inches] apart. Cuts must not extend beyond the edge of the repair area.

520.4.1.1.3. Remove concrete in spalled areas with light, hand-held, high-frequency chipping hammers weighing not more than 14 kilograms [30 pounds], or other approved hand tools. Do not use jack hammers weighing more than 14 kilograms [30 pounds], and do not use pavement breaker devices mounted on or pulled by mobile equipment.

520.4.1.1.4. The surface shall be washed with a sandblasting, high-pressure water jet or water and scrub brush, followed by an air jet to remove free water; however, when certain types of polymer patch materials are used, the pavement should be kept dry and cleaned only with wire brush and compressed air.

520.4.1.2. Joints. Remove joint-sealing and expansion-joint materials flush with the prepared surface, and, if these materials are on the pavement surface to be patched, remove these materials by sandblasting. Do not use solvents. Use care to prevent bonding of the adjacent concrete slabs at the location of the existing joints. Repair materials must not be allowed to bridge a joint or crack.

520.4.1.2.1. Maintain the existing joints by the use of fiberboard or other approved inserts of appropriate dimensions. Apply a small bead of caulk at the base of the joint or crack prior to installing inserts to seal off the bottom of the joint.

520.4.1.2.2. When repairs are located over a working (spalling) crack, the crack shall be treated as a joint. Apply a small bead of caulk at the base of the joint or crack prior to installing fiberboard or other approved material directly over the crack.

520.4.1.3. Bonding Coat. Prior to placing concrete, the previously prepared surfaces (paragraph 520.4.1.1.4) shall be washed with a high-pressure water jet followed by an air jet to remove free water.

520.4.1.3.1. Neat Cement Grout. Coat the clean and dry surface, including sawed faces, with an approximate 2-millimeter [1/16-inch] -thick coat of neat cement grout. Place the grout just prior to concrete placement and scrub with stiff-bristle brushes to fill all voids and crevices in the spall cavity surface. Apply additional brush coats as needed to obtain the required thickness. The concrete patch material must be placed before the grout dries or sets. Remove dried or hardened grout by sandblasting, and re-coat the cavity with fresh grout before placing concrete patch material.

520.4.1.3.2. Epoxy Resin. Epoxy resin bonding coat shall be limited to use on patches with a surface area of less than 600 millimeters [2 feet] square. Coat the clean and dry surface, including sawed faces, with a 0.5- to 1.0-millimeter [20- to 40-mil] -thick film of the epoxy resin grout. The epoxy resin grout shall be placed in one application, just prior to concrete placement, using mechanical combination, mixing, and spraying equipment, or shall be applied in two coats with stiff brushes. The first brush coat shall be scrubbed into the concrete surface, followed by an additional brush coat to obtain the required thickness. When the brush method is used, the initial coat may be allowed to dry; however, the final coat shall be applied just prior to placement of the concrete.

520.4.1.3.3. Proprietary Cementitious Products. The type, use, and application of a bond coat shall be in accordance with the manufacturer's written instructions.

520.4.1.4. Patch Material Selection. The prepared cavity shall be filled with: PCC or latex-modified concrete for cavities more than 9400 cubic centimeters [600 cubic inches] in volume after removal operations; portland cement mortar for cavities between 850 and 9400 cubic centimeters [50 and 600 cubic inches]; and epoxy resin mortar or latex-modified mortar for those cavities less than 850 cubic centimeters [50 cubic inches] in size. Proprietary cementitious patching materials may be used, subject to approval by the Contracting Officer.

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NOTE: See ETL 07-8, ETL 08-2, Testing Protocol for Rigid Spall Repair Materials*, and ETL 08-4,* Testing Protocol for Polymeric Spall Repair Materials*, for additional information regarding PCC spall repair materials.*

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520.4.2. Batching, Mixing, and Proportioning.

520.4.2.1. Equipment. Provide adequate facilities for the accurate measurement and control of each of the materials entering the concrete. The Government shall have free access to the batching and mixing plant at all times. Mixing equipment shall be capable of combining the aggregate, cement, admixture, and water into a uniform mixture and discharging this mixture without segregation. The use of volumetric batching and continuous mixing is acceptable, provided that all operations are in accordance with ASTM C 685/C 685M, *Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing*. Submit the most recent calibration and mixer

efficiency test results for approval. The results must be current within 6 months of concrete production.

520.4.2.2. Conveying. Convey concrete from the mixer to the repair area as rapidly as practicable by methods that will prevent segregation or loss of ingredients.

520.4.2.3. Facilities for Sampling. Provide suitable facilities for readily obtaining representative samples of aggregate and concrete for uniformity test purposes. Furnish the necessary platforms, tools, and equipment for obtaining samples.

520.4.2.4. Mix Proportions. The proportions of materials entering into the concrete mixtures shall be in accordance with the approved job-mix formula. Change the proportions whenever necessary to maintain the workability, strength, and standard of quality required, and to meet the varying conditions encountered during the construction; however, no changes will be made without prior approval.

520.4.2.5. Measurement. Provide the equipment necessary to measure and control the amount of each material in each batch of concrete. Bulk cement shall be weighed, but cement in unopened bags, as packed by the manufacturer, may be used without weighing. If bagged cement is used, batches shall be proportioned so that fractional bags will not be required. One bag of portland cement will be considered as weighing 42 kilograms [94 pounds]. Mixing water and air-entraining admixtures may be measured by volume or by weight. One liter [gallon] of water will be considered as weighing 3.78 kilograms [8.33 pounds].

520.4.2.6. Workability. Maintain the slump of the concrete at the lowest practicable value, not exceeding 50 millimeters [2 inches] when tested in accordance with ASTM C 143/C 143M.

520.4.3. Placing.

520.4.3.1. Portland Cement Concrete (PCC). Place concrete within 45 minutes from the time all ingredients are charged into the mixing drum, before the concrete has obtained its initial set, and while the bonding coat is tacky. The temperature of the concrete, as deposited in the form, shall be not less than 5 °C [40 °F] nor more than 35 °C [90 °F]. Deposit concrete in such a manner as to require a minimum of rehandling, and to least disturb the bonding coat. The placing of concrete shall be rapid and continuous for each area. Workers shall not walk on the bonding-course surface or in the concrete during placing and finishing operations. The concrete shall be thoroughly consolidated by tamping or by means of suitable vibrating equipment.

520.4.3.2. Epoxy Resin Concrete and Mortar. Epoxy resin concrete shall be limited to use on patches with a surface area of less than 600 millimeters [2 feet] square. Place the epoxy resin material in layers not over 50 millimeters [2 inches] thick. The time interval between placement of additional layers shall be such that the temperature of the epoxy resin material does not exceed 60 °C [140 °F] at any time during hardening.

Mechanical vibrators and hand tampers shall be used to consolidate the concrete or mortar. Remove any repair material on the surrounding surfaces of the existing concrete before it hardens. Where the spalled area abuts a joint, an insert or other bond-breaking medium shall be used to prevent bond at the joint face. A reservoir for the joint sealant shall be sawed to the dimensions required for other joints. The reservoir shall be thoroughly cleaned and then sealed with the sealer specified for the joints. Where spalls and popouts are not adjacent to joints and are less than 150 millimeters [6 inches] in maximum dimension, the pavement may be prepared by drilling a core 50 millimeters [2 inches] in diameter greater than the size of the defect, centered over the defect, and 50 millimeters [2 inches] deep or 12 millimeters [1/2 inch] into sound concrete, whichever is greater. The core hole shall be repaired as specified above for other spalls.]

520.4.3.3. Proprietary Cementitious Products. Perform placing, consolidating, finishing, and curing operations in accordance with the manufacturer's written instructions.

520.4.4. Field Test Specimens.

520.4.4.1. General Requirements. Furnish concrete samples, taken in the field and tested 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 in service. Determine the air content in conformance with ASTM C 231. Mold and cure test cylinders in conformance with ASTM C 31/C 31M, *Standard Practice for Making and Curing Concrete Test Specimens in the Field*, and as specified below. Furnish all materials, labor, and facilities required for molding, curing, and protecting test cylinders at the site and under the supervision of the Government. Furnishing curing facilities for test beams shall include furnishing and operating water tanks equipped with temperature-control devices that will automatically maintain the temperature of the water at 23 °C [73 °F] plus or minus 3 °C [5 °F]. Also furnish and maintain at the site, boxes or other facilities suitable for storing the specimens while in the mold at a temperature of 23 °C [73 °F] plus or minus 6 °C [10 °F]. Tests of the fresh concrete and of the hardened concrete cylinders shall be made by and at the expense of the Contractor. Tests of proprietary cementitious products shall be in accordance with the manufacturer's written instructions.

520.4.4.2. Specimens for Strength Tests. Make cylinders for each shift of placed concrete. Mold each group of test cylinders from the same batch of concrete, and make a sufficient number of specimens to provide two compressive strength tests at each test age. Make one group of specimens during the first half of each shift, and the other during the last portion of the shift; however, at the start of paving operations and each time the aggregate source, aggregate characteristics, or mix design is changed, make one additional set of test cylinders.

520.4.5. Finishing. Start finishing operations immediately after placement of the concrete. The finished surfaces of patched areas shall have a surface texture approximating that of the adjacent undisturbed pavements.

520.4.6. Curing. Cure the concrete by protecting it against loss of moisture and rapid temperature changes for a period of not less than 7 days from the beginning of the curing operation. Protect unhardened concrete from rain and flowing water. Provide all equipment needed for adequate curing and protection of the concrete on hand and ready to install before actual concrete placement begins. Cure proprietary cementitious products in accordance with manufacturer's recommendations. Failure to comply with curing requirements will be cause for immediate suspension of concreting operations.

520.4.6.1. Moist Curing. Moist-cure all PCC patches for the first 24 hours after finishing. Immediately after the finishing operations have been completed and the concrete has set sufficiently to prevent marring the surface, the entire surface of the newly laid concrete shall be covered with approved wetted burlap that shall be kept wet for a period of not less than 24 hours. Keep the surface of the newly laid concrete moist until the burlap coverings are in place. Ensure that moist curing is continuous 24 hours per day and that the entire surface is wet. Continue curing the concrete for the duration of the required curing period by this method or one of the methods specified below.

520.4.6.2. Waterproof Paper Blankets or Impermeable Sheets. Immediately after removing the covering used for initial curing, moisten the exposed concrete surfaces with a fine spray of water and then cover with waterproof paper blankets, polyethylene-coated burlap blankets, or impermeable sheets. Polyethylene-coated burlap shall be saturated with water before placing. Sheets shall be placed with the light-colored side up. Sheets shall overlap not less than 300 millimeters [12 inches], with edges taped or secured to form a completely closed joint. Coverings shall be weighted down to prevent displacement or billowing from winds. Immediately repair any tears or holes appearing during the curing period.

520.4.6.3. Membrane-Forming Curing Compound. Apply membrane-forming curing compound immediately to exposed concrete surfaces after removing burlap coverings. Apply the curing compound with an overlapping coverage that will give a two-coat application at a coverage of not more than 20 square meters per liter [200 square feet per gallon] for both coats. When application is made by hand-operated sprayers, apply the second coat in a direction approximately at right angles to the first coat. The concrete shall be properly cured at joints, but no curing compound shall enter joints that are to be sealed with joint-sealing compound. The compound shall form a uniform, continuous, cohesive film that will not check, crack, or peel, and that will be free from pinholes and other imperfections. Concrete surfaces that are subjected to heavy rainfall within 3 hours after the curing compound has been applied shall be resprayed at the coverage specified above and at no additional cost to the Government. Repair areas covered with curing compound that are damaged by pedestrian and vehicular traffic or by subsequent construction operations within the specified curing period at no additional cost to the Government.

520.4.7. Finish Tolerance. The finished surfaces of patched areas shall meet the grade of the adjoining pavements and shall not deviate more than 3 millimeters [1/8 inch] from a true plane surface within the patched area.

520.4.8. Pavement Protection. Protect the patched areas against damage prior to final acceptance of the work by the Government. Exclude traffic from the patched areas by erecting and maintaining barricades and signs until the completion of the curing period of the concrete.

520.4.9. Joints. Joints shall conform in detail and be in alignment with the existing joints. After curing of the concrete, prepare the joints and seal in accordance with section AF 510 PORTLAND CEMENT CONCRETE (PCC) FOR AIRFIELDS.

520.5. Unit Prices.

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NOTE: Delete unit price paragraphs when lump sum bidding is used. Edit the pay item descriptions to suit the project.

****

520.5.1. Measurement.

520.5.1.1. Partial-Depth Spall Repair. The quantity of partial-depth spall repair shall be measured by the number of square meters [feet] repaired by the specified method and accepted as complete.

520.5.2. Payment.

520.5.2.1. The quantities of pay items, determined as specified above, will be paid for at the respective contract unit prices. Payment shall constitute full compensation for all operations necessary to complete the work as specified herein.

520.5.2.2. Payment will be made under:

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NOTE: Edit the pay item list to suit the project.

****

Item 520-1	Partial-Depth PCC Spall Repair	per SM [SF]

AF 600
FIELD-MOLDED JOINT SEALANT
FOR RIGID PAVEMENTS

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

600.2. Materials.

600.2.1. For areas where fuel spillage can be expected (aprons), sealant meeting the requirements of American Society for Testing and Materials (ASTM) D 7116, *Standard Specification for Joint Sealants, Hot Applied, Jet Fuel Resistant Types, for Portland Cement Concrete Pavements*, or ASTM D 5893, *Standard Specification for Cold Applied, Single Component, Chemically Curing Silicone Joint Sealant for Portland Cement Concrete Pavements*, shall be used; however, silicone sealant should not be used on runways where high-pressure water blast is used for rubber removal.

600.2.2. For areas that will be subject to jet blast and/or fuel spillage, sealant meeting U.S. Federal Specification (FS) SS-S-200E, *Sealants, Joint, Two-Component, Jet-Blast Resistant, Cold-Applied, for Portland Cement Concrete Pavement*, Type H or Type M shall be used.

600.2.3. For areas not subject to jet blast or fuel spillage, ASTM D 6690, *Standard Specification for Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavements,* Type II or Type III, or ASTM D 5893, *Standard Specification for Cold Applied, Single Component, Chemically Curing Silicone Joint Sealant for Portland Cement Concrete Pavements*, can be used.

600.2.4. Sealant meeting the requirements of ASTM D 7116 and ASTM D 6690 shall be required to meet the additional requirements of U.S. Army Corps of Engineers (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.

600.2.5. Backer rods and bond breaking tape shall be compatible with the sealant and sealant installation temperatures.

600.2.6. Backer material shall have a width of 25%±5% greater than the joint sealant reservoir.

600.3. Construction.

600.3.1. Joint Sealant Reservoir.

600.3.1.1. For installation in new concrete pavement, cut the pavement joint sealant reservoir into the existing pavement to the width and depth shown on the drawings.

600.3.1.2. Where joint sealant removal and replacement is specified, remove existing joint sealant by plowing, scraping or other means while protecting the pavement from damage.

600.3.1.3. Where joint sealant removal, reface by saw-cut, and install joint sealant is specified, saw-cut the new joint sealant reservoir into the existing pavement to the width and depth shown on the drawings. Ensure that the saw blade is centered so that new reservoir faces are produced on both sides.

600.3.1.4. Where saw-cut and seal linear crack is specified, cracks shall be sawed in accordance with the plan details. Immediately after sawing the crack, the resulting slurry shall be completely removed from the joint and adjacent area by flushing with a jet of water, and by use of other tools as necessary.

600.3.2. After saw-cut and/or joint sealant removal, thoroughly clean the joints by sandblasting and/or water blasting to remove all residue from joint sawing or curing material.

600.3.3. 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.

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

600.3.5. Apply sealant as per the manufacturer's recommendations. Sealants meeting the requirements of ASTM D 7116 and ASTM D 6690 will require heating pots. Sealant meeting Federal Specification (FS) SS-S-200E will require mixing two components before application. Heating will not be required.

600.4. Quality Control (QC) Testing. Follow the manufacturer's recommendations. Ensure that joints to be sealed remain clean.

600.5. Unit Prices.

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NOTE: Delete unit price paragraphs when lump sum bidding is used. Edit the pay item descriptions to suit the project. If the only joint sealant used in the project is associated with new PCC construction, then joint sealant installation should be incidental to the pavement pay item.

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600.5.1. Measurement.

[600.5.1.1. Remove and Replace Joint Sealant. The quantity of joint sealant removal and replacement shall be measured by the linear meter [foot] of sealant in place, complete, and accepted.

600.5.1.2. Remove, Reface by Saw-Cut, and Install Joint Sealant. The quantity of joint sealant removal, reface by saw-cut, and joint sealant installation shall be measured by the linear meter [foot] of sealant in place, complete, and accepted.

600.5.1.3. Saw-cut and Seal Linear Crack. The quantity of saw-cut and seal linear cracks shall be measured by the linear meter [foot] of sealant in place, complete, and accepted.**]**

[600.5.1.1. Joint sealant shall not be measured separately for payment, but shall be considered incidental to the associated pavement item.**]**

****

NOTE: Delete 600.5.2 if all joint sealant is incidental to other pay items.

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[600.5.2. Payment.

600.5.2.1. The quantities of pay items, determined as specified above, will be paid for at the respective contract unit prices. Payment shall constitute full compensation for all operations necessary to complete the work as specified herein.

600.5.2.2. Payment will be made under:

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NOTE: Edit the pay item list to suit the project.

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Item 600-1	Remove and Replace Joint Sealant	per LM [LF]
Item 600-2	Remove, Reface by Saw-Cut, and Install Joint Sealant	per LM [LF]
Item 600-3	Saw-cut and Seal Linear Crack	per LM [LF] **]**

AF 610
AIRFIELD PAVEMENT MARKING AND REMOVAL

610.1. General. This specification covers the requirements for pavement marking.

610.2. Materials.

610.2.1. Paint. Paint shall conform to Federal Specification (FS) TT-P-1952*, Paint, Traffic and Airfield Marking, Waterborne*, color as indicated on the drawings, be homogeneous, and show no hard settlement or other objectionable characteristics.

610.2.2. Reflective Media. Reflective media shall conform to FS TT-B-1325C, *Beads (Glass Spheres) Retro-Reflective*, Type I, Gradation A.

610.3. Construction.

610.3.1. Surface Preparation. Surfaces to be marked shall be thoroughly cleaned and free of dust, dirt, or water prior to marking application. For new rigid pavements requiring early painting, a pretreatment with an aqueous solution containing 3% phosphoric acid and 2% zinc chloride shall be applied to areas to be painted prior to applying the paint. Do not apply paint to portland cement concrete pavement until the concrete in the areas to be painted is clean of curing material. Do not apply paint to asphaltic surfaces until the surface is allowed to cure. For 50 to 100 millimeters [2 to 4 inches] of asphaltic surface course, wait 72 hours before applying paint.

610.3.2. Paint Application. Paint shall be applied to clean, dry surfaces, and only when the air and pavement temperatures are at least 5 °C [40 °F] and not more than 35 °C [95 °F], and when the weather is not foggy or windy.

610.3.3. Reflective Media. Reflective media shall be applied directly to the wet paint immediately after applying the paint.

610.3.4. Rate of Application. Paint shall be applied at the rate of 2.6±0.1 square meters per liter [105±5 square feet per gallon], and reflective media at the rate of 1.0±0.06 kilograms of media per 1.0 liter [8±0.5 pounds of media per gallon] of paint.

610.3.5. Temporary Marking Rate of Application. Temporary markings and glass beads shall be applied at half the rate specified in paragraph 610.3.4. Temporary markings shall be removed in accordance with paragraph 610.3.6.

610.3.6. Marking Removal. Pavement marking shall be removed in the areas shown on the drawings. Removal of marking shall be as complete as possible without damage to the surface. Aggregate shall not be exposed by the removal process. The Contractor shall demonstrate pavement marking removal techniques in an area designated by the

Government. The demonstration area will become the standard for the remainder of the work.

610.4. Quality Control (QC) Testing.

610.4.1. Application rates shall be checked at the start of the job and verified by quality assurance (QA). Examine paint and media containers for signs of age, separation, or damage. Surface preparation shall be approved by QA before paint is placed.

610.4.2. The edges of the markings shall not vary from a straight line more than 12 millimeters in 15 meters [1/2 inch in 50 feet], and the dimensions shall be within a tolerance of ±5%.

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

610.5. Unit Prices.

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NOTE: Delete unit price paragraphs when lump sum bidding is used. Edit the pay item descriptions to suit the project.

****

610.5.1. Measurement.

610.5.1.1. Pavement Marking. The quantity of pavement marking to be paid for shall be the number of square meters [feet] completed and accepted. All paint, including black outline, shall be measured for payment. Where two coats are applied on the same area, the area will be measured for payment only once.

610.5.1.2. Temporary Pavement Marking. The quantity of temporary pavement marking to be paid for shall be the number of square meters [feet] applied and later removed. All paint, including black outline, shall be measured for payment.

610.5.1.3. Pavement Marking Removal. The quantity of pavement marking removal to be paid for shall be the number of square meters [feet] measured in its original position prior to removal.

610.5.2. Payment.

610.5.2.1. The quantities of pay items, determined as specified above, will be paid for at the respective contract unit prices. Payment shall constitute full compensation for all operations necessary to complete the work as specified herein.

610.5.2.2. Payment will be made under:

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NOTE: Edit the pay item list to suit the project.
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Item 610-1	Pavement Marking	per SM [SF]
Item 610-2	Temporary Pavement Marking	per SM [SF]
Item 610-3	Pavement Marking Removal	per SM [SF]

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