

UNIFIED FACILITIES CRITERIA (UFC)

O&M MANUAL: ASPHALT AND CONCRETE PAVEMENT MAINTENANCE AND REPAIR



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O&M MANUAL: ASPHALT AND CONCRETE PAVEMENT REPAIR

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U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by \1\ ... /1/)

Change No.	Date	Location

This UFC supersedes UFC 3-270-01, dated 15 March 2001; UFC 3-270-02, dated 15 March 2001; UFC 3-270-03, dated 15 March 2001; UFC 3-270-04, dated 15 March 2001; UFC 3-250-06, dated 16 Jan 2004; Air Force ETL 96-4, dated 9 July 1996; Air Force ETL 97-2, dated 28 July 1997; Air Force ETL 02-7, dated 7 August 2002; Air Force ETL 02-8, dated 5 September 2002; Air Force ETL 11-26, dated 21 December 2011; and Air Force ETL 14-2, dated 21 November 2014.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with [USD \(AT&L\) Memorandum](#) dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: [Criteria Change Request](#). The form is also accessible from the Internet sites listed below.

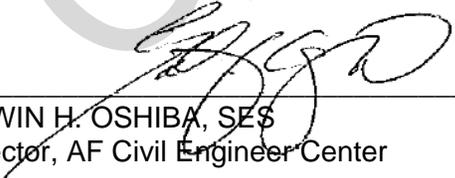
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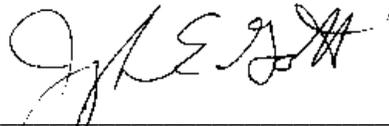
- Whole Building Design Guide web site <http://dod.wbdg.org/>.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

AUTHORIZED BY:


LARRY D. McCALLISTER, PhD, PE, PMP, SES
Chief, Engineering and Construction
Directorate of Civil Works
U.S. Army Corps of Engineers


EDWIN H. OSHIBA, SES
Director, AF Civil Engineer Center


JOSEPH E. GOTT, P.E.
Chief Engineer
Naval Facilities Engineering Command


MICHAEL McANDREW
Deputy Assistant Secretary of Defense
(Facility Investment and Management)
Office of the Assistant Secretary of Defense
(Energy, Installations, and Environment)

**UNIFIED FACILITIES CRITERIA (UFC)
NEW SUMMARY SHEET**

Document: UFC 3-270-01, *O&M: Asphalt and Concrete Pavement Maintenance and Repair*

Superseding: UFC 3-270-01, *Asphalt Maintenance and Repair*; UFC 3-270-02, *Asphalt Crack Repair*; UFC 3-270-03, *Concrete Crack and Partial-Depth Spall Repair*; UFC 3-270-04, *Concrete Repair*; UFC 3-250-06, *Repair of Rigid Pavements Using Epoxy Resin Grouts, Mortars, and Concretes*; ETL 96-4, *Temporary Joint Sealing Details and Procedures for Pavements*; ETL 97-2, *Maintenance and Repair of Rigid Airfield Pavement Surfaces, Joints and Cracks*; ETL 02-7, *Preventing Concrete Deterioration Under B-1 and F/A-18 Aircraft*; ETL 02-8, *Silicone Joint Sealant Specification for Airfield Pavements*; ETL 11-26, *Using Asphalt Surface Treatments as Preventive Maintenance on Asphalt Airfield Pavements*; and ETL 14-2, *Preventing and Repairing Concrete Deterioration Under MV-22 and CV-22 Aircraft*;

Description: UFCs 3-270-01, 3-270-02, 3-270-03, 3-270-04 and UFC 3-250-06 are hereby cancelled and combined into this UFC. To reflect the combination of these four UFCs into one document, the title of UFC 3-270-01 is changed from *Asphalt Maintenance and Repair* to *O&M Manual: Asphalt and Concrete Pavement Maintenance and Repair*. Many figures are updated and the document reviewed to ensure recent developments are included. In addition, the following Air Force Engineering Technical Letters (ETLs) are cancelled and incorporated into this UFC: ETL 96-4, ETL 97-2, ETL 02-7, ETL 02-8, ETL 11-26, and ETL 14-2.

Reasons for Document: This UFC provides engineers with information on the options for maintaining and repairing, as well as preserving and extending, the service life of pavements. It also provides information on which methods are appropriate to address observed pavement distresses. It also outlines materials, equipment, techniques, and cautions required to produce a cost-effective and durable pavement. The overlap in the five superseded UFCs and six cancelled ETLs made it difficult to ensure consistency between documents as modifications to each were added. Combining these UFCs and ETLs into one document facilitates user comprehension and maintains internal consistency during future updates.

Impact: These changes enhance user access to the technical guidance in the documents (one document instead of eleven). This effort reduces the cost to maintain this guidance by reducing ambiguity and reducing the number of documents. There is a potential decrease in initial and lifecycle costs due to increased options available to sustain the pavements throughout the life of the pavement and which will extend to the life of the pavement.

Unification Issues: There are no unification issues.

Disclaimer: Use of the name or mark of any specific manufacturer, commercial product, commodity, or service in this publication does not imply endorsement.

CONTENTS

CHAPTER 1 INTRODUCTION	1
1-1 PURPOSE AND SCOPE.....	1
1-2 APPLICABILITY.....	1
1-3 GENERAL BUILDING REQUIREMENTS.	1
1-4 REFERENCES.	1
1-5 GLOSSARY.....	2
CHAPTER 2 TYPES OF MAINTENANCE AND REPAIR FOR PAVEMENTS.....	3
2-1 INTRODUCTION.	3
2-1.1 Maintenance and Repair.....	3
2-1.2 Pavement Management.....	3
2-1.3 Quality Control.	3
2-2 PAVEMENT MATERIALS.....	4
2-2.1 Safety.....	4
2-2.2 Importance of Weather.	4
2-2.3 Asphalt Pavement Materials.....	7
2-2.4 Grading System for Asphalt Emulsions.....	10
2-2.5 Concrete Pavement Materials.....	11
2-2.6 Concrete Pavements Types.....	15
2-2.7 Cement Standards.....	15
2-3 PAVEMENT DISTRESSES.	18
2-3.1 Asphalt Concrete (AC) Pavement Distresses.	18
2-3.2 Portland Cement Concrete (PCC) Pavement Distresses.....	19
2-4 TYPES OF MAINTENANCE AND REPAIR.	20
2-4.1 Global Preventive Maintenance (PM).	20
2-4.2 Localized Preventive Maintenance (PM).....	20
2-4.3 Operational Maintenance.....	20
2-5 PAVEMENT REPAIR EQUIPMENT.	21
2-5.1 Equipment Inspection.	22
2-5.2 Equipment.....	22
CHAPTER 3 FULL-DEPTH ASPHALT PATCHES	27
3-1 INTRODUCTION.	27

3-2	PROCEDURAL STEPS (FULL-DEPTH PATCH)	27
3-2.1	Mark Repair Area.....	27
3-2.2	Make Saw Cut Through Pavement.....	27
3-2.3	Removal of Defective Material.....	29
3-2.4	Remove, Replace, and Compact the Base.....	29
3-2.5	Apply Tack Coat (and Prime Coat, If Used).....	29
3-2.6	Place the Patch Material.....	30
3-2.7	Compact the Patch Area.....	31
3-2.8	Ensure Surface of Patch is Watertight.....	33
3-2.9	Problem Areas.....	33
CHAPTER 4	PROCEDURAL STEPS (PARTIAL-DEPTH PATCH)	35
4-1	INTRODUCTION	35
CHAPTER 5	SPRAYED ASPHALT SURFACE TREATMENTS	37
5-1	INTRODUCTION	37
5-2	PRIME COAT	37
5-2.1	Procedural Steps (Prime Coat).....	37
5-2.2	Problem Areas (Prime Coat).....	38
5-3	TACK COAT	38
5-3.1	Procedural Steps (Tack Coat).....	39
5-3.2	Problem Areas (Tack Coat).....	39
5-4	FOG SEALS AND REJUVENATORS	39
5-4.1	Procedural Steps (Fog Seals and Rejuvenators).....	40
5-4.2	Problem Areas (Fog Seals and Rejuvenators).....	41
CHAPTER 6	BITUMINOUS SURFACE TREATMENT	43
6-1	INTRODUCTION	43
6-2	SINGLE BITUMINOUS SURFACE TREATMENT (SBST)	43
6-2.1	Procedural Steps (SBST).....	43
6-2.2	Problem Areas (SBST).....	46
CHAPTER 7	DOUBLE BITUMINOUS SURFACE TREATMENT	49
7-1	INTRODUCTION	49
7-1.1	Procedural Steps (DBST).....	49
7-1.2	Problem Areas (DBST).....	50

7-1.3	Sandseal (DBST).....	51
7-1.4	Sand Application and Rolling.....	51
7-1.5	Sweep Excess Material.....	51
7-1.6	Problem Areas.....	52
CHAPTER 8 ASPHALT SLURRY SEALS AND MICROSURFACING		53
8-1	INTRODUCTION.....	53
8-2	MIXTURE MATERIALS.....	53
8-2.1	Emulsions.....	53
8-2.2	Aggregate.....	53
8-2.3	Filler.....	53
8-3	SLURRY SEAL PROCEDURAL STEPS.....	54
8-3.1	Prepare the Surface.....	54
8-3.2	Apply the Slurry.....	54
8-3.3	Rolling the Slurry.....	55
8-3.4	Cure the Slurry.....	56
8-3.5	Problem Areas.....	56
8-3.6	Negative Impacts.....	57
CHAPTER 9 ASPHALT CRACK SEALING		59
9-1	INTRODUCTION.....	59
9-2	WHEN TO SEAL.....	59
9-2.1	Field Evaluations.....	59
9-2.2	Schedule.....	60
9-2.3	Climatic Conditions.....	60
9-2.4	Porous Friction Surfaces.....	61
9-3	SPECIFICATIONS.....	61
9-3.1	ASTM.....	61
9-3.2	Other Specifications.....	61
9-3.3	Testing.....	61
9-4	CRACK SEALING PROCEDURAL STEPS.....	61
9-4.1	Crack Size Guidelines.....	61
9-4.2	Crack Widening.....	63
9-4.3	Initial Crack Cleaning.....	63

9-4.4	Debris Removal.	64
9-4.5	Final Crack Cleaning.	64
9-4.6	Inspection.	64
9-4.7	Crack Cleaning Summary.	64
9-4.8	Backer Rod Material.	67
9-4.9	Inspection Prior to Sealing.	68
9-4.10	Sealant Temperature and Application.	68
9-4.11	Crack Sealing Delays.	69
9-4.12	Inspection After Sealing.	69
9-5	PROBLEM AREAS.	70
9-5.1	Categories of Problems.	70
CHAPTER 10 POROUS FRICTION SURFACES.		73
10-1	INTRODUCTION.	73
10-2	SEALING CRACKS.	73
10-2.1	Prepare the Crack.	73
10-2.2	Seal the Crack.	73
10-2.3	Patching PFS.	74
10-2.4	Raveling Control.	74
10-2.5	Patching Using Standard Hot Asphalt Plant Mix.	74
CHAPTER 11 DIAMOND-GRINDING ASPHALT CONCRETE PAVEMENTS.		77
11-1	INTRODUCTION.	77
11-2	NEED FOR GRINDING.	77
11-3	GRINDING PROCESS.	77
11-4	TEST SECTION.	78
11-5	GRINDING PROCEDURE.	78
11-6	ACCEPTANCE TESTING.	79
CHAPTER 12 CONCRETE PAVEMENT CRACK SEALING.		81
12-1	INTRODUCTION.	81
12-2	KEY STEPS.	81
12-3	GENERAL PRACTICE.	82
12-4	TEST SECTION.	82
12-5	CRACK SEALANTS.	82

12-5.1	Hot-Applied Sealants.	82
12-5.2	Cold-Applied Sealants.	83
12-5.3	Fuel- and Blast-Resistant Sealants.....	83
12-6	SEALANT SHAPE FACTOR.....	83
12-7	BACKER ROD AND SEPARATING MATERIALS.	84
12-7.1	Backer Rod Materials.	84
12-7.2	Separating Materials.	84
12-8	CRACK PREPARATION.....	85
12-8.1	Introduction.	85
12-8.2	Cleaning.....	85
12-9	CRACK SEALING PROCEDURES.....	86
12-9.1	Introduction.	86
12-9.2	Process.....	86
12-9.3	Cautions.....	86
12-10	TEMPORARY CRACK/JOINT SEALING PROCEDURES FOR PCC. ...	87
12-10.1	Introduction.	87
12-10.2	Repair Procedures Neoprene Compression Seal (NCS) Joints.....	87
12-10.3	Random Cracks.	90
12-10.4	Field Molded Joints.....	92
12-10.5	Partial-depth Joints.....	94
CHAPTER 13	PARTIAL-DEPTH REPAIR OF CONCRETE PAVEMENTS	97
13-1	INTRODUCTION.	97
13-2	NEED FOR PARTIAL-DEPTH REPAIR.....	97
13-2.1	Joint Spalling.	97
13-2.2	Mid-slab Spalling.	97
13-2.3	Partial-depth Repair Key Steps.....	98
13-3	SELECTION OF REPAIR BOUNDARIES.....	99
13-4	REMOVAL OF EXISTING CONCRETE.	100
13-4.1	Sawing and Chipping.	100
13-4.2	Milling Process.....	101
13-4.3	Partial Versus Full-depth Repair.	101
13-5	CLEANING.....	102

13-6	JOINT PREPARATION.....	102
13-6.1	Joint Bond-Breaking.....	103
13-6.2	New Joint/Crack Width.....	103
13-6.3	Shoulder Joints.....	104
13-7	PLACEMENT OF PATCH MATERIALS.....	104
13-8	FINISHING.....	105
13-9	TREATMENT OF SAW-CUT RUNOUTS AND PATCH/SLAB INTERFACE.....	105
13-10	CURING.....	105
13-11	JOINT/CRACK RESEALING.....	106
CHAPTER 14	FULL-DEPTH REPAIR OF CONCRETE PAVEMENTS.....	107
14-1	INTRODUCTION.....	107
14-2	NEED FOR FULL-DEPTH REPAIR.....	107
14-2.1	Rigid Pavement Distress Types.....	107
14-2.2	Other Rigid Pavement Concerns.....	108
14-2.3	Full-Depth Repair Key Steps.....	108
14-2.4	Selection of Repair Boundaries.....	109
14-2.5	Sawing Cutting Repair Boundaries.....	110
14-2.6	Removal of Existing Concrete.....	112
14-2.7	Subgrade and Base Preparation.....	114
14-2.8	Dowel and Tie-Bar Placement.....	115
14-2.9	Drilling Dowel and Tie-Bar Holes.....	116
14-2.10	Dowel and Tie-Bar Installation.....	116
14-2.11	Continuous Reinforced Concrete (CRC) Pavement Repair.....	118
14-2.12	Expansion Joints.....	118
14-2.13	Filler Material.....	120
14-2.14	Concrete Placement.....	120
14-2.15	Concrete Finishing and Texturing.....	121
14-2.16	Curing.....	121
14-2.17	Joint Sealing.....	121
14-3	PRECAUTIONS.....	123
CHAPTER 15	CONCRETE PAVEMENT SLAB JACKING.....	125
15-1	INTRODUCTION.....	125

15-2	NEED FOR SLAB JACKING.	125
15-3	SLAB JACKING GROUT MATERIALS.	125
15-3.1	Cement-Fly Ash Grout.	125
15-3.2	High-density Polyurethane Polymer Deep Injection.....	126
15-4	INJECTION HOLE LOCATIONS.	127
15-5	DRILLING INJECTION HOLES.	127
15-6	GROUT PUMPING.	128
15-7	ELEVATION CONTROL DURING SLAB JACKING.	128
15-8	PLUGGING AND CLEANUP.	129
CHAPTER 16 SUBSEALING JOINTED CONCRETE PAVEMENTS.		131
16-1	INTRODUCTION.	131
16-2	NEED FOR SUBSEALING.	131
16-3	PAVEMENT SUBSEALING KEY STEPS.	131
16-4	SUBSEALING GROUT MATERIALS.	132
16-4.1	Polyurethane Polymer Subsealing.....	132
16-5	VOID DETECTION.	132
16-5.1	Visual Inspection.....	133
16-5.2	Proof Rolling.	133
16-5.3	Nondestructive Deflection Testing.	133
16-6	INJECTION HOLE LOCATIONS.	134
16-7	DRILLING HOLES.	135
16-8	GROUT INJECTION.	135
16-9	RETESTING SLAB CORNERS.	135
16-10	PLUGGING AND CLEANUP.	136
CHAPTER 17 PCC PAVEMENT DIAMOND GRINDING.		137
17-1	INTRODUCTION.	137
17-2	NEED FOR GRINDING.	137
17-3	GRINDING PROCESS.	137
17-4	TEST SECTION.	139
17-5	GRINDING PROCEDURE.	139
17-5.1	Roughness Removal.	140
17-5.2	Fault Removal.....	140

17-5.3	Skid Resistance.	141
17-6	ACCEPTANCE TESTING.	141
CHAPTER 18 CONCRETE PAVEMENT LOAD TRANSFER RESTORATION		143
18-1	INTRODUCTION.	143
18-2	NEED FOR LOAD TRANSFER RESTORATION.....	143
18-3	LOAD TRANSFER RESTORATION (LTR) KEY STEPS.....	144
18-4	CORRECTION OF DEFICIENCIES.....	145
18-5	DOWEL LOAD TRANSFER RESTORATION (LTR) PROCESS.....	145
18-5.1	Dowel Size Requirement.	145
18-5.2	Cutting Slots for Dowel Installation.	145
18-5.3	Concrete Removal & Dowel Installation.....	147
18-5.4	Patching Material.	149
18-5.5	Placing Patch Material.	149
18-5.6	Finishing Activities.	150
18-6	KEYED JOINTS LOAD TRANSFER RESTORATION PROCESS.	150
18-6.1	Keyed Joint Key Steps.....	151
18-6.1.1	Keyed Joint Concrete Removal.	151
18-6.1.2	Dowel Bar Placement and Installation.	151
18-6.1.3	Tie Bar Placement and Installation.	151
CHAPTER 19 CONCRETE PAVEMENT RETROFITTED EDGE DRAINAGE.....		153
19-1	INTRODUCTION.	153
19-2	NEED FOR PAVEMENT-EDGE DRAINAGE.	153
19-3	DRAINAGE SYSTEM CLASSIFICATIONS.....	153
19-3.1	Surface Drainage.....	153
19-3.2	Subsurface Drainage.	153
19-4	EDGE DRAINAGE REQUIREMENTS.....	154
19-5	EDGE DRAINAGE CANDIDATES.	154
19-5.1	Edge Drainage Key Steps.....	154
19-6	EDGE DRAINAGE MATERIALS.....	155
19-6.1	Drainage Pipe.	155
19-6.2	Perforated Drainage Pipe.	155
19-6.3	Fin Drains.	156

19-6.4	Filter Material.	156
19-6.5	Dispersive Clays.	157
19-6.6	Filter Fabrics.	157
19-7	SUBSURFACE DRAIN INSTALLATION.	158
19-7.1	Filter Material Placement.	159
19-7.2	Drainage Pipe Outlets.	159
19-7.3	Drainage Pipe Access.	160
19-7.4	Caution.	160
CHAPTER 20	MAINTENANCE OF HEAT-RESISTANT CONCRETE	161
20-1	INTRODUCTION.	161
20-2	MAINTENANCE AND REPAIR.	162
20-2.1	Pavement Markings.	162
20-2.2	VL Pad Surface Grinding.	162
20-2.3	Frequency and Depth.	162
20-2.4	Diamond Grinding Procedures.	162
20-2.5	Water Cutting.	163
20-2.6	Surface Sealing.	163
20-2.7	HTC Patching and Materials.	163
20-2.8	PCC Patching.	164
20-3	SUMMARY OF MITIGATION TIPS.	164
20-3.1	Water/Cement Ratio.	164
20-3.2	PCC Mix.	164
20-3.3	Construction Quality.	165
20-3.4	Proper Material.	165
CHAPTER 21	REPAIR OF PCC DAMAGED BY POL	167
21-1	INTRODUCTION.	167
21-2	PRIMARY DAMAGE MECHANISMS.	167
21-3	REPAIR TECHNIQUES/MATERIALS.	167
21-3.1	Sodium Silicate Application.	167
21-3.2	Multifilament Fibers.	168
21-3.3	Polymer Coatings.	168
21-3.4	Surface-Applied Penetrating Chemically Reactive Silicates.	168

21-3.5	Magnesium Phosphate Cement (MPC)	168
21-4	REQUIREMENTS.....	169
21-4.1	Cleaning.....	169
21-4.2	When to Seal.	169
21-4.3	Distress Repairs.	169
21-4.4	Existing Distress Effects.	169
21-4.5	Where to Seal.	169
21-4.6	High-Temperature Aggregates.	170
21-5	PCC SODIUM SILICATE SURFACE SEALING.	170
21-5.1	Sodium Silicate Solution.	170
21-5.2	Surface Cleaning.	170
21-5.3	When to Seal.	171
21-5.4	Joint Sealing.	171
21-5.5	Paint Markings.	171
21-5.6	Environmental Conditions.	171
21-5.7	Surface Seal Application.....	171
21-5.8	Final Evaluation.	171
21-6	CLEANING POL CONTAMINATION FROM PCC AND PCC JOINTS.	172
21-6.1	Stains.....	172
21-6.2	Dawn (or Simple Green) Dishwashing Detergent and Hot Water.	172
21-6.3	Tri-Sodium Phosphate (TSP).....	172
21-6.4	Sodium Hydroxide.	172
21-6.5	Super Washing Soda.	173
21-6.6	Phosphoric Acid Cleaner.	173
21-6.7	Bacteria and Enzymes that Remove Oil Stains in Concrete.	173
21-6.8	Replacement.....	173
APPENDIX A REFERENCES.....		175
APPENDIX B BEST PRACTICES		183
APPENDIX C GLOSSARY		185

FIGURES

Figure 2-1 Installation of Backer Rod	26
Figure 3-1 Diamond Tip Saw Blade	28
Figure 3-2 Abrasive Blade	28
Figure 3-3 Damaged Pavement Removed by Sawing	28
Figure 3-4 Small Milling Head Attachment	29
Figure 3-5 Hand-spraying Edge of Cut	30
Figure 3-6 Overfill Prior to Compaction	31
Figure 3-7 Vibratory Plate Compactor	32
Figure 3-8 Steel Wheel Roller	32
Figure 3-9 Check Level of Patch Surface	32
Figure 3-10 Seal the Edges	33
Figure 5-1 Spray Bar and Nozzle Settings	38
Figure 5-2 Asphalt Distributor	41
Figure 6-1 Applying Aggregate with Tailgate Spreader on Dump Truck	45
Figure 6-2 Applying Aggregate with Self- Propelled Hopper-type Spreader	45
Figure 6-3 Use Paper for Straight Edge	47
Figure 6-4 Aggregate and Sprayed Asphalt Spread Pattern	47
Figure 8-1 Slurry Seal Spreader Machine	55
Figure 9-1 Alligator Cracking	59
Figure 9-2 Reflective Cracking	60
Figure 9-3 Longitudinal Cracking	60
Figure 9-4 Hairline Crack	65
Figure 9-5 Small Crack	65
Figure 9-6 Medium Crack	66
Figure 9-7 Large Crack	66
Figure 9-8 Crack After Cleaning	67
Figure 9-9 Filling Crack with Sand Emulsion Mixture	67
Figure 9-10 Examples of Backer Rod Materials	68
Figure 9-11 Sealing the Crack	69
Figure 9-12 Crack After Sealing	70
Figure 10-1 View of a Porous Friction Surface (PFS)	73

Figure 10.2. Porous Friction Pavement Using Hot-Asphalt Plant Mix	75
Figure 11-1 Diamond Grinding Equipment	78
Figure 11-2 California Profilograph	79
Figure 12-1 Crack Sealant Reservoir Shape Factor.....	84
Figure 12-2 Existing Spalled NCS Joint	88
Figure 12-3 Repaired NCS Joint, Compression Seal Removed.....	88
Figure 12-4 Existing NCS Random Spall Area.....	89
Figure 12-5 Repaired NCS Random Spall Area, Compression Seal In Place.....	89
Figure 12-6 Repaired NCS Random Spall Area, Section of NCS Removed	90
Figure 12-7 Existing Random Crack	91
Figure 12-8 Repaired Random Crack	92
Figure 12-9 Existing Spalled Field Molded Joint	93
Figure 12-10 Resealed Field Molded Joint With Separating Tape	93
Figure 12-11 Resealed Field Molded Joint with Backer Rod.....	94
Figure 12-12 Existing Partial-depth Spalled Joint.....	95
Figure 12-13 Repaired Partial-depth Joint with Backer Rod.....	95
Figure 13-1 Pavement Joint Spall	98
Figure 13-2 Incompressible Causing Spalling at a Joint or Crack	98
Figure 13-3 Sounding with a Hammer.....	99
Figure 13-4 Typical Spall Repair Boundaries	100
Figure 13-5 Repair Boundary Sawing and Use of Chipping Hammer	101
Figure 13-6 Milling Techniques	101
Figure 13-7 Cleaning Repair Area (Sandblasting/Water Blasting, and Air Blowing)....	102
Figure 13-8 Compressible Insert	103
Figure 13-9 Failure Due to Non-use of Compressible Insert	104
Figure 13-10 Finished Patches	105
Figure 14-1 Shattered Slabs	108
Figure 14-2 Utility Cut	110
Figure 14-3 Diamond Blade Sawing.....	111
Figure 14-4 CRC Pavement Full-depth Repair Layout.....	111
Figure 14-5 Concrete Removal Using Backhoe	112
Figure 14-6 Additional Saw Cuts (Breakup Method)	113

Figure 14-7 Lift-out Method	113
Figure 14-8 Pressure Relief Cuts for Lift-out Method	114
Figure 14-9 Patch Area Compaction	115
Figure 14-10 Drilling Multiple Holes at Mid-depth for Dowel Bars	116
Figure 14-11 Dowel Bar Installation	117
Figure 14-12 Thickened-edge Expansion Joint	119
Figure 14-13 Doweled Expansion Joint.....	119
Figure 14-14 Typical Finishing Techniques for Full-depth Repairs	121
Figure 15-1 Grout Mixing Equipment	126
Figure 15-2 The Polymer Deep Injection Process.....	127
Figure 15-3 Grout Pumping.....	128
Figure 15-4 Elevation Control.....	129
Figure 15-5 Temporary Plugs.....	130
Figure 16-1 Polymer Subsealing Process	132
Figure 16-2 Falling Weight Deflectometer.....	134
Figure 16-3 Four-hole Pattern at Joint for Grout Injection	134
Figure 17-1 Grinding Equipment	138
Figure 17-2 Gang-mounted Diamond Saw Blades.....	138
Figure 17-3 Diamond-ground Surface.....	139
Figure 17-4 California Profilograph	140
Figure 18-1 Load Transfer at a Joint.....	144
Figure 18-2 Gang-Mounted Multiple Saw Blades for Slot Cuts	146
Figure 18-3 Dowel Placement in Slot	146
Figure 18-4 Types of Dowel Bar Misalignment and Effect on Performance	147
Figure 18-5 Use of Chipping Hammers to Remove Concrete	148
Figure 18-6 Use of Compressible Insert.....	148
Figure 18-7 Placing and Consolidating Patch Material.....	149
Figure 18-8 Keyed Joint	150
Figure 18-9 Gang-operated Dowel Drill.....	151
Figure 19-1 Typical Retrofitted Edge Drainage System	155
Figure 19-2 Geocomposite Edge Drain Features & Installation Details	156
Figure 19-3 Trenching Equipment for Installing Pipe Edge Drains.....	159

Figure 19-4 Outlet Pipe Design 160
Figure 20-1 Heat-damaged Concrete..... 161

TABLES

Table 2-1 Common Asphalt Emulsion Grades 10
Table 2-2 Cement Classification Standards 16
Table 6-1 Aggregate Gradations for SBST..... 44
Table 6-2 SBST Binder and Aggregate Application Rates 44
Table 7-1 Aggregate Gradations for DBST 49
Table 7-2 DBST Binder & Aggregate Application Rates 50
Table 7-3 Aggregate Gradations for Sandseal (SS)..... 51
Table 7-4 Potential Negative Impacts of Surface Treatments to Airfields 52
Table 8-1 Aggregate Gradations for Microsurfacing and Slurry Seals 54
Table 17-1 Feathering Distances 141
Table 18-1 Dowel Size Requirements..... 145

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This UFC contains information on materials, equipment, and procedures for repairing and maintaining hot mix asphalt (HMA) and portland cement concrete (PCC) pavements. Typical maintenance and repair (M&R) methods, and problems that might be encountered in using these methods, are discussed. Guidance is provided for using each of these M&R methods. Additional information can be found in the references listed in Appendix A.

This UFC is intended for use as a field UFC for airfield and roadway pavement repair for all U.S. Navy, Army, and Air Force pavements. The described techniques are applicable for airfields, roads, parking lots, and other pavement uses. Probable causes of pavement problems are discussed and suggested M&R measures described in order to correct pavement surface problems at the source.

Not covered in this UFC are maintenance and repairs of surface water drainage systems, pavement markings, ground lighting, and unpaved margins.

1-2 APPLICABILITY.

This UFC applies to all military Service elements and contractors involved in the planning, design, and construction, maintenance, repair, or preservation of DOD pavements worldwide. This UFC is for the M&R of asphalt and concrete pavements. Follow standard practices to ensure good performance and to obtain required pavement service life. Projects where standard practices were not followed resulted in poor performance. In many cases, those providing oversight were not knowledgeable about standard practices. This UFC outlines standard practices and will result in better oversight of work and help identify problem areas during application of the M&R process.

1-3 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DOD Building Code (General Building Requirements)*. UFC 1-200-01 provides applicability of model building codes and government-unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-4 REFERENCES.

Appendix A contains a list of references used in this UFC. The publication date of the code or standard is not included in this UFC. In general, the latest available issuance of the reference is used.

1-5 GLOSSARY.

Appendix C contains acronyms, abbreviations, and terms.

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CHAPTER 2 TYPES OF MAINTENANCE AND REPAIR FOR PAVEMENTS

2-1 INTRODUCTION.

The purpose of M&R of asphalt and concrete pavements is to extend the useful life of the pavement, maintain a smooth riding surface, reduce mission impact, and prevent water from entering the underlying soil.

2-1.1 Maintenance and Repair.

Typical maintenance on asphalt and concrete pavements consists principally of the care of joints, sealing of cracks, surface treatments, replacement of random broken slab panels, full-depth and partial-depth repairs, dowel bar restoration, diamond grinding, slab-jacking, sub-sealing, petroleum, oil, and lubricant (POL) contamination removal, and the correction of minor settlement and drainage faults. Repair consists of the work required to restore a distressed pavement so it may be used at its original designed capacity and/or accommodate the current mission as provided for by applicable Service instructions.

2-1.2 Pavement Management.

Use an effective pavement management and inspection system that provides timely M&R to keep a pavement in optimal condition. Identify the root cause of the pavement distress and address the underlying problem. To implement an effective pavement management and inspection program, use UFC 3-260-16FA, *Airfield Pavement Condition Survey Procedures*, and UFC 3-270-08, *Pavement Maintenance Management*. These UFCs describe all asphalt and concrete pavement distresses and severity levels.

2-1.3 Quality Control.

Perform quality control, whether work is performed in-house or by contract, to obtain effective durable maintenance and repairs. Use an independent certified testing laboratory, referred to herein as the QC lab. Quality control (QC) functions are performed by the QC lab, which are necessary to monitor the work. Mix designs, soil cement design, soils analysis for compaction control, and supporting construction process monitoring are performed by the QC lab. The minimum daily monitoring requirements are described in specified UFGSs. Submit QC lab qualifications for review and approval to the government contracting officer or their designated technical representative. The government contracting officer or their designated technical representative will review the qualifications of the laboratory and, if necessary, visit the QC lab. Include, as a minimum, local area industry standards, , ASTM C78, *Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)*, ASTM C1260, *Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)*, ASTM C1077, *Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation*, ASTM D3666, *Standard Specification for Minimum Requirements*

for *Agencies Testing and Inspecting Road and Paving Materials*, and respective state highway department certifications, when applicable, in evaluation criteria used to determine the suitability of the QC lab.

Before proceeding with the work, construct a test section to demonstrate the capability to perform to the intent of the specification. Demonstrate within the test section the ability to do pavement removal, subgrade preparation, base placement, and concrete mixing, placing, and finishing for both partial- and full-depth repairs. Incorporate the construction of joints, protection of the work, and QC procedures into the test section. Use all procedures and materials used to construct an acceptable test section as the standard of evaluation for performing the work. Incorporate equipment, materials, and procedures used for the approved test section into the work.

2-2 PAVEMENT MATERIALS.

2-2.1 Safety.

Safety hazards, such as fire/explosion hazards, toxicity, and reactivity, are associated with pavement repair materials and equipment. Always provide a Material Safety Data Sheet (MSDS) from the manufacturer with the material. Review the MSDS for personal protective equipment (PPE) and other safety precautions before use.

2-2.2 Importance of Weather.

2-2.2.1 Weather Effects – Asphalt.

2-2.2.1.1 Preferably, perform patching or resurfacing work only during dry weather and on dry surfaces. Place courses only when the surface temperature of the underlying course is greater than 40 degrees F (4 degrees C) for course thicknesses greater than 3 inches (75 millimeters) and 45 degrees F (7 degrees C) for course thicknesses 3 inches (75 millimeters) or less. When hot asphalt mixtures are placed on cold pavements they may quickly cool, making adequate compaction difficult. Moreover, asphalt and asphalt mixtures do not bond adequately to damp surfaces.

2-2.2.1.2 Mixtures containing emulsified or cutback asphalt require more curing time in high humidity. Low temperatures also reduce the rate of evaporation of emulsified or cutback binders during curing. Cationic emulsions generally are less affected by the weather than anionic emulsions. As a result, many agencies specify cationic emulsions for M&R work. Cutback asphalts are now seldom used due to environmental concerns; however, cutback asphalt may be encountered outside of the US.

2-2.2.1.3 Moisture affects seal coats and other surface treatments in the first few hours after placement. Rainfall prior to the time the liquid asphalt solidifies allows the leaching away or separation of asphalt from the aggregate. This results in the loss of some or all of the applied surface treatments.

2-2.2.1.4 Repairs cannot always be made in warm, dry weather. Therefore, QC, quality assurance (QA), equipment, and procedures are required when repairs are

made during poor weather conditions as the repairs are less likely to perform satisfactorily. Sometimes mission requirements take precedent, which requires repairs as soon as practical even though they may only be temporary. Further, delaying repairs may allow small surface defects to become major failures.

2-2.2.2 Weather Effects – Concrete.

2-2.2.2.1 Weather conditions at a job site, hot or cold, windy or calm, dry or humid, may be vastly different from the optimum conditions assumed at the time a concrete mix is specified, designed, or selected. Concrete can be placed in hot or cold weather conditions, provided adequate precautions are taken to alleviate the negative impacts of high or low ambient temperatures.

2-2.2.2.2 The precautions required to ensure a quality end product will vary depending on the actual conditions during concrete placement and the specific application for which the concrete will be used. Do not place concrete when the air temperature is below 40 degrees F (4 degrees C) in the shade. When the air temperature is likely to exceed 90 degrees F (32 degrees C), use concrete having a temperature not exceeding 90 degrees F (32 degrees C) when placed. Keep the surface of placed concrete damp with a water fog until the approved curing medium is applied.

In general, if the temperature at the time of concrete placement will exceed 77 degrees F (25 degrees C) or below 50 degrees F (10 degrees C), develop a plan to negate the effects of temperatures.

2-2.2.3 Hot Weather Effects on Concrete.

Any operation of concreting done at atmospheric temperature above 77 degrees F (25 degrees C) is termed hot weather concreting. The effect of hot weather may be as follows:

- A higher temperature of fresh concrete results in a more rapid hydration and leads to reduced workability/accelerated setting. This reduces the handling time of concrete.
- Concrete mixed, placed, and cured at higher temperature typically develops higher early strength than concrete produced and cured at normal temperature, but at 28 days or later the strength is generally lower.
- Rapid evaporation may cause plastic shrinkage and cracking and subsequent cooling of hardened concrete will introduce tensile stresses.
- Rapid drying of the existing repair surface will lead to premature failure due to poor or failed bond.

2-2.2.4 Cold Weather Effects on Concrete.

Any concreting operation done at a temperature below 50 degrees F (10 degrees C) is termed cold weather concreting. In the absence of special precautions, the effect of cold weather concreting may be as follows:

- When the temperature is falling to about 50 degrees F (10 degrees C) or below, the development of strength of concrete is retarded compared with development at normal temperature. Thus, the time period for removal of form work has to be increased as well as the time to allow for traffic.
- Permanent damage may occur when the concrete in fresh stage is exposed to freezing temperatures before hardening. Concrete may suffer irreparable loss in its properties to an extent that compressive strength may get reduced to 50 percent of what could be expected for normal temperature concrete.
- Large temperature differentials within the concrete member may promote cracking and adversely affect its durability.

2-2.2.5 Precautions.

Precautions may include some or all of the following for hot weather placement:

- Moisten subgrade, steel reinforcement, and form work prior to concrete placement.
- Erect temporary wind breaks to limit wind velocities and sunshades to reduce concrete surface temperatures.
- Cool aggregates and mixing water added to the concrete mixture to reduce its initial temperature. The effect of hot cement on concrete temperature is only minimal.
- Use a concrete consistency that allows rapid placement and consolidation.
- Protect the concrete surface during placement with plastic sheeting or evaporation retarders to maintain the initial moisture in the concrete mixture.
- Provide sufficient labor to minimize the time required to place and finish the concrete, as weather conditions substantially affect the times to initial and final set.
- Consider fogging the area above the concrete placement to raise the relative humidity and satisfy moisture demand of the ambient air.
- Provide appropriate curing methods as soon as possible after the concrete finishing processes have been completed.

- In extreme conditions, consider adjusting the time of concrete placement to take advantage of ambient temperatures, such as early morning or night time placement.

Note: With proper planning and execution, concrete can be successfully placed and finished to produce high-quality, durable concrete at hot or cold temperatures.

2-2.3 Asphalt Pavement Materials.

Asphalt concrete, commonly called asphalt, blacktop, or pavement, is a composite material commonly used to surface roads, parking lots, and airfields. It consists of mineral aggregate bound together with asphalt, laid in layers, and compacted. The terms "asphalt (or asphaltic) concrete," "bituminous asphalt concrete," and "bituminous mixture" are typically used in engineering and construction, which define concrete as any composite material composed of mineral aggregate adhered with a binder. The abbreviation "AC" is sometimes used for "asphalt concrete" but can also denote "asphalt content" or "asphalt cement," referring to the liquid asphalt portion of the composite material. A variety of specialty asphalt concrete mixtures have been developed to meet specific needs, such as stone-matrix asphalt, which is designed to ensure a very strong wearing surface, or porous asphalt pavements, which are permeable and allow water to drain through the pavement for controlling storm water. Mixing of asphalt and aggregate is accomplished in one of several ways described below.

2-2.3.1 Hot Mix Asphalt Concrete (HMAC).

Hot mix asphalt concrete (commonly abbreviated as HMAC or HMA) is produced by heating the asphalt binder to decrease its viscosity and drying the aggregate to remove moisture prior to mixing. Mixing is generally performed with the aggregate at about 300 degrees F (roughly 150 degrees C) for virgin asphalt, 330 degrees F (166 degrees C) for polymer modified asphalt, and asphalt cement at 200 degrees F (93 degrees C). Perform paving and compaction while the asphalt is sufficiently hot. In many countries, paving is restricted to summer months because in winter the compacted base will cool the asphalt too much before it is able to be packed to the required density. HMAC is the form of asphalt concrete most commonly used on high-traffic pavements such as those on major highways and airfields.

2-2.3.2 Superpave Mix Design.

One of the principal results from the Strategic Highway Research Program (SHRP) was the Superpave mix design method. Superpave, short for "superior performing asphalt pavement," is a pavement system designed to provide longer-lasting roadways. The Superpave mix design method was designed to replace the Hveem and Marshall methods. The volumetric analysis common to the Hveem and Marshall methods provides the basis for the Superpave mix design method. The Superpave system ties asphalt binder and aggregate selection into the mix design process, considers traffic and climate as well, and evaluates the finished product. The compaction devices from

the Hveem and Marshall procedures have been replaced by a gyratory compactor and the compaction effort in mix design is tied to expected traffic.

2-2.3.3 Marshall Mix Design.

The basic concepts of the Marshall mix design method were originally developed by Bruce Marshall of the Mississippi Highway Department around 1939 and then refined by the U.S. Army. Currently, the Marshall method is used in some capacity by about 38 states. The Marshall method seeks to select the asphalt binder content at a desired density that satisfies minimum stability and range of flow values. The Marshall method continued to be refined through the 1950s, with various tests on materials, traffic loading, and weather variables. Today, the Marshall method, despite its shortcomings, is probably the most widely used mix design method in the world. It has become so widely used because it was adopted and used by the U.S. military all over the world during and after WWII and it is simple, compact, and inexpensive.

2-2.3.4 Stone Mastic Asphalt (SMA).

SMA can be used as wearing course for roads, paths, and other traffic surfaces. It is a standard method of construction on motorways, federal roads, and city streets with heavy and very high demand traffic. For maintenance of traffic surfaces, SMA is especially suited for thin layers. One of SMA's special advantages is that, within limits, it can be paved in different thicknesses to even out a surface without worrying about possible differences in post compaction.

Wearing courses made with SMA are especially stable and durable. They have proven their superior performance even in areas with heavy traffic and independent of any climatic influence. A wearing course made from SMA with the correct design and mix production as well as proper paving shows the following characteristics due to the high chippings content together with the mastic-like mortar:

- Better resistance to permanent deformation
- High-wearing resistance
- Less cracking due to cold or mechanical stress
- Coarse surface texture
- Good macro roughness
- Good long-term behavior

2-2.3.5 Porous Friction Course (PFC).

Porous or permeable friction courses (PFC) are HMA mixtures placed at the surface of a pavement structure in a thin layer to produce several benefits for the traveling public in terms of safety, economy, and the environment. It is a sacrificial wearing course consisting of an aggregate with relatively uniform grading, little or no fines and mineral

filler, and it is designed to have a high air void content compared to dense-graded mixtures. Special repair procedures specifically applicable to these porous friction surfaces are presented and discussed in Chapter 10.

2-2.3.6 Warm Mix Asphalt (WMA) Concrete.

Warm mix asphalt concrete (commonly abbreviated as WMA) is produced by adding either zeolites, waxes, asphalt emulsions, or sometimes even water to the asphalt binder prior to mixing. This allows significantly lower mixing and laying temperatures and results in lower consumption of fossil fuels, thus releasing less carbon dioxide, aerosols, and vapors. Not only are working conditions improved, but the lower laying-temperature also leads to more rapid availability of the surface for use, which is important for construction sites with critical time schedules. The use of these additives in HMA (2.2.3.1 above) may afford easier compaction and allow cold weather paving or longer hauls. Use of WMA is rapidly expanding.

2-2.3.7 Cold Mix Asphalt Concrete.

Cold mix asphalt concrete is produced by emulsifying the asphalt in water with (essentially) soap prior to mixing with the aggregate. While in its emulsified state, the asphalt is less viscous and the mixture is easy to work and compact. The emulsion will break after enough water evaporates and the cold mix will, ideally, take on the properties of cold HMA. Cold mix is commonly used as a patching material and on lesser-trafficked service roads.

2-2.3.8 Cut-back Asphalt Concrete.

Cut-back asphalt concrete is produced by dissolving the binder in kerosene or another lighter fraction of petroleum before mixing with the aggregate. While in its dissolved state the asphalt is less viscous and the mix is easy to work and compact. After the mix is laid down the lighter fraction evaporates. Because of concerns with pollution from the volatile organic compounds in the lighter fraction, cut-back asphalt has been largely replaced by asphalt emulsion.

2-2.3.9 Mastic Asphalt Concrete.

Mastic asphalt concrete or sheet asphalt is produced by heating hard-grade blown bitumen (oxidation) in a green cooker (mixer) until it has become a viscous liquid, after which the aggregate mix is then added. The bitumen aggregate mixture is cooked (matured) for around six to eight hours and, once it is ready, the mastic asphalt mixer is transported to the work site where experienced layers empty the mixer and either machine or hand lay the mastic asphalt contents on to the road. Mastic asphalt concrete is generally laid to a thickness of around 0.75 to 1.1875 inch (20 to 30 millimeters) for footpath and road applications, and around 0.375 inch (10 millimeters) for flooring or roof applications. In addition to the asphalt and aggregate, additives, such as polymers, and antistripping agents may be added to improve the properties of the final product. Natural asphalt concrete can be produced from bituminous rock, found in some parts of

the world, where porous sedimentary rock has been impregnated with upwelling bitumen.

2-2.4 Grading System for Asphalt Emulsions.

Most asphalt surface treatments contain an emulsified binder. Do not use solvent-based or cutback materials unless approved by the local environmental authority. Use emulsions appropriate for local conditions to ensure proper break and set time. Coal tar emulsions, usually used only as fuel-resistant sealers, are not discussed in this UFC.

Emulsions are classified (ASTM D977, *Standard Specification for Emulsified Asphalt*), on the basis of how quickly the asphalt droplets coalesce, resulting in “breaking” of the emulsion. RS, MS, QS, and SS refer to rapid-setting, medium-setting, quick-setting, and slow-setting, respectively. The breaking time increases from RS to SS. RS emulsions cannot be combined with aggregate. MS emulsions can only be mixed with coarse aggregate. QS and SS emulsions can be mixed with any aggregate. Designations 1 and 2 in emulsion nomenclature refer to the viscosity of the emulsion, with 2 being more viscous. The h designation refers to a base asphalt that is harder (lower penetration). Some emulsions have a HF designation, referring to high float. HF emulsions can provide a thicker asphalt film on aggregates, which is thought to enhance durability. Emulsions suspended by cationic surfactants are designated with a C. No designation refers to emulsions with anionic surfactants. Table 2-1 gives common emulsion grades for different types of surface treatments.

Table 2-1 Common Asphalt Emulsion Grades

Surface Treatment	Typical Asphalt Emulsion Grade Used
Liquid fog seal	RS-1, MS-1, HFMS-1, SS-1, SS-1h, CRS-1, CSS-1h, CQS-1h
Liquid and sand spray seal	RS-1, RS-2, HFMS-2, HFMS-2h, MS-1, HFMS-1, CRS-1, CRS-2, CRS-2h
Slurry seal	SS-1h, CSS-1h, CQS-1h
Microsurfacing	CQS-1h

2-2.4.1 Emulsion Breaking and Curing.

Breaking an asphalt emulsion refers to separating water from the asphalt and the evaporation of water. Some emulsions break when sufficient water has evaporated. Others break through chemical means. Breaking time is reduced by adding chemicals.

Curing asphalt emulsions involves the development of mechanical properties as the asphalt particles coalesce and the water is removed through evaporation. Typical curing times range from 30 minutes to 24 hours. Cure times are a function of

environmental conditions, application rate, substrate properties, and product dilution ratios. Follow the manufacturer's recommendations for closing the pavement to traffic.

2-2.4.2 Shelf Life.

Some asphalt materials have a limited shelf life; therefore, give particular attention to the manufacturer's recommended shelf life when selecting a material. Shelf life typically ranges from three months to two years and depends on storage conditions, such as temperature, humidity, and packaging.

2-2.5 Concrete Pavement Materials.

A concrete pavement consists of a surface layer of concrete placed over a base (granular or stabilized) and subbase (typically granular) over the subgrade, which may incorporate a fill material. Concrete is a mixture of paste and aggregates. The paste, composed of cementitious materials and water, coats the surface of the fine and coarse aggregates. Through a chemical reaction called hydration, the paste hardens and gains strength to form concrete. The cementitious material primarily consists of portland cement but may also incorporate fly ash, slag cement (ground granulated blast furnace slag), silica fume (not common), or proprietary materials. Concrete is made with or without additives (e.g., air entraining, water-reducing) to achieve the required workability, strength, and durability properties. Concrete generally achieves its initial set within about one hour after water is added and will become fairly hard within six to eight hours of placement. Normal concrete will achieve about 90 percent of its long-term strength within about 30 days and will continue to gain strength at an ever-decreasing rate for many years as long as moisture is retained within the consolidated concrete mass and there is no adverse chemical reaction either internally or due to external action. Normal concrete is typically designed to achieve about 4,000 pounds per square inch (psi) (27.5 megapascals) compressive strength at 28 days. Rapid-set or high-early-strength concrete can be designed to achieve strengths of about 2,500 to 3,000 psi (17.2 to 20.7 megapascals) within 12 to 24 hours to allow for early opening of repair areas to traffic. Many rapid-set materials include proprietary cementitious materials.

2-2.5.1 Portland Cement Concrete (PCC).

PCC is generally accepted as the most appropriate material for the partial-depth repair of existing concrete pavements. Typical mixes combine Type I, Type II, or Type III portland cement with aggregate not larger than one-half the minimum repair thickness. Use a material that is a low-slump mixture of air-entrained concrete having a water-to-cement ratio not exceeding 0.44. Type I or Type II PCC can be used when the patch material can be protected from traffic for at least 24 hours. For faster-setting materials such as Type III cements, patches can be opened as soon as the material can withstand loads without plastic deformation. Type I or Type II portland cement, with or without admixtures, is more widely used than most other materials because of its relatively low cost, availability, and ease of use. In cooler weather, insulating layers can be used to retain the heat of hydration and reduce curing time.

Several proprietary portland cement-based repair materials are also available to achieve high early strength and can be used for partial-depth repairs.

2-2.5.2 Gypsum-Based Concrete.

Gypsum-based concrete (calcium sulfate) repair materials gain strength rapidly and can be used in any temperature above freezing. However, gypsum concrete may not perform well when exposed to moisture and freezing weather. Additionally, the presence of free sulfates in the typical gypsum mixture may promote corrosion of reinforcing steel in pavements.

2-2.5.3 Magnesium Phosphate Concrete.

Magnesium phosphate concretes set very rapidly and produce a high-early-strength, impermeable material that will bond to clean, dry surfaces. However, this type of material is extremely sensitive to water, either on the substrate or in the mix (even very small amounts of excess water can reduce strength). Furthermore, magnesium phosphate concrete is very sensitive to aggregate type (for example, some limestone aggregates are not acceptable). In hot weather (i.e., above 90 degrees F [32 degrees C]), many commonly available mixes experience short setting times (e.g., 10 to 15 minutes).

2-2.5.4 Calcium Aluminate Cement.

Calcium aluminate cements gain strength rapidly, have good bonding properties (on a dry surface), and very low shrinkage. However, due to a chemical conversion that occurs in calcium aluminate cement, particularly at high temperatures during curing, strength loss over time is likely to occur; consequently, these materials are not recommended for use as a patching material.

2-2.5.5 Polymer-based Concrete.

Polymer-based concretes are formed by combining polymer resin, aggregate, and an initiator. Aggregate is added to the resin to make the polymer concrete more thermally compatible with the existing concrete (which would otherwise lead to debonding), to provide a wearing surface, and for economy. The main advantage of polymers is that they set much quicker than most of the cementitious materials. However, they are expensive and can be quite sensitive under certain field conditions. Polymers used for pavement repairs can be classified into four categories: epoxies, methacrylates, polyester-styrenes, and urethanes.

When using polymeric materials for partial-depth repairs, use spall repair materials in accordance with TSPWG M 3-270-01.08-4, *Testing Protocol for Polymeric Spall Repair Materials*.

2-2.5.5.1 Epoxy Concrete.

Epoxy concrete repair materials are impermeable and have excellent adhesive properties. When used, it is important that the epoxy concrete be compatible with the concrete in the pavement. Differences in the coefficients of thermal expansion (CTE) between the repair material and the concrete can cause repair failures, but the use of thermally compatible aggregate increases the volume stability and helps reduce the likelihood of debonding. Place deep epoxy repairs in multiple lifts to control heat buildup.

2-2.5.5.2 Methyl Methacrylate (MMA) Concrete.

MMA concretes and high molecular weight methacrylate (HMWM) concretes have long working times, high compressive strengths, and good adhesion. Furthermore, they can be placed over a wide range of temperatures, from 40 to 130 degrees F (4 to 54 degrees C). MMA is manufactured with either an ultra-low viscosity, which is used as a penetrating crack sealer or to fortify extremely porous concrete substrates, or a medium viscosity, which is used as a neat mortar for grouting or thin patches and can be filled with pre-packaged coarse aggregate and used for partial or full-depth patching in a single pour. However, many methacrylates are volatile and may pose a health hazard to those exposed to the fumes for prolonged periods.

2-2.5.5.3 Polyester-styrene Polymers.

Polyester-styrene polymers have many of the same properties as MMA, except that they have a much slower rate of strength gain, which limits their usefulness as a rapid repair material. Polyester-styrene polymers generally cost less and are used more widely than MMA.

2-2.5.5.4 Polyurethane Resin

Polyurethane repair materials generally consist of a two-part polyurethane resin mixed with aggregate. Polyurethanes are generally very quick-setting (90 seconds), which makes a very quick repair. Some polyurethanes claim to be moisture-tolerant; that is, they can be placed on a wet substrate with no adverse effects. These types of materials have been used for several years with variable results.

2-2.5.6 Rapid-set Cement and Polymers.

There are a number of other polymeric materials available for partial-depth repairs, most of which exhibit rapid strength gain and a high degree of impermeability. Furthermore, some of these materials exhibit certain elastic properties that allow them to be placed across a joint without the need for an insert to maintain the joint.

Use rapid-set proprietary patching materials in compliance with the manufacturer's recommendations. This includes bonding, placing, time required before opening to traffic, and temperature ranges. Evaluate epoxy mortar and epoxy concrete mix designs in the laboratory before use. Precondition the epoxy resin catalyst before

blending to produce a liquid blended between 75 and 90 degrees F (24 and 32 degrees C). Mix the epoxy components in compliance with the manufacturer's recommendations prior to adding aggregate. Blend the material in a suitable mixer until homogenous. Mix only the quantity of material that can be used within one hour (dependent on materials and air temperature, may be less than one hour) in each batch.

When using rapid-set cement and polymeric materials for partial-depth repairs, use spall repair materials in accordance with TSPWG M 3-270-01.08-2, *Testing Protocol for Rapid Setting Rigid Repair Material*.

Caution: Use repair materials that are thermally compatible with the existing concrete. When an aggregate is used to extend the repair material, use aggregate that is thermally compatible with the aggregate in the existing concrete; otherwise, the risk of debonding will be high.

2-2.5.7 Bonding Grout.

Bonding grout may be used when using cement-based repair material. The grout consists of one part portland cement to one part sand by volume with sufficient water to produce a mortar with a creamy consistency. The grout is applied as a light coat to the patch area. Place the concrete before the grout dries. If the grout dries or hardens prior to placement of this concrete, remove it by sandblasting. Do not place patches using normal-set concrete when the air temperature is below 50 degrees F (10 degrees C). At temperatures below 55 degrees F (13 degrees C), a longer curing period and/or insulation mats may be required. If the grout cannot be applied correctly, it is preferable not to use the grout and instead lightly dampen the repair area with water, including the vertical sides, just before application of the grout material in the repair area.

For rapid-set proprietary materials, follow the manufacturer's instructions regarding the use or non-use of the bonding grout. Remove all sandblasting residue using oil-free air-blowing equipment just prior to placing the bonding grout, if used. Apply the bonding grout using a stiff bristle brush and scrub into the patch area. Apply evenly in a thin coat (approximately 0.0625 inch [2 millimeters] thick).

Caution: Irrespective of the type of bonding grout used, always apply it to a clean surface and never allow it to puddle or get dry before application of the repair material. If water is used to dampen the repair surfaces, the water is not allowed to pond on the repair surface.

2-2.5.8 Recycled Concrete Pavement Material

Recycled concrete pavement material has many potential uses, which are addressed in UFC 3-250-07, *Standard Practice for Pavement Recycling*. When using recycled concrete pavement materials, consider testing the recycled materials to mitigate potential detrimental risks associated with harmful reactivity such as alkali-silica reaction (ASR), alkali-carbonate reaction (ACR), or sulfate attack.

2-2.6 Concrete Pavements Types.

2-2.6.1 Jointed Plan Concrete Pavement (JPCP).

JPCP may be doweled or not doweled at transverse joints; however, these pavements are always doweled along longitudinal construction joints. Transverse joint spacing used on airfields in the past ranged from about 15 feet (4.5 meters) to about 25 feet (7.5 meters), depending on slab thickness. Currently, the design joint spacing ranges from about 10 feet (3 meters) to about 20 feet (6 meters).

2-2.6.2 Jointed Reinforced Concrete Pavement (JRCP).

JRCP incorporates steel reinforcement and has longer transverse joint spacing, ranging from about 40 to 60 feet (12 to 18 meters) or longer. One or more transverse cracks may develop in each panel and the reinforcement keeps these cracks tight. The transverse joints are doweled. These pavements are not widely used anymore.

2-2.6.3 Continuously Reinforced Concrete Pavement (CRCP).

CRCP has not been widely used by the military. A higher level of reinforcement is used and transverse joints are not provided, except near structures. Use of the high level of reinforcement leads to the development of closely spaced cracking at about 3 to 6 feet (1 to 2 meters) and the steel holds the crack very tight.

2-2.6.4 Jointed Concrete Pavement.

Joints are created in jointed concrete pavements to control cracking locations and provide for unrestrained expansion and contraction of the concrete panels. If the panel contraction is restrained as a result of locked joints during service or improper joint-forming during construction, mid-panel cracking can develop. If the panel expansion is restrained during hot weather, joint spalling can develop and, in extreme cases, joint blow-up may result. Therefore, it is important to make sure that any joint repair activity does not restrict the contraction and expansion of the slab panels.

2-2.7 Cement Standards.

To ensure a level of consistency between cement-producing plants, certain chemical and physical limits are placed on cements. These chemical limits are defined by a variety of standards and specifications. For instance, portland cements and blended hydraulic cements for concrete in the U.S. conform to ASTM C150, *Standard Specification for Portland Cement*, ASTM C595, *Standard Specification for Blended Hydraulic Cement*, or ASTM C1157, *Performance Specification for Hydraulic Cements*.

Table 2-2 Cement Classification Standards

In the US, three separate standards may apply, depending on the category of cement. For portland cement types, ASTM C150 describes:	
Cement Type	Description
Type I	Normal
Type II	Moderate sulfate resistance
Type II (MH)	Moderate heat of hydration (and moderate sulfate resistance)
Type III	High early strength
Type IV	Low heat hydration
Type V	High sulfate resistance
For blended hydraulic cements (specified by ASTM C595) the following nomenclature is used:	
Cement Type	Description
Type IL	Portland-limestone cement
Type IS	Portland-slag cement
Type IP	Portland-pozzolan cement
Type IT	Ternary blended cement
However, with an interest in the industry for performance-based specifications, ASTM C1157 describes cements by their performance attributes:	
Cement Type	Description
Type GU	General use
Type HE	High early-strength
Type MS	Moderate sulfate resistance
Type HS	High sulfate resistance
Type MH	Moderate heat of hydration
Type LH	Low heat of hydration

2-2.7.1 Concrete Pavement Performance.

A concrete pavement provides a relatively long service life when properly designed, constructed, and maintained. In general, the service life of a pavement ends when, under the effects of traffic, weather, and/or lack of proper maintenance, the pavement breaks into small unstable sections, surface and joint problems develop, and extensive maintenance is required on a regular basis.

Properly designed and constructed concrete pavements do not exhibit significant distresses (e.g., cracking, joint faulting) for at least 15 years. As distresses develop, the service life of concrete pavements can be extended by timely maintenance, especially at joints and cracks. Maintaining the joints and cracks to minimize the infiltration of water and prevent the entry of incompressible material into the joint or crack is essential for long pavement service life. Frequent aircraft loadings greater than those for which the pavements were designed will cause early structural failure of the pavement.

2-2.7.2 Concrete Pavement Rigidity.

Concrete pavements are classified as rigid pavements. Concrete pavements bridge small, soft, or settled areas of a subgrade through their slab action or resistance to bending. Overloading of pavements can result from applied loads being greater than the design load, more passes than assumed in the design, or the foundation support being reduced as a result of pumping, excessive moisture, or settlement due to poor construction. Usually, once cracks develop in a panel, continued loading will cause additional cracking and/or panel breaks until the pavement is no longer functional.

2-2.7.3 Concrete Pavement Strength.

Military airfield and roadway concrete pavement design is based on limiting the concrete tensile stresses produced by aircraft or highway truck loads. Flexural strength of concrete is used in the design of concrete pavements. Loads applied to the pavement surface cause bending, with tensile stresses developing at the slab bottom (mid-slab locations) or at the slab top (corner locations, typically) and compressive stresses at the corresponding opposite surface. Since compressive strength of concrete is typically eight to ten times greater than the tensile or flexural strength, the ratio of load-induced tensile stresses at the bottom of the slab to the flexural strength of the concrete typically controls the structural behavior and performance of jointed concrete pavements.

The strength and durability of concrete is directly affected by:

- Quality of cementitious materials
- Water quality
- Cleanliness, durability, strength, and gradation of the aggregates
- Water-cementitious materials ratio
- Density (consolidation) of concrete

- Amount and types of admixtures
- Proportioning and mixing of materials
- Placement, finishing, and curing methods

2-3 PAVEMENT DISTRESSES.

Pavement distresses include items such as cracking, rutting, raveling, or other types of surface deterioration which indicate a decline in the pavement's surface condition or structural load-carrying capacity. Pavement distresses are discussed in detail in UFC 3-260-16FA. Having a pavement distress dictionary will improve communications within the pavement community by fostering more uniform and consistent definitions of pavement distress. Highway agencies, airports, parking facilities, and others with significant investment in pavements will benefit from adopting a standard distress language.

2-3.1 Asphalt Concrete (AC) Pavement Distresses.

1. Cracking
 - a. Alligator or fatigue cracking
 - b. Block cracking
 - c. Edge cracking
 - d. Joint reflection cracking
 - e. Longitudinal cracking
 - f. Slippage cracking
2. Patching and potholes
 - a. Patching and utility cut patching
 - b. Potholes
 - c. Railroad crossing
3. Surface deformation
 - a. Bumps and sags
 - b. Corrugation
 - c. Depression
 - d. Rutting
 - e. Shoving
 - f. Swell
4. Surface defects
 - a. Bleeding

- b. Polished aggregate
- c. Raveling
- d. Weathering
- 5. Miscellaneous distresses
 - a. Lane/shoulder drop-off

2-3.2 Portland Cement Concrete (PCC) Pavement Distresses.

- 1. Cracking
 - a. Corner break
 - b. Divided slab
 - c. Linear cracking
 - d. Shrinkage cracking
 - e. Spalling, corner
 - f. Spalling, joint
- 2. Joint/crack related
 - a. Faulting
 - b. Joint/crack spalling
 - c. Blowup/buckling
 - d. Pumping
 - e. Railroad crossing
- 3. Material related
 - a. Alkali-silica reactivity (ASR)
 - b. Durability ("D") cracking
- 4. Surface distress
 - a. Polished aggregate
 - b. Popouts
 - c. Patching, large and utility cuts
 - d. Patching, small
 - e. Scaling
- 5. Miscellaneous distresses
 - a. Lane/shoulder drop-off

2-4 TYPES OF MAINTENANCE AND REPAIR.

A considerable investment is made in the construction of asphalt and concrete pavements and the vehicles/aircraft that use these surfaces. Therefore, costs decrease dramatically for every additional year of pavement use that does not cause vehicle/aircraft damage or require repeated patching or other repair activity. Routine periodic inspections and rapid pavement repair are essential for reducing the lifecycle costs of these pavements and maintaining the facility in an operation-ready status. A properly constructed and maintained pavement can last for many years and effectively meet the needs of the military.

The primary purposes of sealing cracks, repairing spalls, applying surface treatments, and carrying out other repairs in asphalt and concrete pavements is to reduce the costs associated with vehicle/aircraft damage due to foreign object damage (FOD), to extend the service life of the pavement, and to reduce the lifecycle costs for the pavement structure. Usually, there are multiple options for repairing a distress. First, determine the root cause of a distress then select a repair method to best resolve the cause. Do not apply repair options following pre-established intervals without taking the pavement's condition into consideration. Pavement M&R is grouped into three categories;

2-4.1 Global Preventive Maintenance (PM).

Global PM is used to retard or slow pavement deterioration on a large scale, usually covering more than one section. Generally, global PM is effective at the beginning of pavement life and/or when the climatic-caused distresses have not started or the severity is low. Global PM may be performed periodically like localized PM, but is more commonly performed on a recurring schedule (i.e., at set time intervals).

2-4.2 Localized Preventive Maintenance (PM).

Localized PM consists of M&R actions performed on individual distresses to slow down the rate of pavement deterioration.

2-4.3 Operational Maintenance.

Also referred to as safety maintenance, stop-gap maintenance, and breakdown maintenance, operational maintenance is performed to mitigate distresses on pavements that are below the critical pavement condition index (PCI) to keep them operationally safe for use.

There are numerous types of M&R methods for asphalt and concrete pavements, which include patching, crack sealing, and surface treatments. This UFC presents basic M&R procedures along with relevant distresses. Overlays and new construction are covered under the UFC 3-250-XX pavement series. M&R procedures presented in this UFC include the following:

2-4.3.1 Summary of Asphalt Pavement Repairs.

The following concrete pavement repairs are discussed in this UFC:

- Chapter 3: Full-Depth Asphalt Patches
- Chapter 4: Procedural Steps (Partial-Depth Patch)
- Chapter 5: Sprayed Asphalt Surface Treatments
- Chapter 6: Bituminous Surface Treatment
- Chapter 7: Double Bituminous Surface Treatment
- Chapter 8: Asphalt Slurry Seals and Microsurfacing
- Chapter 9: Asphalt Crack Sealing
- Chapter 10: Porous Friction Surfaces
- Chapter 11: Diamond-Grinding Asphalt Concrete Pavements

Each of the above repair methods addresses specific distresses. Some of the repairs may be performed in combination.

2-4.3.2 Summary of Concrete Pavement Repairs.

The following concrete pavement repairs are discussed in this UFC:

- Chapter 12: Concrete Pavement Crack Sealing
- Chapter 13: Partial-Depth Repair of Concrete Pavements
- Chapter 14: Full-Depth Repair of Concrete Pavements
- Chapter 15: Concrete Pavement Slab Jacking
- Chapter 16: Subsealing Jointed Concrete Pavements
- Chapter 17: Concrete Pavement Diamond Grinding
- Chapter 18: Concrete Pavement Load Transfer Restoration
- Chapter 19: Concrete Pavement Retrofitted Edge Drainage
- Chapter 20: Maintenance of Heat-Resistant Concrete
- Chapter 21: Repair of PCC Damaged by POL

Each of the above repair methods addresses specific distresses. Some of the repairs may be performed in combination. Materials-related distresses, such as ASR and D-cracking, are not addressed in this UFC.

2-5 PAVEMENT REPAIR EQUIPMENT.

Inspect all equipment employed in the pavement repair operations before and during the repair project to ensure safe operation and proper application. Follow proper safety

procedures in accordance with OSHA guidelines and standard practices for the protection of all project personnel. Make hand tools available for working in areas where machinery is not practical or allowed.

2-5.1 Equipment Inspection.

Inspect all repair equipment before and during actual construction. Inspection will determine if the equipment is being properly maintained, if all of the required safety devices are present, if the equipment and technique being used is damaging the pavement, and if the equipment is being operated correctly and safely.

2-5.2 Equipment.

Pavement repair equipment includes the following:

2-5.2.1 Router.

A router is used to create a sealant reservoir by enlarging meandering cracks to the desired depth and width. A vertical spindle router with a diamond bit is recommended to minimize damage to the pavement. However, an impact router may be used if it is equipped with carbide-tipped vertical-sided bits. Do not use impact routers not equipped with carbide-tipped bits or those equipped with V-shaped bits because they tend to chip and damage the pavement. When using a vertical spindle router, use a belt-driven router bit to help prevent injury to the operator and damage to the pavement if the bit jams in the crack. If damage to the pavement is observed, discontinue work until corrective action is taken. Such corrective action may require replacing worn router bits, changing operators, or replacing the equipment.

2-5.2.2 Concrete Saw.

A concrete saw with a water-cooled diamond blade or abrasive disk can be used to widen straight cracks to the desired width and depth. Concrete saws may be used in place of a router if the blade has a diameter of 6 inches (150 millimeters) or less. The 6-inch (150-millimeter) diameter blade allows the saw to follow slightly meandering cracks. However, a saw blade does not follow the meandering crack as well as a router. If a saw is used to widen the crack, a high-pressure water stream can be used to remove the debris created by the saw. Use care to avoid damaging the adjacent pavement when the saw is used.

2-5.2.3 Cold Milling.

Pavement milling (cold planing, asphalt milling, or profiling) is the process of removing at least part of the surface of a paved area such as a road, bridge, or parking lot. Milling removes anywhere from just enough thickness to level and smooth the surface to a full-depth removal. There are a number of different reasons for milling a paved area instead of simply repaving over the existing surface. Recycling of the road surface is one of the main reasons for milling a road surface. Milling is widely used for pavement recycling, where the pavement is removed and ground up to be used as the aggregate in new

pavement. For asphalt surfaces, the product of milling is reclaimed asphalt pavement (RAP), which can be recycled in hot mix asphalt (HMA) (pavement) by combining with new aggregate and asphalt cement (binder) or a recycling agent. This reduces the impact that resurfacing has on the environment.

Milling can also remove distresses from the surface, providing a better driving experience and/or longer roadway life. Milling can remove the following issues:

- Raveling: Aggregate becoming separated from the binder and loose on the road
- Bleeding: The binder (asphalt) coming up to the surface of the road
- Rutting: Formation of low spots in pavement along the direction of travel, usually in the wheel path
- Shoving: A washboard-like effect transverse to the direction of travel
- Ride quality: Uneven road surface, such as swells, bumps, sags, or depressions
- Damage: Resulting from accidents and/or fires

It can also be used to control or change the height of part or all of the road. This can be done to control heights and clearances of other road structures, such as curb reveals, manhole and catch basin heights, shoulder and guardrail heights, and overhead clearances. It can also be done to change the slope or camber of the road or for grade adjustments, which can help with drainage.

2-5.2.4 Dimond Grinding.

Diamond grinding is one of the most cost-effective concrete pavement restoration (CPR) techniques. It consists of “grinding” 0.1875 to 0.25 inch (5 to 7 millimeters) of the surface of JPCP using closely spaced diamond saw blades. The result is a level, smooth, and generally quieter riding surface. The closely spaced grooves left after grinding give the riding surface excellent texture and frictional properties. The same technique and equipment is used for diamond grooving; however, while the purpose of grinding is mainly to restore ride quality and texture, grooving is generally used to reduce hydroplaning and accidents by providing escape channels for surface water. In terms of design, the main difference between grinding and grooving is in the distance between the grooves—about six times higher in the case of grooving. Diamond grinding can also be performed on asphalt pavement.

2-5.2.5 Water Blasting.

The water blasting equipment includes a trailer-mounted water tank, pumps, high-pressure hose, and wand with safety release cutoff control, nozzle, and auxiliary water resupply equipment. Provide and use the water tank and auxiliary resupply equipment of sufficient capacity to permit continuous operations. Provide and use hoses, wands,

and nozzles capable of cleaning the crack faces and the pavement surface on both sides of the crack for a width of at least 0.5 inch (13 millimeters). Provide and use a pressure gauge mounted at the pump that shows the pressure in psi (kPa) at which the equipment is operating.

2-5.2.6 Hot Compressed Air (HCA) Heat Lance.

The HCA heat lance is used to warm, dry, and clean the crack when performing the sealing operation in less-than-desirable conditions. Such conditions occur following rain or when the pavement temperature is below 50 degrees F (10 degrees C). The heat lance can also be used to remove small amounts of vegetation from cracks. Heat lances are capable of producing heated air at 3,000 degrees F (1,650 degrees C) at velocities of up to 3,000 feet per second (915 meters per second); therefore, use extreme care or the asphalt adjacent to the crack can be damaged. Do not remain stationary with the heat lance over one spot but keep moving to ensure the asphalt is not overheated. Overheating will cause the pavement to become charred and brittle, resulting in premature sealant bond failure. Do not heat the cracks using direct flame methods. It is important to remove all debris from the crack but over-blasting could cause the pavement to ravel or create voids in the crack face.

2-5.2.7 Compressed Air.

Compressed air can be employed for the final cleaning phase of the project. Provide and use an air source that produces sufficient pressure and contains no oil that may foul the surface prior to sealing. Some compressors have in-line sources for the constant lubrication of air tools. Remove these devices along with the oil-coated pressure hoses. Install in-line oil and water traps to provide clean air for the air-blasting operation.

2-5.2.8 Sandblasting Equipment.

Sandblasting equipment is used to remove residue left by a saw, loosened aggregate left by a router, vegetation, and other debris. If debris is left in the crack, the sealant will not bond adequately to the asphalt, causing premature failure. Equipment for sandblasting consists of an air compressor, hoses, and a venturi-type nozzle with an opening not to exceed 0.25 inch (6 millimeters). Equip the air compressor with traps that keep the compressed air free of oil and moisture. Use a compressor capable of supplying air at 150 cubic feet per second (4 cubic meters per second) and maintaining a line pressure of 90 psi (620 kilopascals). Exercise caution to prevent over-blasting the crack. It is important to remove all debris from the crack but over-blasting could cause the pavement to ravel or create voids in the crack face. One disadvantage of sandblasting is the requirement to clean the debris after blasting. This cleaning can be difficult and time-consuming.

2-5.2.9 Hot-applied Sealant Applicator (Melter).

Use equipment to heat and install the hot-applied sealant that consists of a double-boiler, agitator-type kettle. The heat transfer medium in the outer space is an oil with a high flash point. The double-boiler helps eliminate hot spots in the heating kettle and the

agitator provides mixing for uniform heating of the sealant. Do not allow use of a direct-heating kettle. Transfer the sealant from the kettle to the crack by means of a direct-connected pressure-type extruding device (hose) with a nozzle that will insert into the crack. Heat the hose or the sealant recirculated. Design equipment to allow the sealant to be circulated back into the inner kettle when sealing is not being performed. Positive temperature devices are used to control the temperature of the oil bath and measure the temperature of the sealant. Recording-type thermometers are useful for monitoring the temperature of the sealant in the kettle as work progresses. Recording-type thermometers are not normally installed on the equipment at the manufacturer but can be installed by the contractor. Position thermometers so they are easy to read.

2-5.2.10 Cold-applied Sealant Applicator.

The necessary equipment for application of cold-applied sealants depends on whether the sealant is a single-component or a two-component mix and whether the material is hand-mixed or machine-mixed. Two-component machine mixers, recommended for larger crack-sealing projects, consist of an extrusion pump, air compressor, and the associated hoses to dispense the components through separate nozzles and mixed in a 50:50 ratio with less than ± 5 percent error just prior to discharge from the nozzle. Hand-mixing equipment for two-component sealants is generally a slow-speed electric drill with a paddle mixer or an air-powered mixer. Mix single-component sealants to overcome any segregation before they are applied to the pavement. Small hand-held caulking guns can also be employed for small jobs.

2-5.2.11 Wire Brushes.

Wire brushes are helpful in removing debris and vegetation from shallow cracks, but they do not easily remove debris, such as saw residue, from the walls of the cracks. Debris on the crack faces will cause the sealant to lose adhesion with the pavement and prematurely fail. Do not use worn brushes to clean the cracks because they will not effectively remove residual debris. Take care when wire brushes are used to clean cracks that have been previously sealed; the brushes will have a tendency to smear the old sealant residue on the crack wall instead of removing it.

2-5.2.12 Power Brooms.

To remove debris from the pavement surface and reduce the potential for FOD, use a vacuum-type power broom.

2-5.2.13 Jackhammers.

For large patching operations where full-depth repairs are needed, use a 30-pound (13.6-kilogram) jackhammer model. For smaller jobs, use a 10- to 15-pound (4.6- to 6.8-kilogram) model. Equip the jackhammer with a chipping hammer and work at an angle of between 45 and 90 degrees relative to the pavement surface. Take special care not to damage the layer of concrete under the spall repair area or cause microcracking around the crack. For partial-depth repairs, do not use a jackhammer that is larger than 30 pounds (13.6 kilograms).

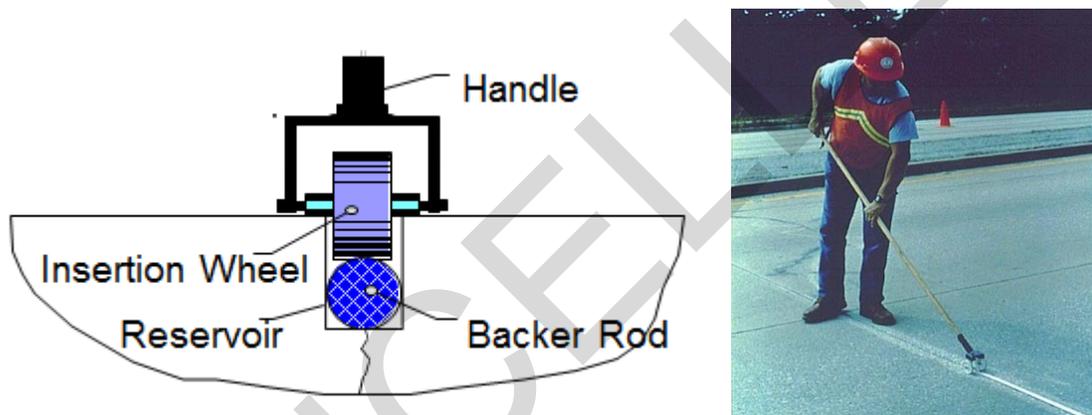
2-5.2.14 Mixers.

Drum or mortar mixers are usually employed for most patching operations. Use a bucket with a hand-held, electric drill-powered (or pneumatic), paddle-wheel mixer for smaller operations.

2-5.2.15 Backer Rod Installation Equipment.

Backer rod may be placed by hand (not recommended, except for short length placement) and many contractors have constructed their own hand-held equipment for this operation. Devices are also available that place the backer rod at a consistent depth without undue stretching or tearing of the backer materials (Figure 2-1).

Figure 2-1 Installation of Backer Rod



2-5.2.16 Sealant Applicators Not Recommended.

Pouring pots or gravity-fed sealant applicators are not recommended for sealing cracks. These applicators have a tendency to trap air in the sealant as it is applied into the crack, creating voids in the sealant. When spot repairs are made to cracks that have been sealed, it may not be feasible to use the hot-applied sealant applicator as described above and pour pots may be used. Equip the pour pot with a nozzle that will fit inside the crack in the same manner as the nozzle of the hot-applied sealant applicator.

2-5.2.17 Hand Tools.

Due to the meandering nature of cracks, hand tools are required to insert the backer rod materials in cracks deeper than 0.75 inch (19 millimeters). Do not twist, cut, or damage the backer rod material with these tools. Ensure the tool is capable of placing the material to the proper depth. When approved by the contracting officer, use hand tools used for repairing or cleaning cracks or removing old crack sealant. Examine the tools to ensure they will not damage the pavement in any manner when properly used.

CHAPTER 3 FULL-DEPTH ASPHALT PATCHES

3-1 INTRODUCTION.

A full-depth patch repairs distresses of medium to high severity, such as alligator cracking, corrugation, depression, oil spillage, rutting, swelling, edge cracking, bumps and sags, and existing patches. A partial-depth patch is used to maintain/repair distresses of low and medium severity, such as corrugations, depressions, rutting, shoving, slippage cracking, swelling, and existing patches.

Full-depth repairs involve removal of the complete pavement down to the subgrade or to an intermediate base or subbase layer that is intact. Partial-depth repairs usually involve removing the failed asphalt surface, excluding the base course, and replacing the surface layer with hot asphalt plant mix.

Procedural steps for partial-depth patches are in Chapter 4.

3-2 PROCEDURAL STEPS (FULL-DEPTH PATCH).

Place full-depth patches using the following steps:

3-2.1 Mark Repair Area.

Use a string line or straightedge to mark straight lines around the repair area. Clearly mark the lines so they are easily visible when sawing the pavement. Mark repair areas to form a square or rectangle with at least 12 inches (300 millimeters) beyond the distressed area.

3-2.2 Make Saw Cut Through Pavement.

Use a concrete saw equipped with a diamond-tip or abrasive blade (Figures 3-1 and 3-2, respectively) to saw the pavement. Saw the perimeter of the patch since milling tends to leave a rough edge. Overlap saw cuts so that a vertical and square corner is formed (Figure 3-3). Since diamond-tip blades usually require water, completely dry the repair area before placing the prime or tack coat. However, there are some types of diamond-tip blades designed to dry-cut asphalt pavements. The abrasive saw blade is less costly and does not require water when sawing, but they tend to wear quickly. Always confirm the saw blade is the correct diameter to allow cutting to the full pavement depth. Make sure the saw blade is rated for the revolutions per minute (rpm) of the saw; otherwise, the blade could shatter during sawing due to the mismatch.

Figure 3-1 Diamond Tip Saw Blade

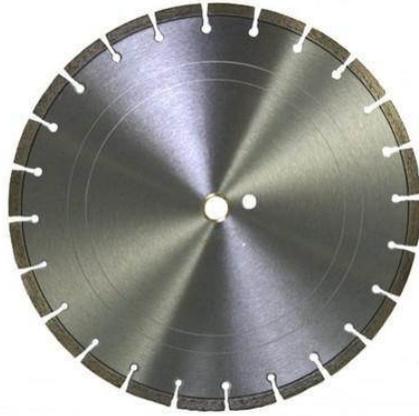


Figure 3-2 Abrasive Blade



Figure 3-3 Damaged Pavement Removed by Sawing



3-2.3 Removal of Defective Material.

Remove the defective material by milling, backhoe, or with a jackhammer. Small areas are sometimes removed with a backhoe, small milling head, or jackhammer, while large areas are usually removed with a milling machine or milling head attachment (Figure 3-4). Saw-cut the perimeter of the patch as vertical as possible, regardless of the method used to remove material.

Use an asphalt bit in the jackhammer. Start the jackhammer from the middle of the repair area and work outward toward the edges. Making an additional saw cut a few inches from the border will allow the cut edges to remain square when removing the asphalt mixture. (Do not rock the hammer near the edge—this will damage the vertical face.) After completing the removal of material, remove and discard the loose material.

Figure 3-4 Small Milling Head Attachment



3-2.4 Remove, Replace, and Compact the Base.

When performing a full-depth patch, inspect the base to ensure adequate material conditions. Remove all unacceptable base, subbase, or subgrade and replace the poor-quality material with acceptable material that can be satisfactorily compacted. If subgrade material is removed, crushed stone or other suitable base material may be used to backfill to the top of the subgrade. Place new materials in 2- to 3-inch (50- to 75-millimeter) lifts, with each lift compacted to the required density. When removing the entire thickness of asphalt pavement, the base material is always disturbed; therefore, reshape and recompact the base material prior to performing the next step. After removal of material, make provision to remove any water that enters the resulting hole.

3-2.5 Apply Tack Coat (and Prime Coat, If Used).

Apply a thin tack coat to the edges and bottom of the patch. This coating provides an improved bond between the old and new materials. Ensure the patch area edges are

clean, dry, and free of any dust so the tack coat will bond to the edges. Use tack coat materials that are cutback grades RC-70 or RC-250, or emulsion grades RS-1, MS-1, SS-1, SS-1h, CSS-1, or CSS-1h. The same grade of asphalt binder used in the asphalt mix can also be used as a tack coat, but this is difficult in small areas. If used, apply it hot and apply the patch material hot enough to soften the asphalt cement to obtain the required bond.

Use a prime coat can by spraying the sides and bottom of the hole to be patched with hot-asphalt plant mix if a tack coat is not used. Prime coat materials cutback grades RC-70, MC-30, MC-70, or SC-70, or emulsion grades SS-1, SS-1h, CSS-1, or CSS-1h. Applying too much material can cause bleeding. Allow prime coats time to penetrate the base material. They are usually absorbed into the underlying material within two to three hours and fully cured in less than 48 hours. Use a prime coat application rate of 0.05 to 0.2 gallon per square yard (0.23 to 0.90 liter per square meter), depending on the porosity of the material treated. Use a tack coat application rate of 0.05 to 0.10 gallon per square yard (0.23 to 0.45 liter per square meter). Use a hand-spray wand to apply the tack coat at the bottom and sides of the patch (Figure 3-5) if the area is large enough. If a wand is not available or if the area is too small, use a stiff brush. To prevent bleeding, do not apply excess tack to the patch areas.

Figure 3-5 Hand-spraying Edge of Cut



3-2.6 Place the Patch Material.

Use good-quality HMA to fill the patch. Place and compact the material in 2- to 3-inch (50- to 75-millimeter) lifts. In order for the patch to be level with the surrounding pavement, overfill the patch area to allow for compaction (Figure 3-6). When placing by

hand, a good rule of thumb is to overfill by 40 percent thicker than the desired compacted thickness, depending on the mix; e.g., 3 inches (76 millimeters) compacted = 4.25 inches (108 millimeters) uncompacted. Do not overwork patch material with a lute, shovel, or rake since this tends to segregate materials and creates additional mixture cooling. When placing with an asphalt paver, a good rule of thumb is to place the asphalt mixture about 20 to 25 percent thicker to allow for compaction.

Figure 3-6 Overfill Prior to Compaction



3-2.7 Compact the Patch Area.

Compact the mix to the proper level using methods described in UFC 3-250-03, *Standard Practice Manual for Flexible Pavements*. It is important to ensure that sufficient material was provided to the patch so adequate density is obtained. The size of the patch determines which type of compactor to use. For a very small patch area or areas, a hand tamper can be used. Larger areas require a vibratory plate tamper (Figure 3-7), a steel-wheel roller (Figure 3-8), or similar compactor. To ensure the required compaction, use the proper equipment as dictated by the patch size. Always compact the edges of the patch first, followed by compaction of the remaining patch area in the direction of traffic. Overlap previous compaction lanes by approximately 6 inches (150 millimeters) across the patch area (Figure 3-8). When the patch is completely compacted, ensure its level is no higher or lower than 0.125 inch (3 millimeters) above or below the surrounding surface (Figure 3-9). Good oversight and density and smoothness testing are required to achieve a good patch.

Figure 3-7 Vibratory Plate Compactor



Figure 3-8 Steel Wheel Roller



Figure 3-9 Check Level of Patch Surface



3-2.8 Ensure Surface of Patch is Watertight.

If performed satisfactorily, the tack coat material applied to the side of the prepared hole is a good sealer between the existing edge and the patch. However, if the surface appears open at the edge of the patch or the surface of the patch is open then additional sealing may be needed on the surface. If the edge is open, seal it with a sand emulsion mix to give it the texture of a slurry seal (Figure 3-10). Refer to the International Slurry Surfacing Association guidelines (<http://slurry.org/guidelines>) for additional information. Ensure the edge seal is no more than 2 inches (50 millimeters) wide. If the entire surface is open then seal the entire surface with the slurry seal. Apply this material with a small brush for small sections or with a broom or small squeegee for larger sections.

Figure 3-10 Seal the Edges



3-2.9 Problem Areas.

Adequate compaction and obtaining satisfactory smoothness are major challenges when constructing patches. Use care in removing material to ensure the edges and bottom of the repair are square. Remove all unsatisfactory material when patching. It is critical that the underlying material is compacted before applying the patch. Compaction lifts less than 3 inches (75 millimeters) work best. If a spray wand is used to apply tack coat, perform a test on an adjacent area to ensure the correct application rate. Use care when applying tack coat to the edges. For best results, follow recommended best practices for spray nozzles, equipment settings, and other operations.

Note: If using cutback asphalts as a tack coat, comply with local environmental regulations.

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CHAPTER 4 PROCEDURAL STEPS (PARTIAL-DEPTH PATCH).

4-1 INTRODUCTION.

Partial-depth patch procedural steps are identical to full-depth patch (Chapter 3). The one exception is that when saw cutting the pavement, control the patch depth to only allow cutting to the depth required for the repair. Furthermore, removal of the material in the area is usually performed with a cold milling or cold planing device. If the material has delaminated from the layer below, a light-weight jackhammer (10 to 17 pounds [4.5 to 7.7 kilograms]) and/or a shovel or equipment bucket may be used to remove the material from the repair area.

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CHAPTER 5 SPRAYED ASPHALT SURFACE TREATMENTS

5-1 INTRODUCTION.

Use a sprayed asphalt surface treatment at an appropriate time to provide beneficial preventive maintenance. Placing a surface treatment too soon can prevent the surface of the asphalt mix from becoming sufficiently stiff to resist deformations under traffic. Delaying treatments too long will limit the treatment's ability to provide preventive maintenance. Severely weathered or cracked pavements are candidates for maintenance by replacement and will not significantly benefit from surface treatments. Do not place surface treatments on runway pavements unless approved by the Pavements Discipline Working Group (DWG) or their designated representative since they can cause FOD and reduce friction.

5-2 PRIME COAT.

A prime coat is a spray application of bituminous material applied to the surface of a base course that is to be covered with an asphalt pavement layer. The primary purpose of the prime coat is to waterproof the unbound material until it can be covered with asphalt mixture. The prime coat can also help prevent damage to the base during construction. Materials that can be used for prime coats are described in paragraph 3-2.5.

5-2.1 Procedural Steps (Prime Coat).

Conduct the following steps to apply a prime coat:

5-2.1.1 Prepare the Surface.

Ensure the surface is free of all loose material such as dirt, clay, dust, or any other undesirable material. Use a light brooming to remove these undesirable materials. If the base is excessively dry, lightly sprinkle with water prior to application of the prime coat to improve penetration of the material into the underlying layer.

5-2.1.2 Apply the Prime.

Use a distributor if the area to be primed is large. Use a hand spray wand to apply prime coat applications on smaller areas. Prime coat application rates are 0.05 to 0.2 gallon per square yard (0.23 to 0.9 liter per square meter). Coat the entire area. Since the primary purpose of a prime coat is to protect the underlying layer from rain until it is covered, the prime coat is sometimes omitted in patched areas when the surface can be covered with HMA prior to rainfall.

5-2.1.3 Allow Prime to Cure.

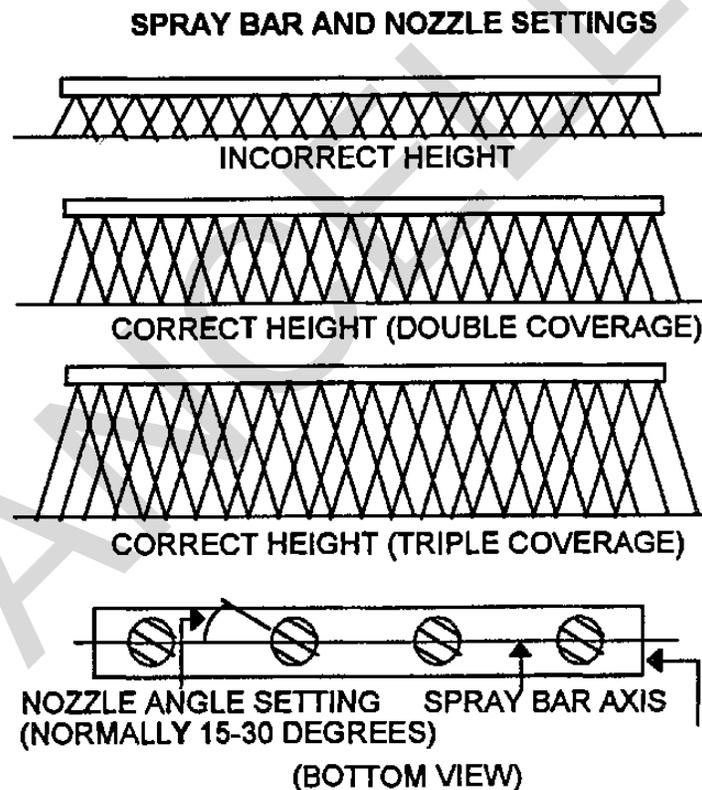
Cure prime coats for as long as necessary. Required curing time is typically 48 hours but satisfactory curing will likely occur in less time, especially in hot, windy conditions.

Blot with fine sand or mineral dust if there is excess prime on the surface after penetration into the underlying materials is complete.

5-2.2 Problem Areas (Prime Coat).

A major potential problem is applying too much prime coat material so there is excess on the surface. Test application rates prior to priming. Determine application rates in accordance with ASTM D2995, *Practice for Determining Application Rate for Bituminous Distributors*. Check proper nozzles and settings on the distributor spray bar or hand-wand. Use nozzles with openings that are the same size. Check nozzles to ensure they are not plugged and are set at the proper angle and height (Figure 5-1). Comply with local environmental regulations when using RC-70 or other cutbacks as a prime coat.

Figure 5-1 Spray Bar and Nozzle Settings



5-3 TACK COAT.

The tack coat is applied to an existing pavement surface before it is overlaid with a new asphalt overlay. The tack coat provides a bond between the old and new pavement. Guidance for materials is provided in paragraph 2-2.

5-3.1 Procedural Steps (Tack Coat).

Conduct the following steps to apply a tack coat:

5-3.1.1 Prepare the Surface.

Clean and dry the surface and ensure it is free of dust, loose dirt, and other debris. Clean the surface around and inside the patch with brooms, air, and water.

5-3.1.2 Apply the Tack.

Use a distributor to apply tack coats over large areas. Use a hand-wand for small patches and hard-to-apply areas. If a wand is not available, apply the tack coat to patch edges with a stiff brush. Apply the tack coat at a proper application rate in an even and uniform coat over the entire area. Apply no more tack material than can be covered by the end of a working day. Application rates for tack coats range from 0.05 to 0.1 gallon per square yard (0.23 to 0.45 liter per square meter).

5-3.1.3 Allow Tack to Cure.

Allow the tack coat to cure before placing the overlay or patch material. Cure times will vary according to the type of tack material used and climatic conditions but typically it is a few minutes up to one or two hours. When asphalt cement is used as a tack coat, no cure time is required.

5-3.2 Problem Areas (Tack Coat).

An excessive application of tack will cause bleeding and slippage; therefore, apply at the proper application rate. Test application rates in accordance with ASTM D2995 prior to spraying the tack material. Check nozzles and settings on the distributor spray bar or hand-wand to ensure they are proper. Check nozzles to ensure they are not plugged and adjust nozzles to the proper angle and height. Clean and dry areas prior to tack coating. Comply with local environmental regulations when using RC-70 or other cutbacks as a tack coat. Overlay material that is tacked on the same day; however, as long as traffic is kept off of the surface and it remains clean, the tack may be effective for several days. It may be necessary to slightly increase the tack coat application if it has been in place for too long.

5-4 FOG SEALS AND REJUVENATORS.

Consider surface treatments for use when non-load-associated surface distresses such as non-structural cracking or raveling first begin. The recommended sealer process, once non-structural cracking and/or raveling is first observed, is a fog seal (except for runways). Continue application of the fog seal on an approximately three-year cycle, depending on pavement condition, as long as surface friction is maintained and texture depth is at least 0.03 inch (0.8 millimeter) when tested according to the grease smear test (FAA AC 150/5320-12C, *Measurement, Construction, and Maintenance of Skid-Resistant Airport Surfaces*).

A fog seal is a spray application of a diluted asphalt or tar emulsion. Emulsions used for fog seals are SS-1, SS-1h, CSS-1, or CSS-1h.

Rejuvenators are commercially available products used to restore oxidized pavement surfaces. Rejuvenators do not solve raveling issues (unless raveling is very minor) or reduce cracking problems (unless cracking is very minor hairline cracking). Often, rejuvenators can cause pavement surfaces to be slippery for up to a year; therefore, choose areas and application rates with extreme care. Since there are numerous commercially available products, a list of rejuvenators is not presented in this UFC. Fog seals and rejuvenators are normally used as preventive maintenance procedures on roads and only on airfield shoulders and overruns. Do not apply over airfield pavements without approval of the Pavements DWG or their designated representative.

5-4.1 Procedural Steps (Fog Seals and Rejuvenators).

Apply fog seals and rejuvenators using the following steps:

5-4.1.1 Prepare the Surface.

Thoroughly clean the surface prior to application of fog seals or rejuvenators. Repair distresses before application of fog seal or rejuvenator.

5-4.1.2 Determine Proper Application Rate.

The application rate will vary according to the quantity of material the pavement absorbs and the texture of the surface; therefore, spray small field test sections with different application rates to determine the best rate to apply. Adjust the rate so the treated surface has good friction, is not unstable, and does not contain excess material remaining on the surface after 12 to 24 hours of curing.

5-4.1.3 Dilute the Material.

The material can be used undiluted but is usually diluted. Dilution rates can be as high as 1 part emulsion to 10 parts water, with an average rate of 1 part emulsion to 4 parts water. Follow the manufacturer's dilution directions. Diluting the rejuvenator with water requires a higher application rate.

5-4.1.4 Apply the Material.

Apply the material with a calibrated asphalt distributor (Figure 5-2). The calibration of the distributor is critical. Important procedures are discussed in paragraph 5-2. To avoid excessive reduction in friction, apply the asphalt material in multiple applications over the entire area so each small increase in application rate can be evaluated for its effectiveness prior to adding another application.

Figure 5-2 Asphalt Distributor



5-4.1.5 Cure Time.

Fully cure the fog seal before allowing traffic on the treated pavement. Cure time is usually 12 to 24 hours.

5-4.2 Problem Areas (Fog Seals and Rejuvenators).

Calibrate, adjust, and clean the distributor as discussed in paragraph 5-2.2 to avoid problems with coverage. Do not apply rejuvenator on airfields without prior approval from the AFCEC Pavements subject matter expert (SME), USACE Pavements SME, NAVFAC Pavements SME, or USACE/TSMCX pavement engineer. Follow proper application and dilution rates to avoid potential problems with excessive material application. Conduct preliminary tests on small test sections to determine the proper application and dilution rates.

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CHAPTER 6 BITUMINOUS SURFACE TREATMENT

6-1 INTRODUCTION.

Single and double bituminous surface treatments (SBST and DBST, respectively) consist of sprayed asphalt applications followed immediately by one or more layers of aggregate. These treatments are used to retard deterioration of raveling, improve skid resistance, seal small cracks, and waterproof the surface. Do not use SBST or DBST on airfield pavements except for overruns and not within 200 feet (61 meters) of the threshold, but SBST or DBST can be used on light-traffic roads, parking lots, and overruns. Another type of bituminous surface treatment, sandseal, is presented in Chapter 7. A variation of SBST to repair bleeding is presented and consists of applying hot sand followed by rolling.

6-2 SINGLE BITUMINOUS SURFACE TREATMENT (SBST).

Use the following bituminous materials for SBST: cutback (RC-250, RC-800, or RC-3000) or emulsion (RS-1, RS-2, CRS-1, or CRS-2). MS and SS asphalt emulsions and medium-curing (MC) cutback asphalt can be used in some cases; however, these materials are not typically recommended because the time for cure is extended and this may result in the treatment being tender for an extended period of time. Use of any other material is prohibited without the approval of the Pavements DWG or their designated representative.

6-2.1 Procedural Steps (SBST).

Place SBST using the following steps:

6-2.1.1 Prepare the Area (SBST).

Repair all failed areas prior to applying an SBST and thoroughly clean all surfaces prior to treatment. Apply prime and/or tack coats in accordance with the procedures in Chapter 5.

6-2.1.2 Apply the Binder Material (SBST).

Apply the binder (asphalt material) with an asphalt distributor. Calibrate the distributor prior to each use. Use the same precautions as discussed for sprayed asphalt treatments in Chapter 5. An asphalt emulsion changes in color from brown to black as it breaks and cures. Apply the aggregate before the binder material has broken and turned black. Provide materials meeting one of the gradations in Table 6-1. Apply the binder and aggregates using the application rates shown in Table 6-2. Do not use Gradation 1, which is a coarse grading for SBST.

6-2.1.3 Apply the Aggregate (SBST).

Apply the aggregate immediately after binder material is applied. Apply the aggregate with tailgate spreaders on dump trucks or by self-propelled hopper-type spreaders

(Figures 6-1 and 6-2, respectively). Calibrate spreaders to ensure uniformity of the aggregate at the required rate. Use only aggregate that is clean, dry, and free of dust or other undesirable material. A slightly damp aggregate can be used and works best with emulsions since this small amount of moisture will ensure better coating of the aggregate. Use aggregates that are hard, angular, and abrasion-resistant. Lightweight aggregates are sometimes used to improve friction properties. Construct a test section to ensure the resulting surface is satisfactory prior to large scale or production applications. Construct a test section when making adjustments to the treatment as necessary to provide a satisfactory surface.

Table 6-1 Aggregate Gradations for SBST

% Passing by Weight, Gradation Designation			
Sieve Size	No. 1 SBST	No. 2 SBST	No. 3 SBST
1 in. (25.4 mm)	100	—	—
0.75 in. (19.1 mm)	90 - 100	100	—
0.5 in. (12.7 mm)	20 - 55	90 - 100	100
0.375 in. (9.5 mm)	0 - 15	40 - 70	85 - 100
No. 4 (4.8 mm)	0 - 5	0 - 15	10 - 30
No. 8 (2.4 mm)	—	0 - 5	0 - 10
No. 16 (1.2 mm)	—	—	0 - 5

Table 6-2 SBST Binder and Aggregate Application Rates

Gradation No.	Binder Application Rates gal/yd² (l/m²)	Aggregate Application Rates lb/yd² (kg/m²)
1 SBST	0.40–0.50 (1.81–2.26)	40–50 (22–27)
2 SBST	0.30–0.45 (1.36–2.04)	25–30 (14–16)
3 SBST	0.20–0.35 (0.91–1.58)	20–25 (11–14)

Figure 6-1 Applying Aggregate with Tailgate Spreader on Dump Truck



Figure 6-2 Applying Aggregate with Self-Propelled Hopper-type Spreader



6-2.1.4 Roll the Aggregate (SBST).

Roll the aggregate immediately after application. Use a pneumatic-tire roller with tire pressures of 60 to 80 psi (414 to 552 kilopascals) and tire loads (weights) equal to the largest tire load that will operate on the surface. Use a pneumatic-tire roller to avoid crushing the aggregate. If approved by the contracting officer, a steel-wheel roller can be used; however, use a weight that is heavy enough to seat the aggregate but not so heavy as to crush the aggregate. The steel wheel will bridge over low spots and may not properly seat the aggregate. Continue to roll the treatment area until all aggregate particles are properly seated.

6-2.1.5 Sweep the Area (SBST).

Allow the treated area to cure for at least 24 hours before brooming to remove loose particles. Broom during the coolest portion of the day to prevent dislodging aggregate. Use only enough pressure on the broom to remove the loose particles and not dislodge seated aggregate.

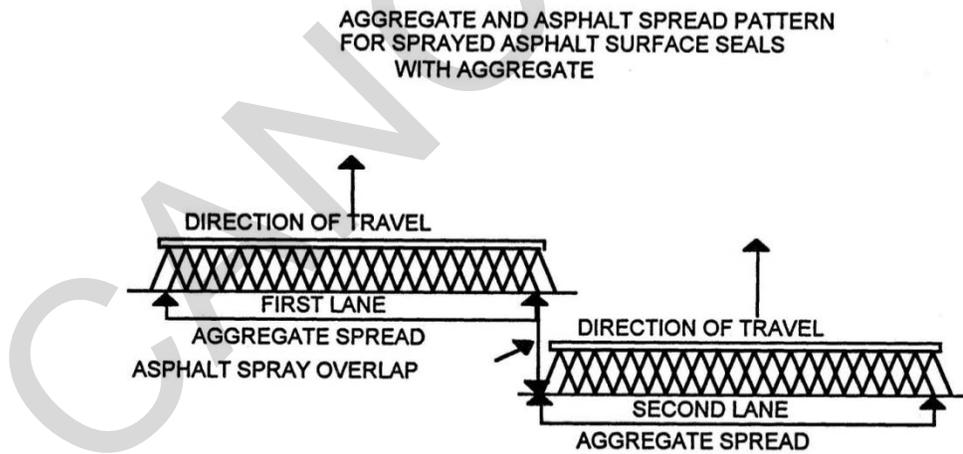
6-2.2 Problem Areas (SBST).

Calibrate all equipment before material placement. Use a test section to ensure all equipment is calibrated and working properly. Use building paper where the spreading of the binder and aggregate begins and ends to make clean and straight transverse joints (Figure 6-3). Remove the paper after application to form a straight edge. Do not spread the aggregate beyond the area of full binder thickness to prevent a buildup of aggregate along the longitudinal joint (Figure 6-4). This distance varies according to the spray width of the nozzle, but it is usually about 6 to 8 inches (150 to 200 millimeters) from the edge of the spray. On the adjacent pass, apply aggregate from the edge of the aggregate on the first pass to about 6 to 8 inches (150 to 200 millimeters) from the edge of the asphalt spray on the opposite side. After completing the work and opening the treated area to traffic, post for 3 days speed limits of no more than 20 miles per hour (32 kilometers per hour). This will ensure that the asphalt is fully cured, help to ensure better seating of the aggregate, and minimize dislodging of additional aggregate.

Figure 6-3 Use Paper for Straight Edge



Figure 6-4 Aggregate and Sprayed Asphalt Spread Pattern



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CHAPTER 7 DOUBLE BITUMINOUS SURFACE TREATMENT.

7-1 INTRODUCTION.

This treatment is essentially the same as the SBST, except that more than one application of binder and aggregate is used. The most common treatment is the DBST. The same bituminous materials used for SBST can also be used for DBST. Aggregate gradations and application rates to be used are shown in Tables 7-1 and 7-2.

7-1.1 Procedural Steps (DBST).

Place DBST using the following steps:

7-1.1.1 Prepare the Area.

Follow the SBST procedures (Chapter 6).

7-1.1.2 Apply the Binder Material.

Follow the SBST procedures (Chapter 6), except two applications of binder and aggregate are placed using rates shown in Tables 7-1 and 7-2.

Table 7-1 Aggregate Gradations for DBST

Sieve Size	% Passing by Weight, Gradation Designation			
	No. 1 DBST	No. 2 DBST	No.3 DBST	No. 4 DBST
1 in. (25.4mm)	100	---	---	---
0.75 in. (19.1 mm)	90 - 100	100		---
0.5 in. (12.7 mm)	20 - 55	90 - 100	100	---
0.375 in. (9.5 mm)	0 - 15	40 - 70	85 - 100	100
No. 4 (4.8 mm)	0 - 5	0 - 15	10 - 30	85 - 100
No. 8 (2.4 mm)	---	0 - 5	0 - 10	10 - 40
No. 16 (1.2 mm)	---	---	0 - 5	0 - 10
No. 50 (300 μm)	---	---	---	0 - 5

Table 7-2 DBST Binder & Aggregate Application Rates

First Application		
Gradation No.	Bituminous Material* gal/yd ² (l/m ²)	Aggregate lb/yd ² (kg/m ²)
1 DBST	0.20–0.30 (0.91–1.36)	40–50 (22–27)
2 DBST	0.15–0.20 (0.68–0.91)	25–30 (14–16)
Second Application		
Gradation No.	Bituminous Material** gal/yd ² (l/m ²)	Aggregate lb/yd ² (kg/m ²)
3 DBST	0.30–0.45 (1.36–2.04)	20–25 (11–14)
4 DBST	0.20–0.30 (0.91–1.36)	15–20 (8–11)
<p>* If an emulsion is used, increase the application rate by 10 percent. ** Ensure the second application is approximately 50 percent greater than first application. Note: Use gradations in pairs. If gradation 1 is used for the first application then use gradation 2 for the second application and the same for gradations 3 and 4.</p>		

7-1.1.3 Apply the Aggregate.

Use the SBST procedures (paragraph 6-2.1.3).

7-1.1.4 Roll the Aggregate.

Use the SBST procedures (paragraph 6-2.1.4).

7-1.1.5 Sweep the Area.

Use the SBST procedures (paragraph 6-2.1.5).

7-1.1.6 Apply Second Application.

To apply the second application of binder and aggregate, the same steps are followed as for the first application.

7-1.2 Problem Areas (DBST).

DBST applications suffer from the same problems as SBST (paragraph 6-2.2). Remedy or mitigate these problems using the same procedures.

7-1.3 Sandseal (DBST).

Sand seal can be used to address a bleeding pavement surface or provide a thin sealer. When used to address bleeding, do not apply asphalt binder before the sand seal is placed since the primary purpose is to blot up the excess binder on the surface. Use sand with the gradations in Table 7-3. Use gradation 2 for a thinner application of sand. Potential problems include difficulty in getting an even application of sand and difficulty in treating a non-uniform surface underneath. Hence, it is possible that excessive sand will be placed in some areas and not enough in others. When binder is used, select the binder similar to that for SBST (Chapter 6).

Table 7-3 Aggregate Gradations for Sandseal (SS)

Sieve Size	% Passing by Weight, Gradation Designation	
	No. 1 SS	No. 2 SS
0.5 in. (12.7 mm)	—	—
0.375 in. (9.5 mm)	100	—
No. 4 (4.8 mm)	85 - 100	100
No. 8 (2.4 mm)	10 - 40	10 - 40
No. 16 (1.2 mm)	0 - 10	0 - 10
No. 50 (300 μm)	0 - 5	0 - 5

7-1.4 Sand Application and Rolling.

Use the following steps when treating a pavement with bleeding problems:

7-1.4.1 Apply Hot Sand.

Heat the sand to above 275 degrees F (135 degrees C) and spread the sand with a tailgate or box spreader, or by hand. Apply at a rate of 10 to 15 pounds per square yard (5 to 8 kilograms per square meter).

7-1.4.2 Roll the Sand.

Immediately roll the sand with a pneumatic roller after spreading.

7-1.5 Sweep Excess Material.

Sweep the area with a vacuum sweeper after the treated area has sufficiently cooled to remove excess sand.

7-1.5.1 Aggregates.

Use clean, angular, and durable aggregate in a slurry seal or microsurfacing. The minimum sand equivalent value for aggregate used in a slurry seal is 45 (ASTM D2419, *Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate*, AASHTO T176, *Standard Method of Test for Plastic Fineness in Graded Aggregates and Soils by Use of the Sand Equivalent Test*) and a maximum Los Angeles abrasion test value of 35 in the parent rock (ASTM C131, *Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine*, AASHTO T96, *Standard Method of Test for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine*).

Ensure the aggregate used in microsurfacing has a minimum sand equivalent value of 65 and a maximum Los Angeles abrasion test value of 30 in the parent rock. In addition, limit the maximum soundness value of aggregates for slurry seals and microsurfacing to 15 percent in the parent rock using Na₂SO₄ (sodium sulfate) or 25 percent using MgSO₄ (magnesium sulfate) testing (ASTM C88, *Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate*, AASHTO T104, *Standard Method of Test for Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate*).

7-1.6 Problem Areas.

Table 7-4 lists the impacts for each type of surface treatment. Many problems associated with surface treatments occur after its service life has passed. Actual service life depends on the product, application method, application rate, and pavement surface preparation. Some surface treatments are only intended to last a few years while others remain effective in excess of eight years.

Table 7-4 Potential Negative Impacts of Surface Treatments to Airfields

Surface Distress	Liquid Spray Seal	Liquid and Sand Spray Seal	Slurry Seal	Microsurfacing
Decreased friction	H	H	P	N
Debonding	N	P	H	P
Raveling	N	P	P	P

- N - Not a significant concern
- P - Potential for minor impact
- H - High potential for impact

CHAPTER 8 ASPHALT SLURRY SEALS AND MICROSURFACING

8-1 INTRODUCTION.

A slurry seal is a mixture of asphalt emulsion, aggregate, water, and mineral filler. Slurry seals are used to seal and protect worn, weathered, and cracked pavement from the effects of further weather and traffic. Another use is to improve friction properties. A special form of slurry seal has been used in high-traffic areas up to and including interstate highways. Microsurfacing is a heavy-duty slurry seal and includes the use of a polymer-modified asphalt binder. This product has been used to fill ruts on high-volume roadways. In traffic areas, use microsurfacing or slurry seals a maximum of two times between overlays and consider on five- to seven-year cycles. Do not use a slurry seal or microsurfacing on airfield pavements or other high-traffic areas without approval from the contracting officer or Pavements DWG or their designated representative.

8-2 MIXTURE MATERIALS.

8-2.1 Emulsions.

Use one of the following emulsions in a slurry seal: SS-1, SS-1h, CSS-1, or CSS-1h. Use a polymer-modified asphalt binder for microsurfacing. Some microsurfacing mixtures are proprietary products.

8-2.2 Aggregate.

Use clean, angular, and durable aggregates in slurry seals or microspheres. Slurry seals and microsurfacing use well-graded aggregates and are classified according to the gradation of the aggregate used. Use aggregates with a minimum sand equivalent value of 45 (ASTM D2419, AASHTO T176) and a maximum Los Angeles abrasion test value of 35 in the parent rock (ASTM C131, AASHTO T96) in slurry seals. Use aggregates with a minimum sand equivalent value of 65 and a maximum Los Angeles abrasion test value of 30 in the parent rock in microspheres. In addition, limit the maximum soundness value of aggregates for slurry seals and microsurfacing to 15 percent in the parent rock using Na_2SO_4 (sodium sulfate) or 25 percent using MgSO_4 (magnesium sulfate) testing (ASTM C88, AASHTO T104).

Use the aggregate gradations in Table 6-1 and application rates in Table 6-2 when slurry sealing or microsurfacing. The gradations typically include 0.5 to 3.0 percent mineral filler. Use only Type II and Type III gradations for airfield applications. Aggregate gradations to be used are shown in Table 8-1.

8-2.3 Filler.

Use portland cement or hydrated lime if a filler is needed in the slurry. The filler tends to improve the stability of the mixture. If stability or segregation problems occur, use mineral filler at 0.4 to 0.5 percent of the total mixture. Water is the primary control for workability of the mixture; therefore, use only potable water.

Table 8-1 Aggregate Gradations for Microsurfacing and Slurry Seals

Sieve Size	% Passing by Weight, Gradation Designation		
	Type 1	Type 2	Type 3
3/8 in. (9.5 mm)	100	100	100
No. 4 (4.8 mm)	100	90 - 100	70 - 90
No. 8 (2.4 mm)	90 - 100	65 - 90	45 - 70
No. 16 (1.2 mm)	65 - 90	45 - 70	28 - 50
No. 30 (600 µm)	40 - 65	30 - 50	19 - 34
No. 50 (300 µm)	25 - 42	18 - 30	12 - 25
No. 100 (150 µm)	15 - 30	10 - 21	7 - 18
No. 200 (75 µm)	10 - 20	5 - 15	5 - 15
Application Rate (lb/yd² dry aggregate)	8 - 12	12 - 20	18 - 30

8-3 SLURRY SEAL PROCEDURAL STEPS.

Place a slurry seal using the following steps:

8-3.1 Prepare the Surface.

Remove all loose material (including any loose or flaking paint), dirt, and vegetation from the surface. Seal cracks greater than 0.125 inch (3 millimeters) wide. Place the sealant 0.125 to 0.25 inch (3 to 6 millimeters) below the surface during crack sealing. After sealing all cracks and cleaning the surface, spray a very light tack coat at a rate of 0.05 to 0.10 gallon per square yard (0.23 to 0.45 liter per square meter) and allow to fully cure.

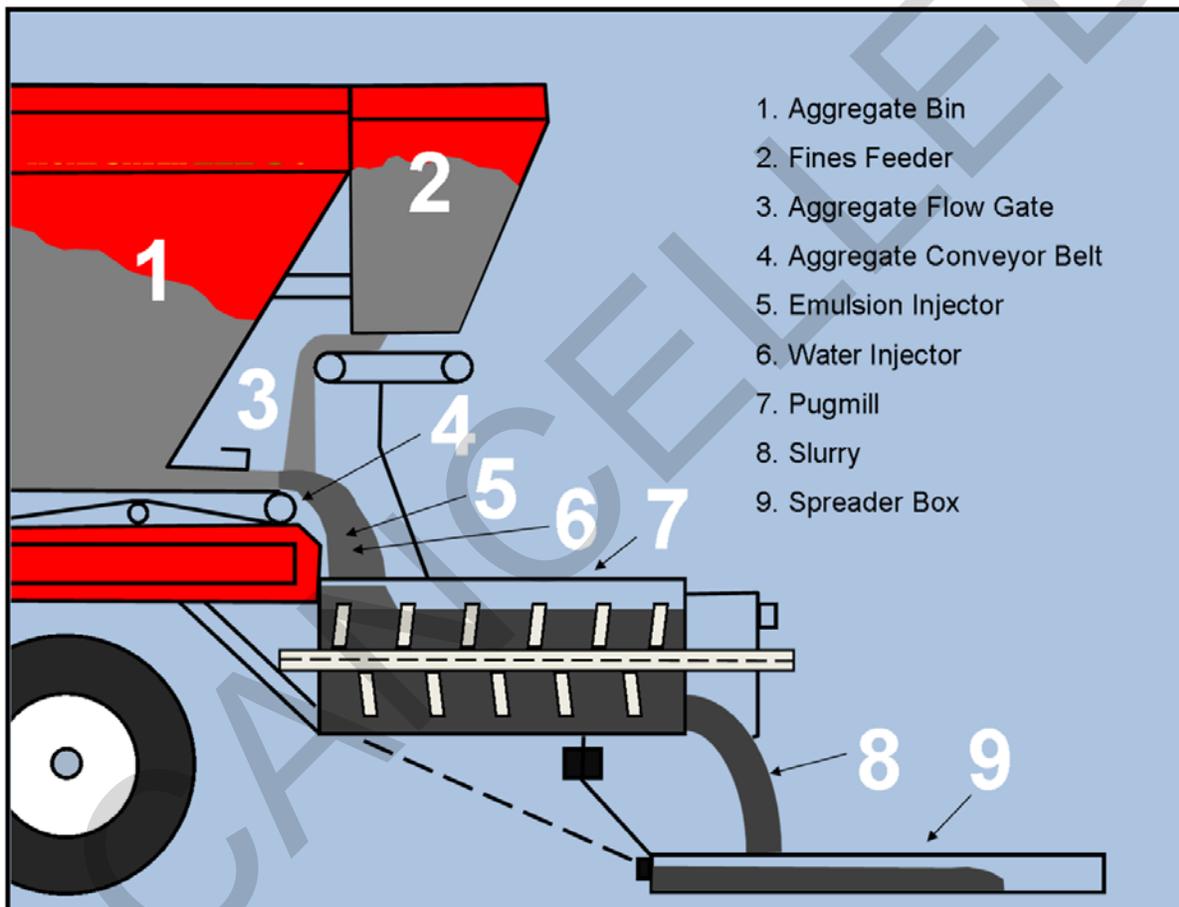
8-3.2 Apply the Slurry.

Apply a fog spray of water to the surface with the spray bar on the slurry machine immediately before applying the slurry. Ensure there is no standing water after the spray. Adjust the spray to compensate for temperature, surface texture, humidity, and dryness of the surface. Apply the slurry with a slurry machine (Figure 8-1). The slurry machine is a self-propelled, continuous-flow mixing unit. Provide and use a device that is capable of delivering the proper amount of aggregate, water, mineral filler, and emulsion to the mixing unit. The mixing unit is either a single or double pugmill mixer.

The mixing unit discharges the material into the spreader box that is equipped with flexible squeegees and width adjustment. Other parts of the machine include the spray bar for wetting the pavement and an aggregate prewetting device.

Use a burlap drag behind the spreader box to improve the joints and improve the texture and appearance of the mixture. Apply the slurry from 0.125 inch (3 millimeters) up to but no more than 0.25 inch (6 millimeters) thick in one pass. If more than one pass is applied, fully cure the previous layer before applying the second application.

Figure 8-1 Slurry Seal Spreader Machine



8-3.3 Rolling the Slurry.

A slurry seal is not always rolled but rolling does provide improved performance. Roll the slurry to reduce voids, limit surface imperfections, and increase the slurry's resistance to water. Roll the slurry after it has cured enough to support the roller without removing any of the slurry mixture. Use a 5-ton (4,540-kilogram) pneumatic-tire roller with tire pressures of 50 pounds per square inch (345 kilopascals) to roll the slurry.

8-3.4 Cure the Slurry.

The time to allow for curing will vary according to the application rate of the emulsion and aggregate and weather conditions. The slurry cures by evaporation of water from the surface, by deposition of asphalt on the aggregate which frees the water, or by a combination of these. The material at the top will typically cure faster than the material at the bottom. Fully cure the slurry seal before opening the treated area to traffic.

8-3.5 Problem Areas.

Construct a test strip to ensure proper slurry machine calibration and correct mixture. Do not overwork the slurry when hand-applying the slurry; overworking causes the emulsion to break prematurely. Apply the second lane while the edge of the previous lane is still fluid and workable, if possible. If the previous lane's edge is not workable then allow the slurry material to cure enough for the spreader box to not damage the previous lane. Keep the burlap drag clean and replace when necessary. Material buildup on the burlap drag causes streaking and gouging. Inspect the flexible lining of the spreader box for wear or accumulation of cured slurry. Replace the lining when worn. Remove any cured slurry from the lining.

8-3.5.1 General Rule.

Do not place surface treatments on asphalt concrete pavements during the first year of service without approval of the Pavements DWG or their designated representative.

8-3.5.2 Fog Seal Consideration.

Do not apply a fog seal over a slurry seal or microsurface without approval of the Pavements DWG or their designated representative.

8-3.5.3 Slurry Seal Consideration.

Do not use slurry seals on airfield pavements where frequent ice/snow removal occurs without approval of the Pavements DWG or their designated representative. Ice/snow removal equipment can potentially tear the slurry from the underlying pavement.

8-3.5.4 Surface Treatments and Fuel Spillage.

Do not use these surface treatments in areas prone to fuel spillage without approval of the Pavements DWG or their designated representative. Alternative fuel-resistant sealers are appropriate for these areas.

8-3.5.5 Surface Treatments and Crack Sealing.

The use of surface treatments does not negate the need for routine crack sealing. Crack sealing is an additional maintenance procedure required to extend the life of asphalt concrete pavements. Using a slurry seal or microsurfacing results in smaller cracks being sealed but larger cracks will continue to need sealing.

8-3.6 Negative Impacts.

Table 7-4 lists the potential negative impacts for each type of surface treatment. Many problems associated with surface treatments occur after its service life is passed. Actual service life depends on the product, application method, application rate, and pavement surface preparation. Some surface treatments are only intended to last a few years, while others remain effective in excess of eight years.

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CHAPTER 9 ASPHALT CRACK SEALING

9-1 INTRODUCTION.

The purpose of sealing cracks in asphalt pavements is to protect the pavement structure from premature failure. The use of proper crack preparation and sealing techniques can extend the effective life of the sealant, thereby increasing the life of the pavement and reducing maintenance costs. Unsealed cracks allow water intrusion and debris retention in the crack opening. Water intrusion in the cracks penetrates into the base and subbase materials, creating the potential for a loss of strength in these materials. The weakened pavement structure can result in load-related failures such as alligator cracking (Figure 9-1). The debris retention can cause the pavement to “push up” at the edges of the crack when the pavement expands due to thermal changes. This decreases the rideability of the pavement surface. These failures and deficiencies increase the lifecycle cost of the pavements by requiring increased maintenance.

Figure 9-1 Alligator Cracking



9-2 WHEN TO SEAL.

9-2.1 Field Evaluations.

Conduct field evaluations at least twice a year, once during the summer months and once during the winter months. Seasonal evaluations will enable a determination of the number and size of cracks and allow performance evaluations of any existing sealant when the cracks are at their smallest and largest width. Consider sealing when cracks have become approximately 0.25 inch (6 millimeters) wide. Do not seal cracks less than 0.25 inch (6 millimeters) wide unless they cover a large percentage of the pavement.

Use a surface treatment such as seal coating or overlay on pavements that have many cracks less than 0.25 inch (6 millimeters) wide or smaller.

9-2.2 Schedule.

Plan and schedule crack sealing in accordance with field evaluations. Make spot repairs to sealed cracks where the sealant material has failed. Figures 9-2 and 9-3 show typical areas in need of sealing. Consider a major resealing project when a large percentage of the area has failed sealant or cracks with no sealant at all.

Figure 9-2 Reflective Cracking



Figure 9-3 Longitudinal Cracking



9-2.3 Climatic Conditions.

Schedule crack sealing projects during the normal construction season. A normally low rainfall period in the spring or fall is preferred. Do not seal crack(s) until the temperature

of the pavement is 50 degrees F (10 degrees C) and rising. Do not seal crack(s) until the crack is free of moisture and debris.

9-2.4 Porous Friction Surfaces.

The guidelines for sealing cracks in a porous friction surface (PFS) are different from a normal asphalt surface. Use the procedures in Chapter 10 for sealing cracks in a PFS.

9-3 SPECIFICATIONS.

9-3.1 ASTM.

Use crack sealant conforming to ASTM D6690, *Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavements*. When selecting a sealant, consider climatic regional temperature performance. Also consider sealant characteristics in high-volume pedestrian traffic where some materials have a tendency to track onto the pavement and stick to the soles of shoes.

9-3.2 Other Specifications.

Rubberized asphalt sealants that are not covered by the above specifications can be used only on roads and only when an appropriate state department of transportation (DOT) or local municipality material specification is available and after the sealant has been approved by the AFCEC Pavements SME, NAVFAC Pavements SME, or USACE Transportation Systems Center (TSMCX) pavement engineer. The DOT and local specifications will often be modified to account for the temperature variations of the region. Asphalt cements that contain synthetic fibers have been used successfully on a limited basis as a crack sealant. Use state or municipality specifications for these materials but only after the sealant has been approved by the Pavements DWG or their designated representative.

9-3.3 Testing.

Test the crack sealant material by a government-approved independent laboratory for specification conformance before it is used on a project. If the quantity of sealant for the project is less than 500 pounds (227 kilograms) then the manufacturer's certificate of compliance may be accepted in place of testing. Evaluate local field performance data from past sealing projects, if available, to determine which type of sealant to seal the cracks.

9-4 CRACK SEALING PROCEDURAL STEPS.

9-4.1 Crack Size Guidelines.

Procedures for sealing will vary depending upon the size of the crack. Use the following steps as a guide:

9-4.1.1 Hairline Cracks (Less Than 0.25 Inch [6 Millimeters]).

See Figure 9-4. It is very difficult to successfully insert sealant material into a crack that is less than 0.25 inch (6 millimeters). Typically, these cracks are not sealed unless they cover 80 percent or more of the pavement area. If the cracks do require sealing, a surface treatment could be the most effective method. The surface treatment used will depend upon the area being treated and the predicted future traffic. A SBST or DBST could be satisfactory for a roadway or parking lot but not for an airfield. Surface treatments and slurry seals are not recommended for airfields that will encounter jet and high-tire-pressure aircraft because the surface treatment or slurry seal will normally deteriorate quickly. Consider options such as an asphalt overlay or pavement recycling for airfield pavements. For additional information on various types of surface treatments, see UFGS 32 12 36.13, *Asphaltic Seal and Fog Coats*, UFGS 32 12 11, *Bituminous Surface Treatment*, and UFC 3-250-03.

9-4.1.2 Small and Medium Cracks (0.25 to 2 Inches [6 to 50 Millimeters]).

See Figures 9-5 and 9-6. Widen small cracks to a nominal width of 0.125 inch (3 millimeters) greater than the existing nominal or average width. Widening the cracks 0.125 inch (3 millimeters) will help eliminate the potential for raveling of the pavement along the edges of the crack and will provide a sealant reservoir with vertical faces. After the crack has been cleaned and inspected, it is ready for sealing. The depth of the cracks to be sealed is determined and, if the depth is greater than 0.75 inch (19 millimeters), a backer rod material is inserted. If the depth of the crack is not deep enough to accommodate the backer rod and maintain a sealant depth of 0.5 to 0.75 inch (13 to 19 millimeters) then the crack can be routed or the backer rod material omitted.

9-4.1.3 Large Cracks (Greater Than 2 Inches [50 Millimeters]).

See Figure 9-7. Fill cracks that are 2 inches (50 millimeters) and larger with a sand asphalt or fine-graded asphalt mix and compacted. The procedures and equipment used are identical to those used to repair potholes. Cut or route the edges vertical and clean the cracks to obtain a patch that meets the specified requirement. The asphalt material could prematurely fail if the proper cleaning and patching procedures are not followed. Square by sawing, fill with asphalt mix, and compact the cracks. Refer to TM 5-624/NAVFAC MO-102/AFJMAN 32-1040, *Maintenance and Repair of Surface Areas*, for additional information.

9-4.1.4 Cracks in Pavements to be Overlaid.

Small and medium cracks in pavements to be overlaid are usually not filled prior to overlay. Also, if milling occurs, it is very difficult to locate these small cracks so sealing will be very difficult. However, many designers require these cracks to be filled with an emulsion, a sand emulsion mixture (Figure 9-9), or one of the types of sealants previously mentioned. Recess the material in the crack a minimum of 0.25 inch (6 millimeters) to prevent the material from “bleeding” through the overlay. Bleeding occurs when the asphalt cement in the crack sealant material is drawn to the surface of the

overlay. Bleeding causes the pavement above the crack to become soft and a crack or bump in the overlay is usually the end result.

9-4.2 Crack Widening.

Use a router to widen meandering cracks. Use a saw with a small-diameter blade to widen straight cracks. When a saw is used, clean the crack with a high-pressure water stream or a sandblaster to remove debris created by the saw. The recommended procedure is to use a router since water would not be required. When resealing, remove all of the old sealant from the crack. After the crack has been widened or the existing sealant has been removed, clean the crack to prevent any debris from contaminating the crack.

9-4.3 Initial Crack Cleaning.

Use the sandblasting equipment, water-blasting equipment, HCA heat lance, or wire brushes to clean cracks. Information about this equipment follows:

9-4.3.1 Sandblasting.

When sandblasting equipment is used, establish a technique that enables both faces of the crack to be sandblasted. Use a multiple-pass technique consisting of positioning the sandblaster nozzle approximately 1 inch (25 millimeters) above the pavement surface, sandblasting the entire length of one crack face then sandblasting the entire length of the opposite crack face. Sandblast approximately 1 inch (25 millimeters) of the pavement surface on both sides of the crack to remove debris. Do not over-blast the cracks. Over-blasting can damage the pavement, causing raveling and premature bond failure of the sealant. Demonstrate the cleaning technique on 5 feet (1.5 meters) of cracks in an area not subject to direct wheel traffic to ensure proper techniques are used.

9-4.3.2 Water Blasting.

Water-blast the crack faces and pavement surfaces extending a minimum of 0.5 inch (13 millimeters) from the crack edges. Use a multiple-pass technique until the surfaces are free of dust, dirt, old sealant residue, or foreign debris that might prevent the sealant material from bonding to the asphalt pavement. After final cleaning and immediately prior to sealing, blow out the cracks with compressed air and leave them completely free of debris and water. Excessive water pressure can cause damage to the asphalt adjacent to the crack and result in loss of material. If the pressure is too low then the joint will not be properly cleaned. Demonstrate the cleaning technique on 5 feet (1.5 meters) of cracks in an area not subject to direct wheel traffic to ensure proper techniques are used.

9-4.3.3 HCA Heat Lance.

Use the HCA heat lance when the pavement is wet and/or cold (pavement temperature below 50 degrees F [10 degrees C]). Use extreme care to ensure the crack faces do not

become overheated or burned. Overheating the crack faces will greatly reduce the life expectancy of the seal and adjacent pavement. Adhesion failure of the sealant or additional cracking of the pavement between the area that was overheated and the remainder of the pavement is expected.

9-4.3.4 Wire Brushes.

Wire brushes are sometimes used during sealing projects; however, wire brushes are not always capable of removing debris from the crack faces and this debris can cause adhesion failures. Inspect the wire brushes to ensure they are not worn. Inspect the cleaned crack to ensure all debris and dust have been removed.

9-4.4 Debris Removal.

Remove debris from the crack after water-blasting or sandblasting. This method normally removes the debris more effectively with less chance of pavement damage.

9-4.5 Final Crack Cleaning.

Once the old sealant and debris have been removed from the crack, clean the crack with compressed air. The compressed air is blown into the crack to remove sand or any debris that was loosened during the initial cleaning. The compressed air also helps remove moisture.

9-4.6 Inspection.

Inspection is the final phase of crack preparation. Inspect the crack for cleanliness and dryness. It is essential for the crack to be clean and dry so the sealant will adhere to the pavement. One method to check for cleanliness is to rub one's finger along the crack face. If a dusty residue is left on the finger, re-clean the crack. If there is no residue, the crack is ready for sealing.

9-4.7 Crack Cleaning Summary.

The cleanliness of the crack is one of the most important factors in crack preparation that affects the life of the sealant. It is not the only important factor, but it is one that can be controlled. After the crack has been inspected and approved for cleanliness, the crack is ready to be sealed (Figure 9-8).

Figure 9-4 Hairline Crack



Figure 9-5 Small Crack



Figure 9-6 Medium Crack



Figure 9-7 Large Crack



Figure 9-8 Crack After Cleaning

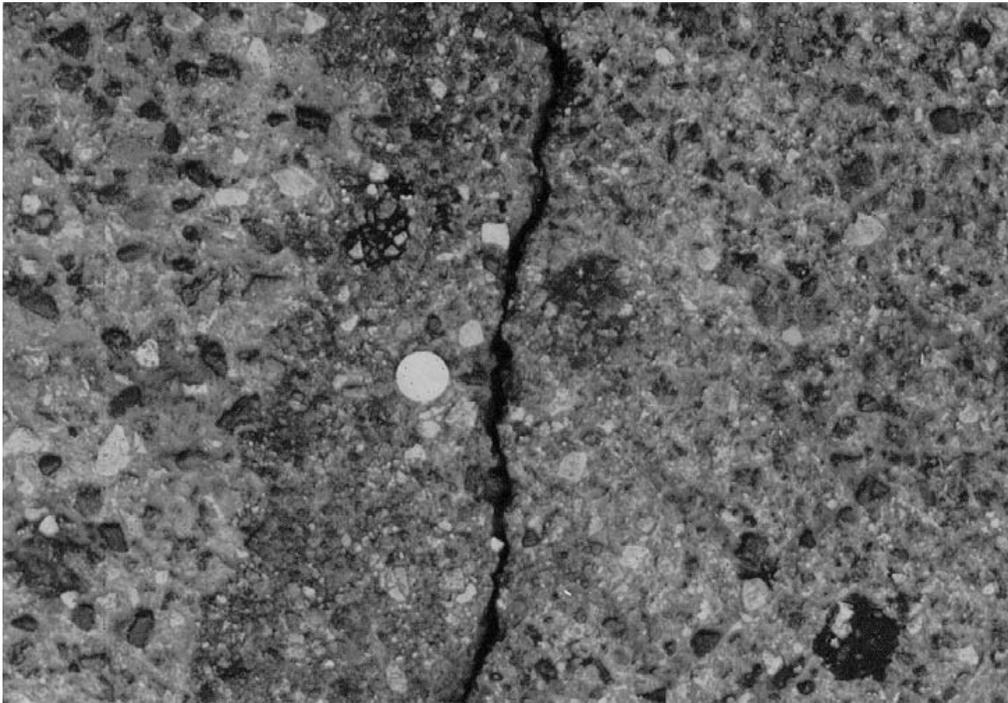


Figure 9-9 Filling Crack with Sand Emulsion Mixture

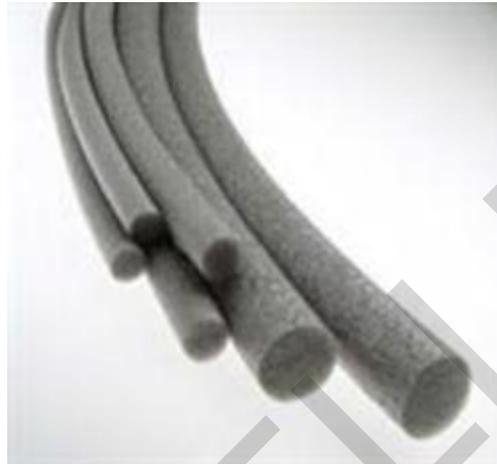


9-4.8 Backer Rod Material.

The backer rod (Figure 9-10) is a compressible, non-shrinking, non-absorptive material. Provide and use backer rods whose melting point is higher than the pouring temperature of the sealant. Provide and use backer rod that is approximately 25 percent wider in diameter than the nominal width of the crack. The larger size will enable the sealant to be inserted without dislodging the backer rod. Place the backer rod to a depth that will provide a shape factor (depth-to-width ratio) of approximately 1 for petroleum-based sealants. However, do not place the top of the backer rod deeper than 0.75 inch (19 millimeters). This will provide a reservoir for the sealant that will minimize the

internal stresses in the sealant. High internal stresses can create cohesion failure, split the material, or dislodge loose aggregate from the pavement, damaging the effectiveness of the seal. However, if the shape factor is too small, adhesion failure can occur; therefore, it is important to maintain the proper shape factor.

Figure 9-10 Examples of Backer Rod Materials



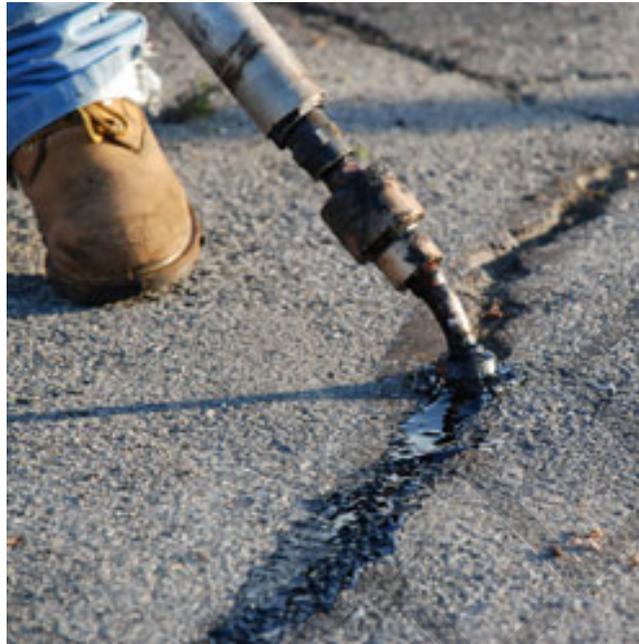
9-4.9 Inspection Prior to Sealing.

Inspect the cracks immediately prior to sealing. Ensure the backer rod is at the specified depth and that debris has not been blown into the crack. Clean cracks are essential in obtaining adhesion between the sealant and the crack face.

9-4.10 Sealant Temperature and Application.

Check the temperature of the sealant to ensure it is at the manufacturer's recommended application temperature. Insert the nozzle of the application equipment into the crack and seal the crack from the bottom to the top (Figure 9-11). Sealing in this manner minimizes bubbling of the sealant due to entrapped air. Recess the sealant approximately 0.125 to 0.25 inch (3 to 6 millimeters) below the pavement surface to prevent tracking. Remove excess sealant with a squeegee or similar equipment.

Figure 9-11 Sealing the Crack



9-4.11 Crack Sealing Delays.

Blow out with compressed air before sealing any cracks that are not sealed the same day they are prepared. Clean and dry cracks again if rain delays the sealing operation to remove any debris that may have been washed into the crack by rain. Use the sandblaster, wire brushes, or HCA heat lance, but not by using only compressed-air cleaning to remove debris washed in by the rain.

9-4.12 Inspection After Sealing.

Inspect the sealant to ensure the sealant is bonding to the pavement and that the cracks were not overfilled after the cracks have been sealed (Figure 9-12). Overfilled material can track onto the pavement surface and/or stick to pedestrians' shoes. Inspect the sealant to ensure the proper sealant recess has been obtained. Sealants that are not properly recessed will be pushed above the pavement surface as the pavement expands and become damaged by traffic. Cracks that have been under-filled can have additional crack sealant applied.

Figure 9-12 Crack After Sealing



9-5 PROBLEM AREAS.

9-5.1 Categories of Problems.

Many problems that arise during a sealing project can be divided into three categories: crack sealant materials, crack preparation, and crack sealant application. The following information is presented for these three sealing problems:

9-5.1.1 Materials.

One of the main problems associated with sealant materials is nonconformance to the required specification. Test the sealant through an independent laboratory to minimize this problem. Another problem is a combination between materials and application that involves the sealant not setting up or curing after it has been applied to the crack. This problem is often caused by overheating the sealant before it is applied to the crack. The overheating can be caused by heating the sealant at too high a temperature or heating it at the recommended pouring temperature for a longer period of time than recommended by the manufacturer.

Most sealants used to seal cracks in asphalt concrete pavements are asphalt cement-based materials and overheating causes the light volatiles to “cook off” or evaporate. This causes the sealant to become brittle, resulting in premature failure of the sealant. Monitor the temperature of the sealant in the application equipment and discard any material that is overheated or heated for longer than four hours to eliminate this problem. Discard the sealant remaining in the equipment and thoroughly clean the equipment after each day’s work has been completed.

9-5.1.2 Preparation.

The main problem associated with crack preparation is the cleanliness of the crack. The crack sealant will not adequately bond to the pavement if there is oil, dust, debris, or loose aggregate remaining in the crack. Damaging the pavement during the routing process can also be a problem. Prevent jamming in the crack by following each crack and controlling the speed of the equipment. Dry the crack prior to placing sealant to prevent the moisture from vaporizing when the sealant is placed, which will result in loss of bond to the crack wall.

9-5.1.2.1 Dust and Debris.

Checking for dust and debris in the crack is a relatively simple procedure: rub a finger along the crack; if the finger gets dusty, the crack is dirty. Checking for moisture is more of a judgment decision. There is no test for checking the moisture of a crack except by observation or feeling with one's hand. It is important that the crack is dry at the time of sealant application so the sealant will bond to the pavement.

9-5.1.2.2 Crack Preparation Methods.

An additional problem dealing with crack preparation is deciding which method to use. This is a problem because most cracks are not uniform in size and the surrounding pavement will have varying degrees of deterioration. Make adjustments as work progresses. The main consideration for crack preparation is that the crack be cleaned without damaging the surrounding pavement.

9-5.1.3 Application.

There are two major problems associated with crack sealant application. The first problem is brittleness of the sealant material due to overheating or prolonged heating. Brittleness is a materials problem because some sealant materials are more susceptible to overheating than others, but it is also an application problem because it can be corrected by implementing a good quality control program. Monitor the temperature of the sealant and discard any material that is overheated or heated for longer than four hours to eliminate this problem. Discard the sealant remaining in the equipment and clean the equipment thoroughly after each day's work has been completed.

The second problem is overfilling the crack. The sealant can be tracked onto the pavement and abraded if the crack is overfilled. Reduce, if not eliminate, overfilling the crack by vigilant quality control measures and inspection. Remove excess sealant with a squeegee or similar object before the sealant cools. Fill from the bottom up to prevent entrapped air.

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CHAPTER 10 POROUS FRICTION SURFACES.

10-1 INTRODUCTION.

A porous friction surface (PFS) is an open-graded asphaltic concrete wearing surface containing a large amount of air voids that allow water to drain vertically and laterally through the pavement structure (Figure 10-1). These surfaces are usually 0.75 to 1 inch (19 to 25 millimeters) thick and the large void content provides a means to prevent hydroplaning at high speeds. The surface texture of the PFC provides excellent skid resistance and decreases tire spray under wet conditions. Several procedures to repair a PFS are presented in the following paragraphs.

Figure 10-1 View of a Porous Friction Surface (PFS)



10-2 SEALING CRACKS.

The guidelines for sealing cracks in a PFS are different from a normal asphalt surface. The materials used for sealing cracks on a PFS are the same as for a normal asphalt pavement. Use the following steps for sealing cracks on a PFS:

10-2.1 Prepare the Crack.

To prepare the crack, remove all loose material and ensure the crack is free of dust and dirt.

10-2.2 Seal the Crack.

Follow the same sealant placement procedures as for an asphalt surface (Chapter 9). Do not seal cracks 0.25 inch (6 millimeters) wide or less unless loose debris is causing a FOD problem. Seal cracks from 0.25 to 0.75 inch (6 to 19 millimeters) if they are raveling and causing a FOD problem. Fill cracks greater than 0.75 inch (19 millimeters) wide with a PFS asphalt mixture and rolled with a steel-wheel roller. Only seal

longitudinal cracks when regular sweeping methods no longer remove all loose aggregate from the surface. The loose aggregate can block internal drainage. Seal transverse cracks except those perpendicular to the water flow. In any case, do not seal the joint if it will interfere with water drainage.

10-2.3 Patching PFS.

If correctly performed, a PFS patch is indistinguishable from the remainder of the surface. Patch PFS using the following steps:

10-2.3.1 Remove Defective PFS.

Do not saw PFS when patching. Only use a milling machine to remove any defective PFS. Mill the full depth and extent of PFS damage.

10-2.3.2 Clean and Tack Repair Area.

Remove the defective material and, if necessary, repair the underlying pavement. Thoroughly clean the repair area before placing the tack coat. Apply a light tack coat to the bottom of the repair area. Do not apply tack coat to the edges of the repair areas as this will clog or interfere with the flow of water through the PFS.

10-2.3.3 Place Patch Material.

Provide and use repair material that conforms to the existing PFS. Roll the repair material using the same method as the original construction after material is placed. A cold-mix asphalt can be used for a temporary repair.

10-2.4 Raveling Control.

Apply a very light spray of asphalt emulsion to help control raveling of the PFS until replacement of the area can be completed. If this procedure is performed, do not apply so much as to hinder drainage of the PFS.

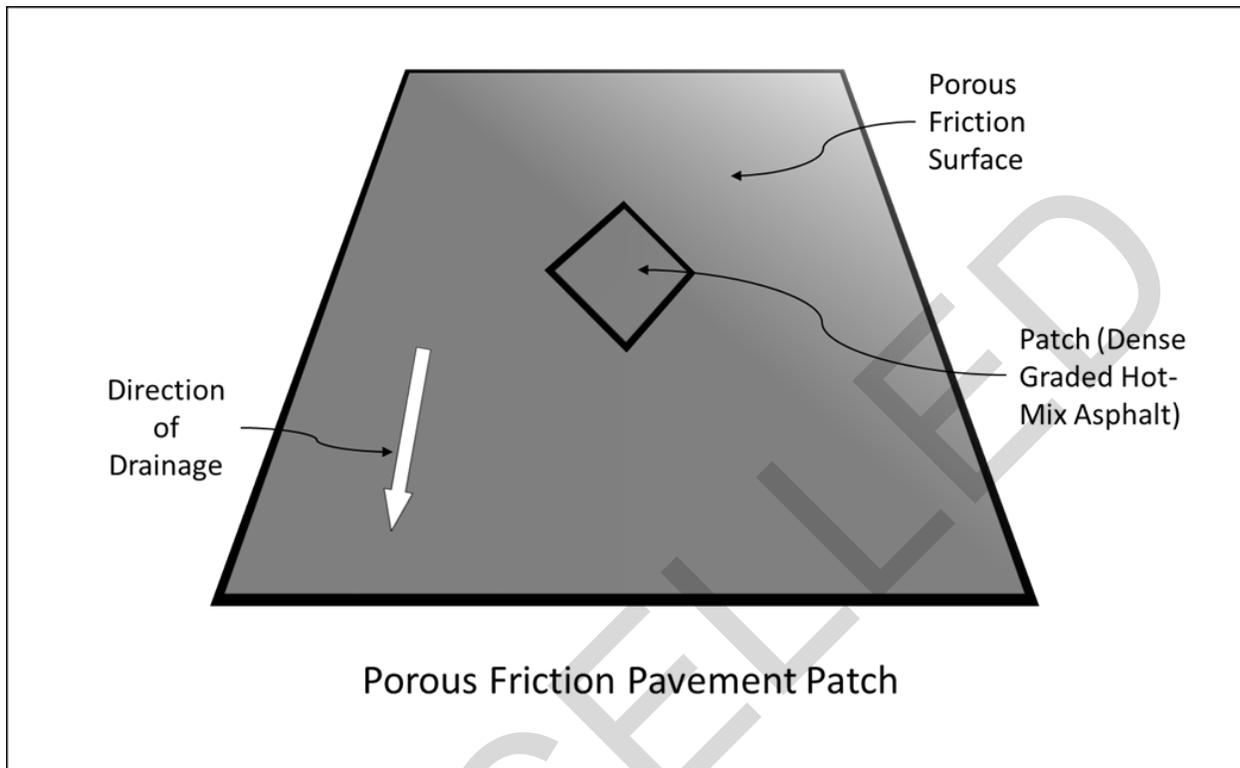
10-2.5 Patching Using Standard Hot Asphalt Plant Mix.

If a standard hot asphalt plant mix is used to repair a PFS, employ the following steps:

10-2.5.1 Mark the Repair Area.

Lay out and mark the boundaries of the repair for saw cutting. Shape the patch as a diamond with a point of the diamond at the highest elevation (Figure 10-2). This will allow water to flow around the patch area.

Figure 10.2. Porous Friction Pavement Using Hot-Asphalt Plant Mix



10-2.5.2 Remove Defective PFS.

Saw the area to the thickness of the porous friction surface. Remove defective material. Do not damage the edges of the patch.

10-2.5.3 Place Patch Material.

Apply tack coat to the sides and bottom of the patch area. Do not over-apply the tack coat. After the tack coat has cured, place and compact a well-graded hot asphalt plant mix.

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CHAPTER 11 DIAMOND-GRINDING ASPHALT CONCRETE PAVEMENTS

11-1 INTRODUCTION.

Diamond grinding, using closely spaced diamond saw blades mounted on a rotating shaft, removes a thin layer of the concrete surface to correct for faults at joints and crack locations and correct for surface defects, such as wheel path rutting. As such, diamond grinding results in re-profiling the pavement and improves the pavement's ride quality.

Diamond grinding removes bumps, re-profiles pavements, removes surface defects, and restores the pavement to a smooth surface. Because the hardness of the aggregate will influence the grinding operation, identify the type of aggregate in the asphalt pavement when the work is to be contracted. Limit grinding to small, localized areas. Do not grind more than 10 percent of the surface area without prior approval of the Pavements DWG or their designated representative.

11-2 NEED FOR GRINDING.

Consider diamond grinding when a pavement has bumps in excess of 0.125 inch (3 millimeters), roughness in excess of 0.125 inch (3 millimeters) in a 10-foot (3-meter) length, or rutting up to 0.375 inch (10 millimeters). If skid resistance is to be examined, examine skid resistance on the areas not scheduled for grinding for any of the previously mentioned defects. **[caution missing as in Ch. 17]**

11-3 GRINDING PROCESS.

The diamond-grinding process results in less impact than milling. The pavement grinder is similar to a wood plane. The front wheels are designed to pass over a fault or bump, the cutting head shaves it off, and the rear wheels ride in a smooth path left by the cutting head. Diamond grinding requires heavy, specially designed equipment (Figure 11-1) that uses diamond saw blades gang-mounted on a cutting head. Spacers are placed between the saw blades to reduce the amount of cutting to be done. This combination of saw blades and spacers gives the pavement the characteristic corduroy texture that improves skid resistance.

Figure 11-1 Diamond Grinding Equipment



11-4 TEST SECTION.

Before work begins, use the equipment in a test section to ensure that proper blade spacing is being used for the specific aggregate on the project. The width of the spacers between the saw blades varies depending on the hardness of the aggregates. The harder the aggregate, the thinner the spacing between the blades. When grinding aggregate susceptible to polishing, use a wider spacing.

11-5 GRINDING PROCEDURE.

When areas have been identified as being too rough, set a level of restoration and grind sections having excess roughness. Test the roughness again following the grinding. Test using a California profilograph (Figure 11-2), Mays Ride Meter, or 12-foot (3.7-meter) straightedge. Establish the grade prior to grinding. Do not use the old pavement surface as the reference unless a long beam or skid is used. Grinding a sag will not remove roughness.

Skid resistance can be improved by grinding. Only grind those lanes needing improved friction. Feather the edges of the ground areas into the adjoining pavement to eliminate a sharp drop-off. Grind the pavement in the longitudinal direction. Produce a uniform finished surface and provide positive lateral surface drainage. Continuously remove the

slurry residue resulting from the grinding operation. Do not permit the grinding slurry to flow across adjacent lanes into gutters or flow into other drainage facilities.

Figure 11-2 California Profilograph



11-6 ACCEPTANCE TESTING.

Test the pavement for smoothness after completing the grinding and texturing. Accept only those pavement surfaces that meet the surface tolerance for a new pavement as required by the specifying agency. Use the same test equipment and procedure used in the initial evaluation for the acceptance testing. Do not reduce the nominal load-carrying capacity of the pavement through grinding without prior approval of the Pavements DWG or their designated representative.

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CHAPTER 12 CONCRETE PAVEMENT CRACK SEALING

12-1 INTRODUCTION.

Concrete pavement cracking is a result of tensile stress in the concrete slab exceeding the tensile strength of the concrete at the time of cracking. The cracking may develop soon after concrete placement or develop after some time. The cracking may be due to a number of factors such as marginal pavement design, poor construction practices, environmental conditions, and repeated traffic loading (fatigue related). The cracking may include the following types of cracks: transverse cracking, longitudinal cracking, corner cracking, or randomly oriented cracking.

Crack sealing, together with joint resealing, is the most commonly performed pavement maintenance activity. It reduces the amount of moisture that can infiltrate a pavement structure, thus reducing moisture-related distresses such as pumping, crack faulting, base and subbase erosion, and corner breaks at crack locations. It also prevents the intrusion of incompressible materials so compression-related distresses such as crack spalling, blowups, and slab shattering are minimized. The compression-related damage typically occurs at or along cracks oriented in the transverse direction; however, joint spalling can be of concern for cracks oriented in other directions.

Crack sealing is most effective when performed on concrete pavements that exhibit low-severity structural deterioration and when the cracks are full-depth but relatively narrow, with minimal spalling. Crack sealing may be used on cracks of low or medium severity where the crack width is 0.5 inch (13 millimeters) or less. If load transfer restoration (LTR) or partial-depth patching at the crack location is to be applied, seal cracks after these activities have been completed. If the cracks have deteriorated and exhibit a high degree of spalling, consider full-depth patching.

12-2 KEY STEPS.

The key steps in performing effective crack sealing include the following:

- Old sealant removal, if any
- Crack sawing/routing to specified depth and width
- Crack reservoir cleaning by sandblasting, water-blasting, and air-blasting
- Backer rod installation to control depth of sealant
- New sealant installation, typically hot-poured or cold-poured

12-3 GENERAL PRACTICE.

The general practice is to make only small sections of repair at a time to prevent the sawed or routed crack faces from being exposed to weather for more than 24 hours. If the cracks are wet, dry them with a high-pressure air compressor before placing the sealant and backer rod.

12-4 TEST SECTION.

Saw or route a test section of approximately 200 linear feet (60 meters) of cracks. Do not begin the full crack-sealing project until the contracting officer has approved a successful test section. Re-accomplish the test section until it meets requirements and is approved. Use the same procedures and materials in the full project that were used and approved in the approved test section. Demonstrate that crack sawing or routing does not cause spalling exceeding 0.25 inch (6 millimeters) in width or depth. Demonstrate cleaning of the crack faces before placement of any sealant. For two-component sealants, demonstrate and verify the mixing ratio is within a specified tolerance according to the manufacturer's specifications for that particular sealant. If using hot-applied sealants, use calibrated thermometers to verify correct application temperatures. Demonstrate that all equipment is in good working condition.

Use sealant that conforms to UFGS 32 01 19, *Field Molded Sealants for Sealing Joints in Rigid Pavements*, or the applicable ASTM specifications and is approved for use at a particular facility by the base engineer.

12-5 CRACK SEALANTS.

Concrete crack repair sealants are essentially the same as joint sealants. Crack sealants mitigate two problem areas: moisture intrusion into the pavement base and debris retention in the crack opening. Crack sealants are either hot-applied thermoplastic materials or cold-applied thermosetting materials.

12-5.1 Hot-Applied Sealants.

Hot-applied thermoplastic sealant materials are bitumen-based materials that typically soften upon heating and harden upon cooling, usually without a change in chemical composition. These sealants vary in their elastic and thermal properties and are affected by weathering to some degree. Thermoplastic sealants are typically applied in a heated form and include the following:

- Rubberized asphalt: Self-leveling (most commonly used)
- Polymeric materials: Self-leveling
- Elastic materials: Jet fuel-resistant
- Elastomeric polyvinyl chloride (PVC) coal tar: Jet fuel-resistant

12-5.2 Cold-Applied Sealants.

Cold-applied thermosetting sealant materials are typically one- or two-component materials that either set by the release of solvents or cure through a chemical reaction. These sealants cost more than the commonly used rubberized asphalt sealants. Liquid oxygen (LOX) is a one-component cold-applied thermosetting compatible sealant. Thermosetting sealants include the following:

- Silicone (most widely used):
 - Non-sag, toolable, low modulus
 - Self-leveling, low modulus
 - Self-leveling, ultra-low modulus
- Polysulfide and polyurethane: Self-leveling, low modulus
- Two-component elastomeric polymer: Jet fuel-resistant
- W.R. Meadows Poly-Jet LOX

Caution: The performance of sealant material is sensitive to crack reservoir moisture and cleanliness. Do not use expensive sealant materials unless good sealant installation practices can be assured at the job site.

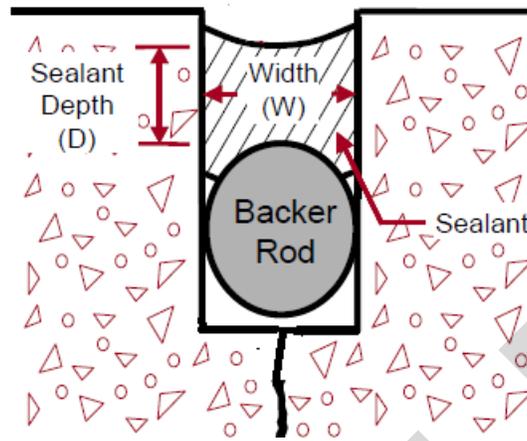
12-5.3 Fuel- and Blast-Resistant Sealants.

Additional considerations for crack repair material are jet fuel and jet blast resistance. The crack to be repaired may be located in an area where fuel or lubricating or hydraulic fluid spillage may occur or in an area subjected to high temperature from jet blast or exhaust from auxiliary power units (APU). Use repair materials that conform to UFGS 32 01 19 or ASTM specifications designated for joint and crack sealants for use in these areas.

12-6 SEALANT SHAPE FACTOR.

For crack sealing to be effective over the long term, route or saw the crack to the designated width and depth for the particular type of sealant employed in the crack repair. The dimensions of a typical crack reservoir (Figure 12-1) are defined by a shape factor, S , that is the ratio of the depth of the sealant (D) to its width (W). Shape factors generally range from 0.5 to 2.0, with 1.0 being most common; however, these dimensions may be specific to the type of sealant employed in the repair operation and a recommended value will be supplied by the sealant manufacturer. The depth of the sealant is controlled by use of a backer rod, as shown in Figure 12-1.

Figure 12-1 Crack Sealant Reservoir Shape Factor



Silicone sealants require a shape factor of approximately 0.5. For example, if the width (W) of the sawed crack is 0.5 inch (13 millimeters), saw the crack to a minimum depth of 1.25 inches (30 millimeters) to accommodate a backer rod of 0.625 inch (16 millimeters). The top of the backer rod will be 0.5 inch (13 millimeters) below the pavement surface. This allows for a depth (D) of 0.25 to 0.375 inch (6 to 9 millimeters) of silicone sealant on top of the crown of the backer rod to keep the sealant at 0.125 to 0.25 inch (3 to 6 millimeters) below the pavement surface.

12-7 BACKER ROD AND SEPARATING MATERIALS.

12-7.1 Backer Rod Materials.

The backer rod is placed in the sawed or routed crack to minimize excess stress on the sealant material from an improper shape factor and to prevent three-sided adhesion that would inhibit the ability of the sealant to expand and compress under thermal stress. Use a backer rod material that is chemically inert to prevent reaction with the sealant, flexible to conform to the shape of the crack path, non-absorptive to prevent water retention, non-shrinkable, and compressible to allow for easy installation.

Typical backer rod materials are polychloroprene, polystyrene, polyurethane, and polyethylene closed-cell forms. Do not use paper, rope, or cord. Use a backer rod material with a melting temperature that is at least 25 degrees F (14 degrees C) higher than the sealant application temperature to prevent damage during sealant placement.

Provide and use a backer rod with an uncompressed diameter at least 25 percent larger than the sealant reservoir width to ensure it remains in position during the sealing operation. Use a backer rod when repairing cracks by sealing.

12-7.2 Separating Materials.

A separating tape may be used when the sealant reservoir dimensions correspond to that for the proper shape factor for the sealant material to be used and the use of a

backer rod would lead to an incorrect shape factor for that sealant material. The separating material is usually a thin adhesive tape or a flexible plastic strip employed to prevent three-sided adhesion of the sealant. Use materials that are flexible enough to deform with the sealant as the concrete expands and contracts. However, only use this repair method when the crack has been sawed to provide a reservoir of the proper depth and width.

12-8 CRACK PREPARATION.

12-8.1 Introduction.

One essential element of the crack-sealing operation is proper preparation of the crack and the crack face. If the prepared crack faces are dirty or wet, the sealant will not adhere to the concrete surface and eventually will separate from the crack wall. Schedule the crack-sealing operation such that the prepared cracks are sealed as soon as possible to prevent contamination of the crack faces before sealant application. If vegetation is growing in the cracks, remove it and use a hot lance or a water-based herbicide to kill the weeds within the cracks. Oil-based herbicides can leave a residue that may prevent adhesion of the sealant to the crack face.

Route or saw the cracks to the proper depth and width according to the shape factor previously discussed or designated by the manufacturer's recommendations for the particular sealant being used. The random orientation of most concrete pavement cracks makes it difficult to create a uniform sealant reservoir directly over the crack.

After completing the sawing or routing operation, clean the crack face to remove laitance, sawing debris, and other foreign material. Perform cleaning with a multiple-pass technique in which one side of the sawed crack face is cleaned, followed by the other face. Sand or water-blast the pavement surface directly adjacent to the sawed crack to remove any debris or material that may cause problems during crack sealing.

12-8.2 Cleaning.

The importance of proper cleaning of the crack faces cannot be over-emphasized. Surface dust, debris, and laitance remaining in the sawed crack can prevent adhesion of the crack sealant to the prepared crack face. Follow the initial cleaning operation with final cleaning using high-pressure air to remove material remaining in the sawed cracks. Do not use water blasting for final cleaning as it will require additional time to dry out the crack faces. Repeat this cleaning process immediately prior to placing the sealant in the sawed reservoir if the sealant is not placed within three hours of the cleaning. Use a vacuum sweeper, shop vacuum, power broom, or hand broom to remove sand and dust adjacent to the crack to prevent the sand and dust from reentering the crack.

12-9 CRACK SEALING PROCEDURES.

12-9.1 Introduction.

Only seal cracks when the air and the pavement temperatures are above 50 degrees F (10 degrees C) and rising. Constantly monitor application temperatures for hot-applied crack sealants to ensure they are in the correct range.

12-9.2 Process.

Ensure the crack faces are clean and free of moisture. If moisture is present, use compressed air to dry the crack face before sealing. Seal the crack using the following steps:

1. Fill the crack from the bottom up to prevent air from becoming trapped under the sealant and bubbling.
2. Fill the crack from beginning to end in one smooth operation whenever practical.
3. Fill the crack to a depth of 0.25 inch (6 millimeters) below the surface of the pavement
4. Do not open the sealed pavement to traffic until the sealant has adequately cooled or cured so as not to be picked up by vehicle tires.
5. Remove all excess sealant application or spills and any other debris from the sealant application work and properly dispose of it.
6. For hot-applied sealants, remove and discard sealant remaining in the pot at the end of a day's work. Do not reheat and use the sealant unless the sealant supplier allows reheating and use.

12-9.3 Cautions.

Comply with the following precautions:

- For crack resealing, completely remove the old sealant.
- Do not start sealing cracks if rain is imminent or within 10 miles and moving toward the worksite.
- Do not begin, continue, or apply sealant if there is any sign of moisture on the surface adjacent to the crack or along the prepared crack faces.
- Follow the sealant manufacturer's installation instructions.
- Avoid getting voids or bubbles in the applied sealant.
- Do not apply sealant that rises above a point that is 0.25 inch (6 millimeters) below the pavement surface or rises over the pavement surface as it will be picked up by traffic or it will be pushed above the

pavement surface during hot weather and make the sealing process ineffective.

- Provide and use equipment with all safety mechanisms and guards in place and functioning properly during the crack sawing or routing and cleaning operations. Do not permit operators to use equipment without the proper use of required personal protective gear.

12-10 TEMPORARY CRACK/JOINT SEALING PROCEDURES FOR PCC.

12-10.1 Introduction.

Short-term performance (less than two years) of pavement joint and crack repairs is acceptable in circumstances identified by the contracting officer or engineer in charge. Example: The pavement is scheduled to be abandoned in two years but is maintained due to FOD potential from spalling. This guidance provides standard procedures and details for temporarily sealing joints and cracks in rigid pavements.

12-10.2 Repair Procedures Neoprene Compression Seal (NCS) Joints.

12-10.2.1 Compression Seal Removal Procedures.

See Figures 12-2 and 12-3. Perform the following key steps when removing seals:

1. Remove compression seal.
2. Remove all loose and poorly bonded concrete from the joint and joint walls.
3. Sandblast joint walls and bottom.
4. Air blow reservoir to remove debris and dry joint.
5. Install separating tape along joint bottom.
6. Prime joint reservoir walls if recommended by sealant manufacturer's published installation procedures.
7. Fill reservoir to within 0.375 inch (9 millimeters), \pm 0.125 inch (3 millimeters) of slab surface.

Figure 12-2 Existing Spalled NCS Joint

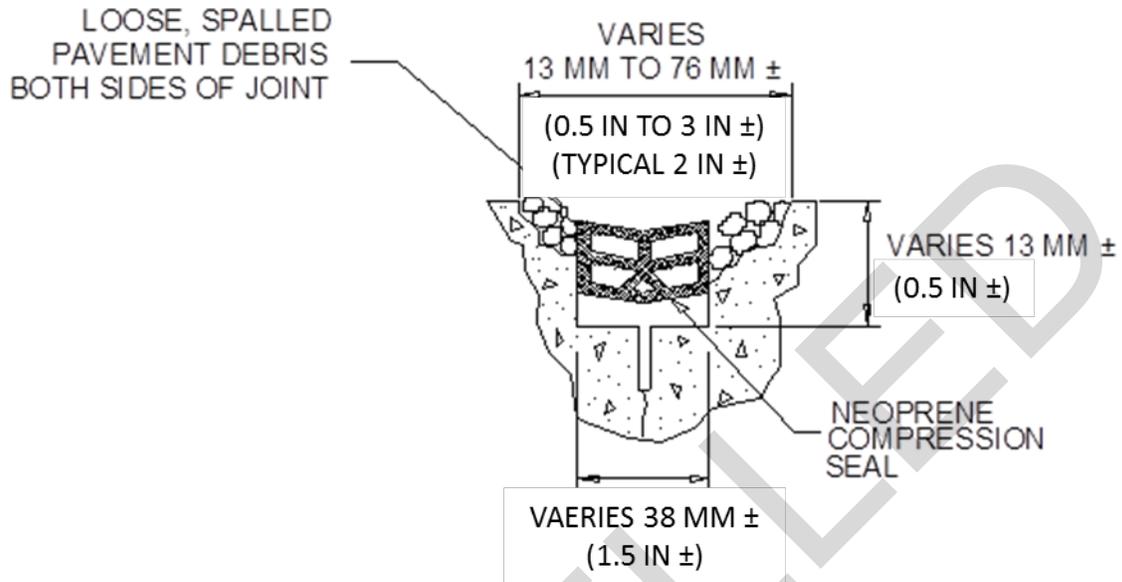
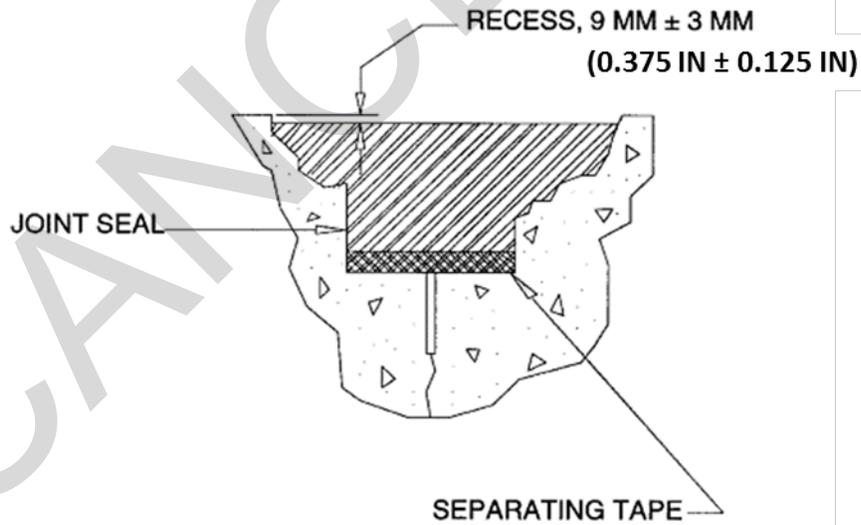


Figure 12-3 Repaired NCS Joint, Compression Seal Removed



12-10.2.2 Compression Seal in Place Procedures.

See Figures 12-4 and 12-5. The key steps in performing effective seal in place include the following:

1. Remove loose or delaminated concrete by hand, chisel, or other tool as required.
2. Air-blast to a clean condition.
3. Fill with sealant to top of existing compression seal.

Figure 12-4 Existing NCS Random Spall Area

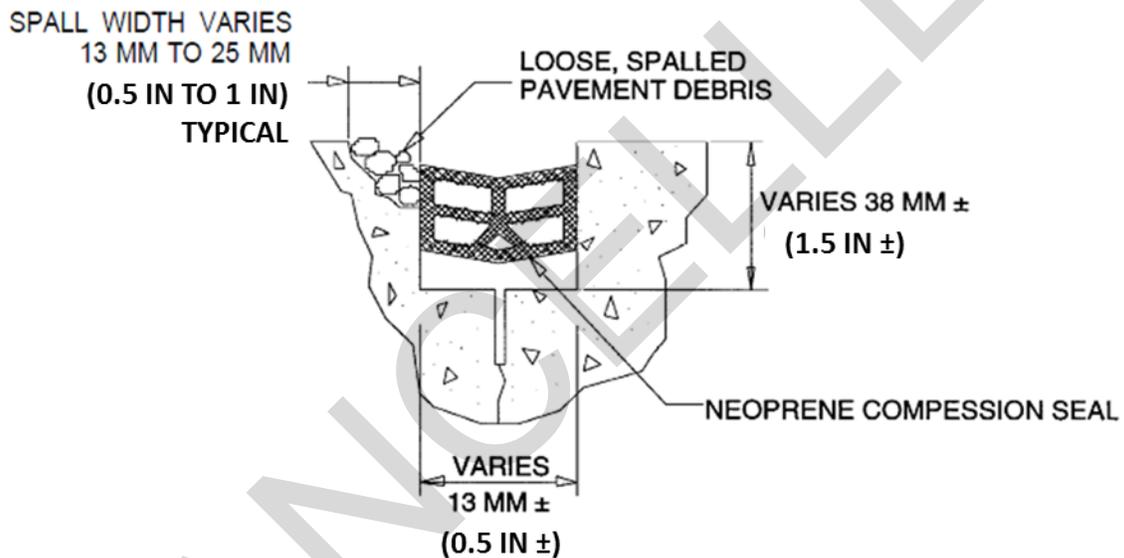
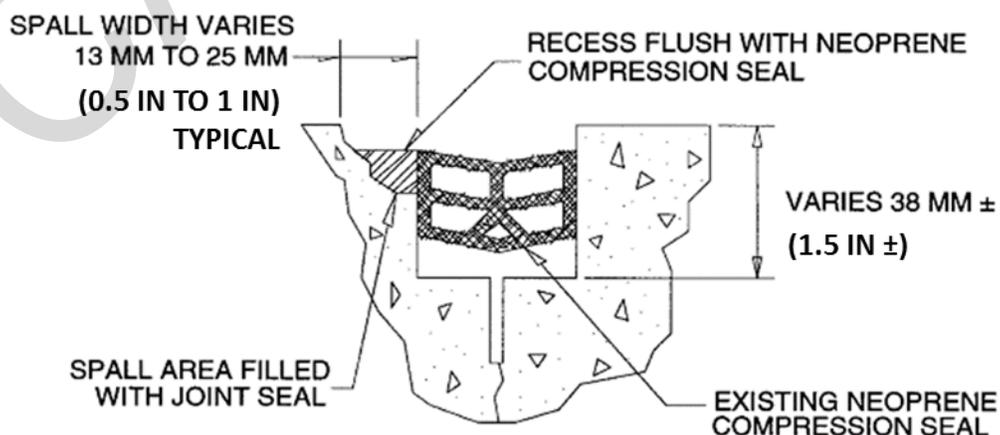


Figure 12-5 Repaired NCS Random Spall Area, Compression Seal in Place

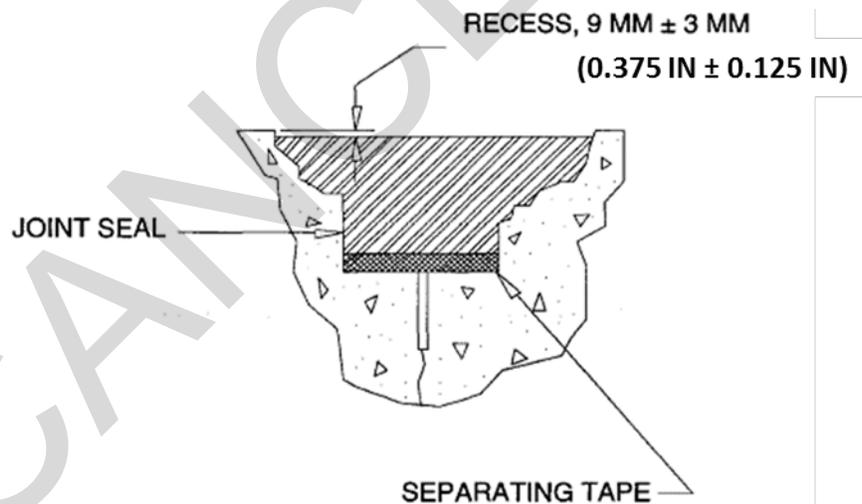


12-10.2.3 Section of Compression Seal Removed.

See Figures 12-6. The key steps in performing effective seal removal include the following:

1. Cut and remove neoprene compression seal.
2. Remove all loose, poorly bonded, and delaminated concrete from joint and joint walls.
3. Sandblast joint walls and bottom.
4. Air-blow reservoir to remove debris and dry joint.
5. Install separating tape along joint bottom.
6. Prime joint reservoir walls if recommended by sealant manufacturer's published installation procedures.
7. Fill reservoir to within 0.375 inch (9 millimeters), \pm 0.125 inch (3 millimeters) of slab surface.

Figure 12-6 Repaired NCS Random Spall Area, Section of NCS Removed



12-10.3 Random Cracks.

See Figures 12-7 and 12-8. The key steps in performing effective random crack sealing include the following:

1. Rout crack with vertical spindle router or crack chasing saw. Width of cut: 0.5 inch (13 millimeters), minimum; depth of cut: 0.625 inch (17 millimeters), minimum. Use a vertical spindle router where crack chasing saw kerf (0.5-inch [13 millimeters] width) will not remain over cracks.

2. Flush crack seal reservoir with high-pressure water only if wet sawing of crack reservoir is used.
3. Remove all loose, poorly bonded, and delaminated concrete debris from crack seal reservoir (walls and bottom) by chipping with hammer or chisel.
4. Sandblast both walls and bottom of crack seal reservoir.
5. Air-blow reservoir to remove debris and dry joint.
6. Install separating tape in bottom of crack seal reservoir.
7. Prime joint reservoir walls if recommended by sealant manufacturer's published installation procedures.
8. Fill reservoir to within 0.125 to 0.25 inch (3 to 6 millimeters) of slab surface.

Figure 12-7 Existing Random Crack

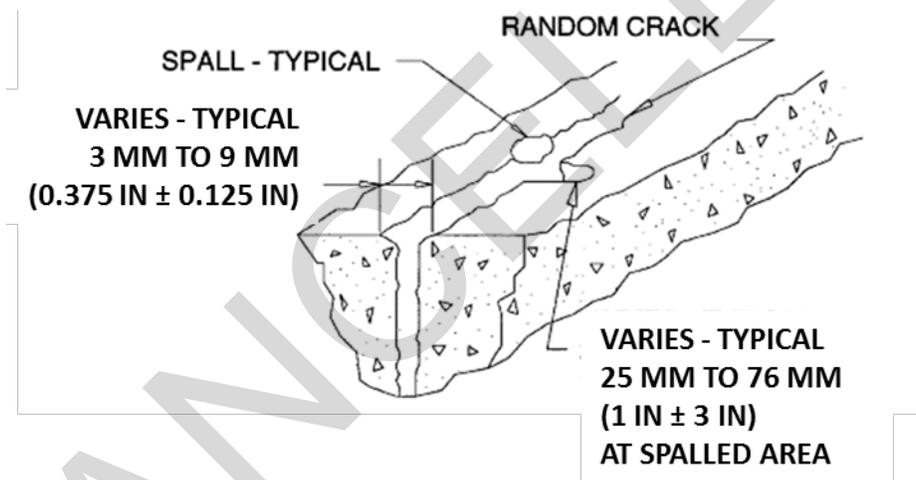
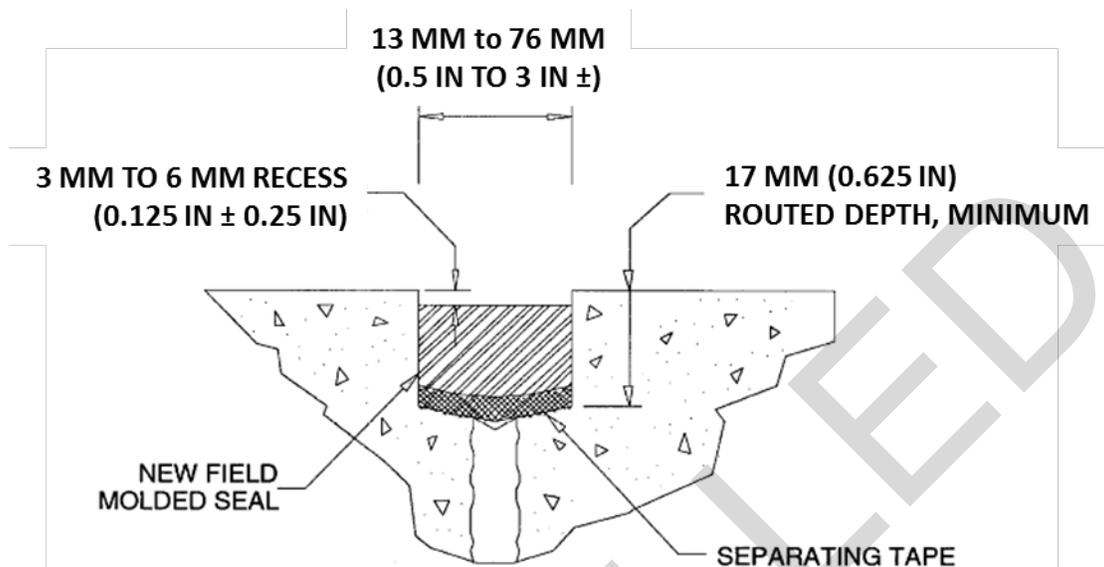


Figure 12-8 Repaired Random Crack



12-10.4 Field Molded Joints.

See Figures 12-9, 12-10, and 12-11. The key steps in performing effective field molded crack sealing include the following:

1. Remove existing seal by saw-cutting with gang of saw blades. Width of cut: one saw blade width greater than existing joint width (excluding spalls); depth of cut: 0.625 inch (17 millimeters), minimum. For joints with backer rod, remove to bottom of backer rod. Existing joint seal or expansion board below saw-cut may remain in bottom of joint. Where spalling has widened the joint reservoir, saw-cut width need not be expanded beyond width required for unspalled condition.
2. Flush joint seal reservoir with high-pressure water only if it was wet sawed.
3. Remove all loose, poorly bonded, and delaminated concrete debris from joint seal reservoir (walls and bottom) by chipping with a hammer or chisel.
4. Sandblast both walls and bottom of joint seal reservoir.
5. Air-blow reservoir to remove debris and dry joint.
6. Install separating tape or backer rod in bottom of joint seal reservoir. See details for proposed repair of joints.
7. Prime joint reservoir walls if recommended by sealant manufacturer's published installation procedures.

8. Fill reservoir to within 0.125 to 0.25 inch (3 to 6 millimeters) of slab surface.

Figure 12-9 Existing Spalled Field Molded Joint

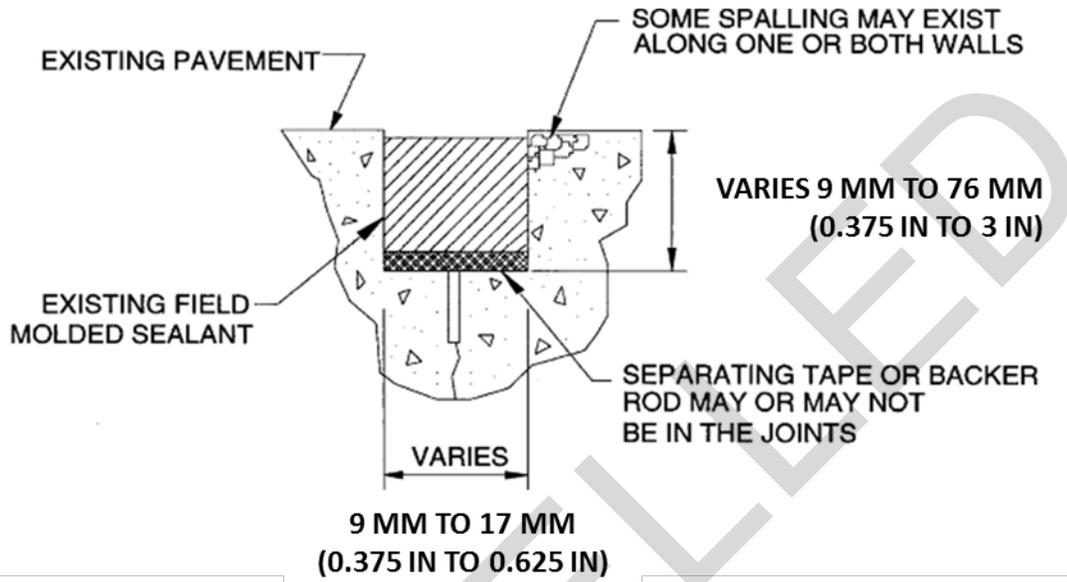


Figure 12-10 Resealed Field Molded Joint with Separating Tape

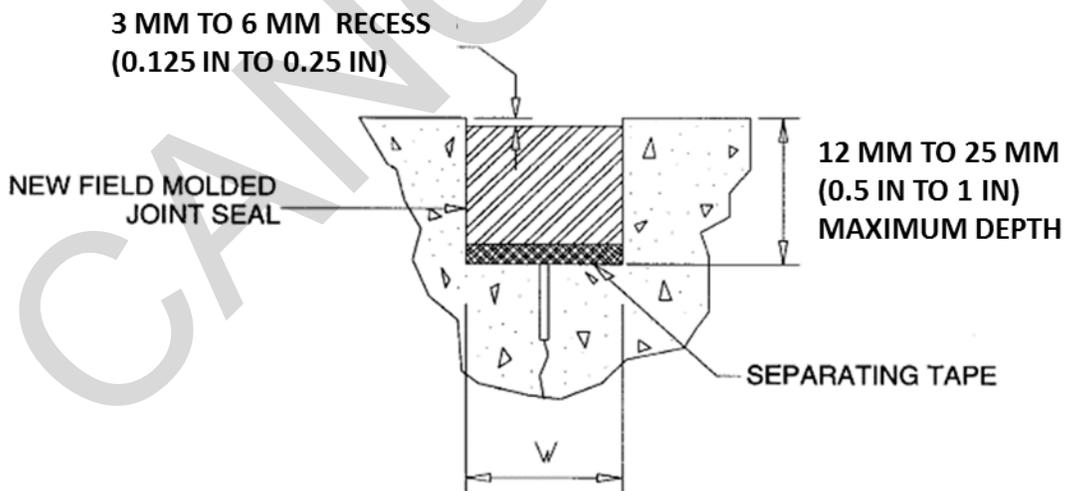
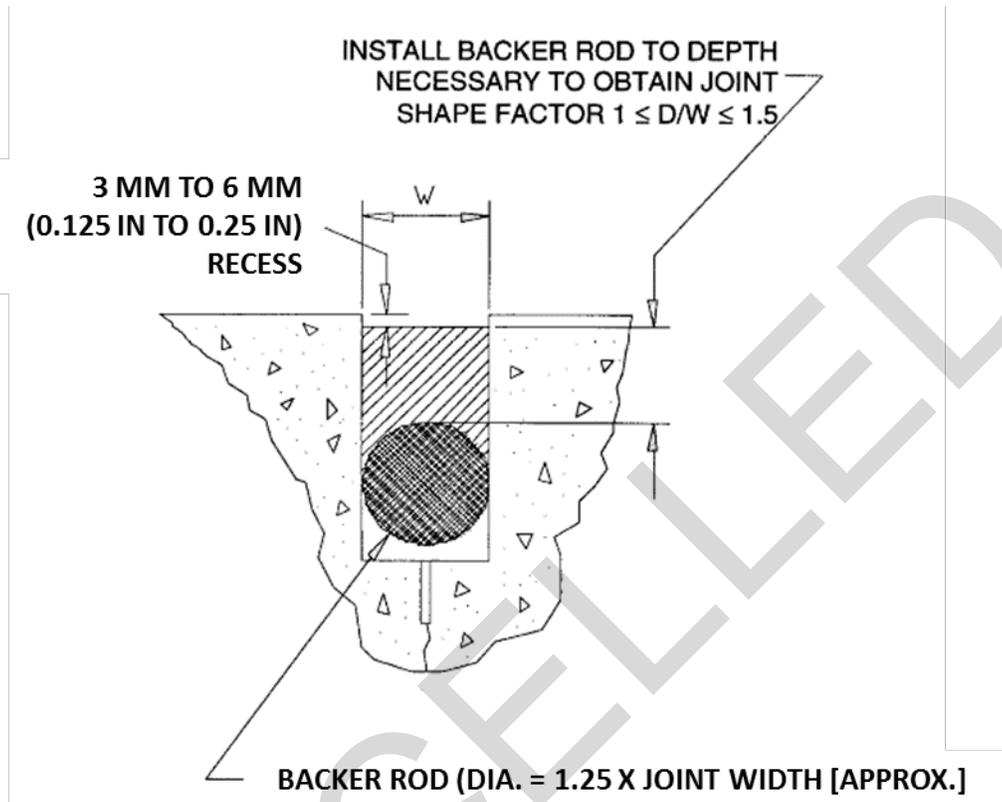


Figure 12-11 Resealed Field Molded Joint with Backer Rod



12-10.5 Partial-depth Joints.

See Figures 12-12 and 12-13. The key steps in performing effective partial-depth crack sealing include the following:

1. Make vertical saw-cut 2 inches (51 millimeters) deep, approximately 3 inches (76 millimeters) from distressed area. Overlap corner saw-cuts by 1 inch (25 millimeters), minimum.
2. Remove all concrete and loose material within the sawed area to sound concrete (3 inches [76 millimeters] minimum depth).
3. Use a separating medium to maintain and protect joints.
4. Use bonding agent to insure good contact between the pavement and patch as recommended by manufacturer's instructions.
5. Apply patch.
6. Apply curing compound to the patch surface if recommended by manufacturer's instructions.
7. After patch has cured, clean joint and apply joint sealant.

Figure 12-12 Existing Partial-depth Spalled Joint

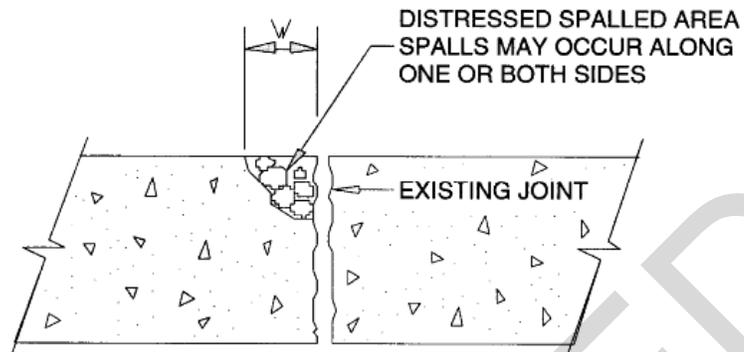
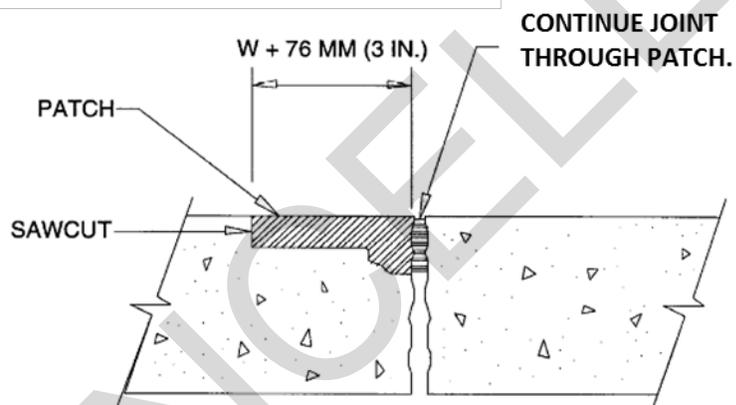


Figure 12-13 Repaired Partial-depth Joint with Backer Rod



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CHAPTER 13 PARTIAL-DEPTH REPAIR OF CONCRETE PAVEMENTS

13-1 INTRODUCTION.

The purpose of partial-depth repairs is to correct localized areas of concrete pavement distress. Repair of this type restores rideability, deters further deterioration, reduces FOD potential, and provides proper edges so joints can be effectively resealed. Spalling can be a significant distress for airfield pavements because spalling leads to loose material, which results in FOD. Timely spall repairs can extend the service life of the pavement. Partial-depth repairs of spalled joint areas also restore a well-defined uniform joint sealant reservoir prior to joint resealing.

Partial-depth repairs perform well when installed correctly; however, partial-depth repair can exhibit premature failures due to improper installation techniques.

13-2 NEED FOR PARTIAL-DEPTH REPAIR.

Partial-depth repair is typically used to repair spalling either at pavement joints and cracks (Figure 13-1) or at mid-slab locations. In this chapter, reference is made to joint spalling repair only; however, the discussion is also applicable to crack spalling repair. Spalling is typically a localized distress and therefore warrants a localized repair.

If several severe spalls are present along one joint, it may be more economical to place a full-depth repair along the entire joint than to repair individual spalls. Also, if the spall depth is greater than one-third of the slab thickness, use full-depth patching.

13-2.1 Joint Spalling.

Spalling along a joint can occur when unsealed joints are filled with incompressible materials that prevent expansion of the slab in hot weather and result in breakage of the concrete (Figure 13-2). Other causes of spalling at joints include keyway failures (of oversized, poorly designed keyways), poor construction, poor repairs, dowel bar lockup, improperly located dowels, and dowels in reamed-out sockets. Minor spall at joints may also be caused by snowplows.

13-2.2 Mid-slab Spalling.

Spalling at mid-slab is generally caused by reinforcement that is too close to the surface and foreign matter or poor surface finish in the original PCC. Spalls create a rough ride and can accelerate deterioration.

Figure 13-1 Pavement Joint Spall



Figure 13-2 Incompressible Causing Spalling at a Joint or Crack



13-2.3 Partial-depth Repair Key Steps.

The key steps in performing a partial-depth spall repair include the following:

1. Selection of repair boundaries
2. Removal of existing unsound concrete
3. Cleaning the repair area
4. Joint preparation for joint spall repair
5. Selection of the patch (repair) material
6. Placement of the patch material
7. Finishing activities
8. Treatment of saw-cut runouts and patch/slab vertical interface

9. Patch curing
10. Joint resealing

13-3 SELECTION OF REPAIR BOUNDARIES.

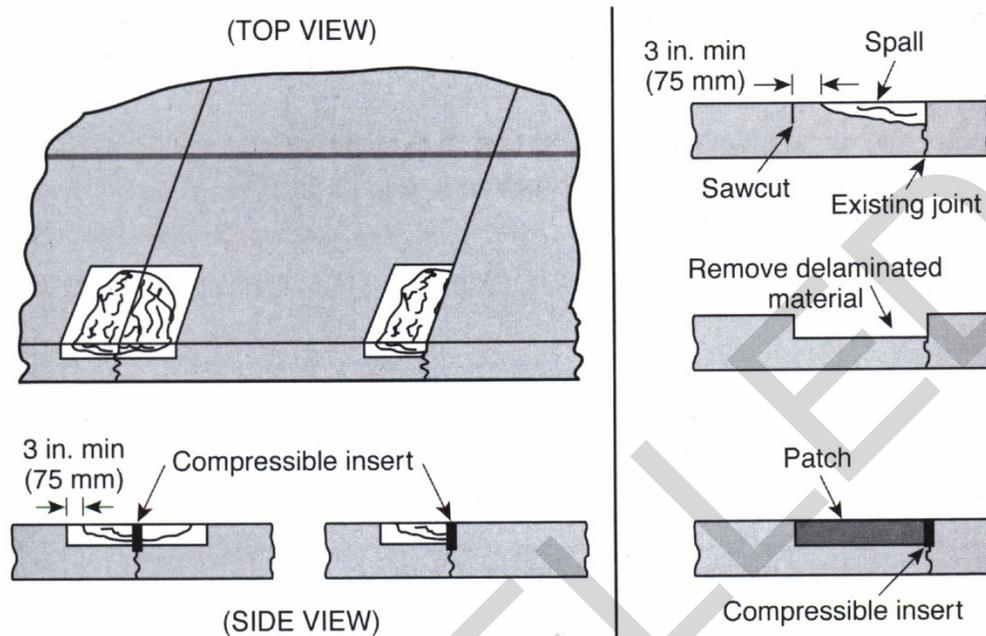
Prior to commencing work, survey the pavement to determine areas of unsound or delaminated concrete to establish the repair boundaries. During the survey, use a sounding technique to identify all areas of unsound concrete or delamination. Sounding the pavement to find delamination and spall removal areas is accomplished by striking the existing concrete surface with a steel rod or carpenter's hammer (Figure 13-3). Delaminated or unsound concrete will produce a dull or hollow thud, while sound concrete will produce a sharp metallic ring. Locate and remove all weak and deteriorated concrete to ensure the repair is effective.

Extend the repair boundaries beyond the detected delaminated or spalled area by 3 inches (75 millimeters) to assure removal of all unsound concrete (Figure 13-4). Keep the repair boundaries square or rectangular in line with the jointing pattern to avoid irregular shapes; irregular shapes may cause cracks to develop in the repair material. Consider combining repair areas along a joint if they are closer than 24 inches (600 millimeters) apart. This will help reduce costs and eliminate numerous small patches.

Figure 13-3 Sounding with a Hammer



Figure 13-4 Typical Spall Repair Boundaries



It is good practice to use rectangular-shaped repairs for all partial-depth spall repairs. The minimum length and width of the rectangular saw-cut boundary around a joint spall is 6 inches (150 millimeters). For corner spalls, do not make the rectangular saw-cut boundaries closer than 6 inches (150 millimeters) from the joint corner.

13-4 REMOVAL OF EXISTING CONCRETE.

13-4.1 Sawing and Chipping.

To remove concrete by sawing and chipping, make a minimum 2-inch (50-millimeter) -deep saw cut (in a rectangular pattern at least 3 inches [76 millimeters] outside all visible deterioration) around the perimeter of the repair area. This will provide a vertical face of sufficient depth to provide stability to the patch (Figure 13-4). Additional saw-cuts may be made within the repair area to speed chipping. A saw cut 2 inches (50 millimeters) away from joints might reduce the possibility of damaging the opposite joint face. A saw cut along the opposite joint face made by skimming the blade along the joint face will remove sealant residue and leave a clean vertical joint face. Remove concrete within the repair area to the bottom of the saw cuts or to 0.5 inch (13 millimeters) into visually sound and clean concrete, whichever is deeper, with light pneumatic tools (Figure 13-5). It is important that the proper tools are used. The recommended maximum size of the chipping hammer for partial-depth repairs is 30 pounds (13.6 kilograms).

Figure 13-5 Repair Boundary Sawing and Use of Chipping Hammer



13-4.2 Milling Process.

Concrete within the repair area can also be removed by carbide-tipped cold milling equipment. Cold milling is especially effective where the repair area extends over the majority of the slab width (Figure 13-6) or along a long length of a longitudinal joint. Equip milling machines with a device for stopping at a preset depth to prevent excessive removal or damage to existing dowel bars or reinforcement.

After removal of the concrete in the repair area, survey by sounding the pavement again to ensure all unsound or delaminated concrete has been removed.

Figure 13-6 Milling Techniques



13-4.3 Partial Versus Full-depth Repair.

Occasionally, surface spalling will actually extend through the full slab depth or for more than one-third the slab depth. Do not attempt partial-depth repair at such locations. Mark the area and perform a full-depth repair. Make full-depth repairs if the concrete below one-third the slab depth is damaged during chipping or if dowel bars or reinforcing are encountered during removal.

Caution: Do not, under any circumstances, rest/place partial-depth repair material directly upon dowel bars or reinforcement. Typically, if a dowel bar is exposed

within the repair area, it would indicate that the depth of repair is not acceptable. Completely expose steel reinforcement that is encountered in spall areas by removing at least 0.5 inch (13 millimeters) of concrete around the steel bars and the bars cleaned and covered with the patch material.

13-5 CLEANING.

Prior to patching, clean the exposed faces, bottom of the patch area, and any exposed steel to remove all loose particles, oil, dirt, dust, asphaltic concrete, rust, and other contaminants. As a minimum, air-blow with compressed air, wash with high-pressure water, and air-blow again (Figure 13-7). Check the prepared surface prior to placing the new patch material. Thoroughly clean the area with a power broom, vacuum sweeper, or hand broom to prevent debris from reentering the repair zone. Any contamination of the surface will reduce the bond between the patch material and the existing concrete.

Figure 13-7 Cleaning Repair Area (Sandblasting/Water Blasting, and Air Blowing)



13-6 JOINT PREPARATION.

When placing a partial-depth patch along a joint, do not allow the repair patch to bond to the joint face of the adjacent concrete and do not allow the repair material to penetrate into the joint. The most frequent cause of failure of partial-depth repairs at joints is excessive compressive stresses on the repair material abutting the adjacent concrete joint face. Partial-depth repairs placed directly against transverse joints will be crushed by the compressive forces created when the slabs expand and insufficient room is provided for the thermal expansion. Failure may also occur when the repair material is allowed to infiltrate the joint opening along the sides of the repair area and below the bottom of the repair, resisting slab movement and thereby preventing the joint from functioning.

13-6.1 Joint Bond-Breaking.

Elimination of bond between the patch and the adjacent concrete face can be accomplished by using a compressible insert. Styrofoam, asphalt-impregnated fiberboard (Figure 13-8), and plastic joint inserts are commonly used along the joint prior to placing the patch material. Patches that abut working joints or cracks that penetrate the full depth of the slab require a compressible insert or other bond-breaking medium to reform the joint or crack and prevent the repair material from flowing into the side and bottom of the joint areas undergoing repair. Use of an insert will form a uniform face against which the joint or crack can be properly sealed and will separate the patch from the adjacent slab.

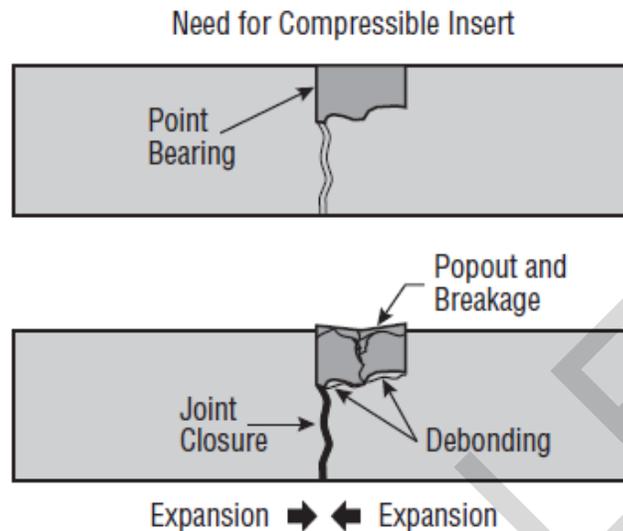
Figure 13-8 Compressible Insert



13-6.2 New Joint/Crack Width.

Ensure the new joint or crack width adjacent to the repair is equal to or more than the width of the existing joint or crack. Failure to reform the joint or crack as described can result in point bearing stress at the repair area and failure by blowup, delamination, or new shear planes, sometimes in the adjacent slab (Figure 13-9).

Figure 13-9 Failure Due to Non-use of Compressible Insert



13-6.3 Shoulder Joints.

When placing a partial-depth patch along a shoulder joint, place a piece of joint material along the slab edge even with the surface to prevent the patch material from penetrating the open shoulder interface. A wooden form may also be used for this purpose. Otherwise, the material may restrict longitudinal movement of the slab in response to thermal changes and result in damage to the repair or the shoulder.

13-7 PLACEMENT OF PATCH MATERIALS.

The volume of material required for a partial-depth repair is usually less than 2 cubic feet (0.056 cubic meter); therefore, mix cement-based patching material onsite in a small mobile drum or paddle mixer. Transit mix trucks and other large equipment cannot efficiently produce such small quantities since maximum mixing times for a given temperature may be exceeded, decrease the quality, and result in waste of material. Slightly overfill the repair area to compensate for consolidation. Tamp the repair to consolidate the repair material. The patch material also may be consolidated by small spud vibrators to eliminate voids at the interface of the patch and the existing concrete. Vibrators greater than 1 inch (25 millimeters) in diameter are not recommended for this work. On very small repairs, hand tools are sufficient to work the repair and attain adequate consolidation.

When using premixed or proprietary materials, follow the vendor's instructions related to patch material placement. If the patch material packaging is damaged, do not use the patch material.

13-8 FINISHING.

Finish the patch area flush to the cross-section of the existing pavement without leaving excess material on the adjacent pavement surface (Figure 13-10). The recommended finishing procedure is to screed from the center of the patch area to the patch boundaries. By moving the screed toward the patch boundaries, the material is pushed toward the vertical interface to increase the potential for high bond strength. After finishing, give the patch a burlap drag or broom finish to approximately match the surface finish of the existing adjacent concrete pavement unless a grinding operation is to follow.

Figure 13-10 Finished Patches



13-9 TREATMENT OF SAW-CUT RUNOUTS AND PATCH/SLAB INTERFACE.

Use the paste portion of the repair material to fill any saw-cut runouts that extend beyond the patch perimeter at patch corners. This will prevent any spalling at these locations.

If the repair material is properly placed in the patch area there will not be any need to place any sealer type material along the perimeter of the patch surface. However, if within a few days or few weeks, the patch material appears to be pulling away from the existing concrete, seal the patch/slab interface with a cement grout or an epoxy material. Use of a joint sealant for this purpose is not recommended.

13-10 CURING.

Proper curing of cement-based partial-depth repairs is very important due to the large surface of small patches compared to the volume of patch material, as well as the fact that concrete gains bond strength much slower than it gains compressive strength. Proper curing requires the application of curing compound at the time bleed water, if any, has evaporated from the surface of the patch. Because curing is critical for cement-based patches, for the first 24 hours wet-cure with burlap or a similar material and apply a curing compound after that period. In hot or dry climates, cure the patches for three days with a double mat of saturated burlap covered with polyethylene sheeting over

which plywood or lumber is placed. Remove the covering and re-saturate the burlap as often as is necessary, but at a minimum of once a day, and the covering re-placed.

For premixed and proprietary repair materials, follow the manufacturer's directions regarding curing. Some rapid strength material may not require curing application and can be opened to traffic within four hours.

13-11 JOINT/CRACK RESEALING.

Resealing the repaired joint is extremely important because it will help prevent moisture and incompressible materials from entering the joint or crack and causing further damage. It is important that the new transverse and longitudinal joints constructed within the patch area be formed or sawed to provide the proper joint seal reservoir and match surrounding joints. Ensure the joint faces are clean and dry for good sealant performance.

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CHAPTER 14 FULL-DEPTH REPAIR OF CONCRETE PAVEMENTS

14-1 INTRODUCTION.

When normal maintenance procedures can no longer correct the deteriorated concrete pavements, full-depth repair may become necessary to restore damaged areas to their original condition and extend the service life of the pavement. Full-depth repairs are generally necessary when slabs have been shattered (Figure 14-1) or have deteriorated to such an extent that the safe support of the required load is no longer possible. Full-depth repairs are an effective means of restoring the rideability and structural integrity of deteriorated concrete pavements and, therefore, extending their service life.

14-2 NEED FOR FULL-DEPTH REPAIR.

There are several types of distress that occur at or near transverse joints that may require full-depth repair when classified as medium- or high-severity level distress. Comprehensive distress manuals (ASTM D6433, *Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys*, and ASTM D5340, *Standard Test Method for Airport Pavement Condition Index Surveys*) are available that define distress types and severity levels.

14-2.1 Rigid Pavement Distress Types.

Types of distress that occur in rigid pavements that may justify full-depth repair when classified as medium- or high-severity distresses include:

- Blowup
- Corner break
- Durability ("D") cracking
- Patch deterioration
- Shattered slab (a slab broken into four or five pieces with some or all cracks of high severity or a slab broken into six or more pieces with over 15 percent of the cracks of medium or high severity) (Figure 14-1)
- Spalling (if spalling extends to greater than one-third the slab thickness)
- Punchout
- Railroad crossing distress

Figure 14-1 Shattered Slabs



14-2.2 Other Rigid Pavement Concerns.

Concrete pavements may also exhibit spalling and faulting at intermediate cracks. This deterioration may be caused by repeated heavy traffic loads, failure of doweled joints to function properly, and/or the intrusion of incompressible materials in the open cracks. If the spalling extends to greater than one-third the slab thickness or if the faulting is in excess of 0.5 inch (12 millimeters), full-depth repair at the crack locations may be considered.

14-2.3 Full-Depth Repair Key Steps.

The key steps in performing a full-depth repair include the following:

1. Selection of repair boundaries
2. Sawing of repair boundaries
3. Removal of existing concrete
4. Restoring the repair area support (subgrade and base preparation)
5. Dowel bar and tie-bar placement
6. Replacing reinforcement, if any
7. Restoring expansion joints, if any
8. Use of filler material at joints
9. Dowel bar placement
10. Concrete placement
11. Concrete finishing and texturing
12. Curing
13. Joint sealing

14. Opening to traffic.

Caution: Successful performance of full-depth repairs requires proper restoration of the base and subgrade and provision of effective load transfer across trafficked joints, other than thickened edge slip joints. Also, full-depth repairs are not effective over the long-term if the existing pavement exhibits materials-related distress, such as D-cracking or ASR.

14-2.4 Selection of Repair Boundaries.

First, conduct a detailed survey to accurately identify the required repair areas so all significant underlying distresses are identified and corrected. Quite often, and particularly in freeze-thaw climates, the deterioration near joints and cracks is greater at the bottom of the slab than is apparent from the top of the slab.

In both plain jointed and reinforced jointed concrete pavement, partial-slab replacement is acceptable where the distresses are within one-half of the slab length. Full-width slab patching is required if the original slab width is less than 20 feet (6 meters) or full-depth cracks are located within the interior area of the slab. A minimum slab length is required to avoid rocking and pumping of the repair. General experience indicates that 10 feet (3 meters) is a minimum length for airfield applications. For roadways with 11- to 14-foot (3.4- to 4.3-meter) -wide lanes, the repair area needs to be full lane width with a minimum length of 6 feet (1.8 meters). If the repair extends over half the length of the panel, consider full panel replacement.

14-2.4.1 Saw Cut.

Saw cut will be a minimum of 3 feet (900 millimeters) from a joint and the minimum patch length will be 6 feet (1.8 meters). Saw cut in lines forming rectangles parallel with or perpendicular to the jointing pattern.

14-2.4.2 Patch Boundary.

Extend the patch boundary to the joint(s) if the length of the patch is greater than half the length of the panel.

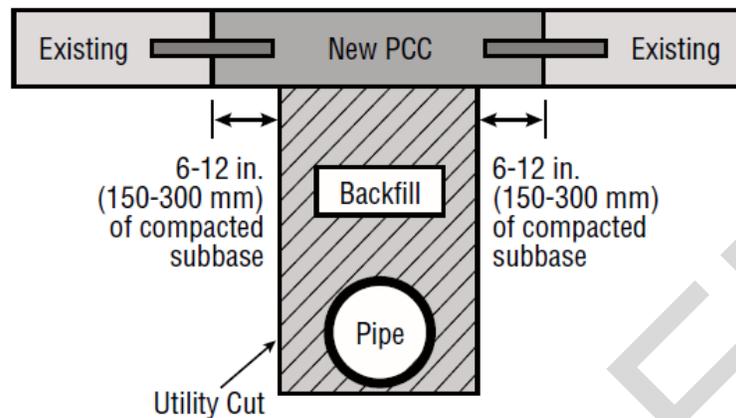
14-2.4.3 Utility Cut.

If the patch is a utility cut, make cut about 12 inches (300 millimeters) beyond limits of the excavation and any sloughing of the trench. This saw cut limit of the excavation area allows the repair concrete to extend beyond the excavation. (Figure 14-2)

14-2.4.4 Continuously Reinforced Concrete.

For continuously reinforced concrete, position the patch area so the distressed portion is in the middle of the patch area. Patch at least 6 feet (1.8 meters) in length if reinforcing steel is to be tied, and at least 4 feet (1.2 meters) long if welded or if mechanical splices are used to connect reinforcing steel.

Figure 14-2 Utility Cut



14-2.5 Sawing Cutting Repair Boundaries.

The repair boundaries of mesh-reinforced, plain doweled, and plain undoweled jointed concrete pavement are typically cut full-depth using diamond blade sawing (Figure 14-3). Sawing is the recommended method.

14-2.5.1 Hammer Use.

Do not use hammers to outline the area. The rough joint formed by hammers typically spalls in service and it is difficult to lift out the concrete within the repair boundaries or break it up with large pavement breakers.

14-2.5.2 Partial-Depth Cuts.

The use of the partial-depth saw cut is not recommended. The partial-depth saw cut does provide some aggregate interlock due to a rough face but micro-cracking will develop at the bottom of the repair area and the bottom of the slab may spall when using a large pavement breaker to shatter the concrete within the repair boundaries.

14-2.5.3 Full-Depth Cuts.

Full-depth saw cuts will completely separate the concrete that is to be removed, leaving undamaged vertical faces, and eliminate damage at the bottom of the remaining slab.

14-2.5.4 Warm Weather.

On warm days, a double saw cut method may be necessary to prevent binding of the sawing blade.

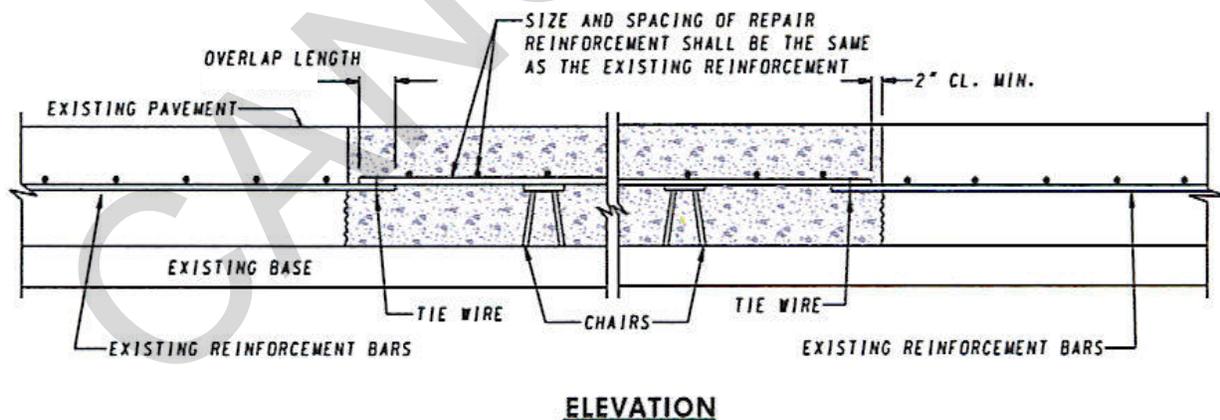
Figure 14-3 Diamond Blade Sawing



14-2.5.5 Continuously Reinforced Concrete (CRC).

The repair boundaries of CRC pavement are provided by sawing full depth at the repair boundaries. Partial-depth saw cuts above the reinforcing steel are then provided at a distance (typically about 20 inches [500 millimeters]) required by the lap length of the reinforcement) from the repair boundaries (Figure 14-4). Locate the partial-depth saw cuts at least 18 inches (450 millimeters) from the nearest tight crack and do not saw across an existing crack. If any of the reinforcing steel is cut during partial-sawing, extend the repair area by the required lap length of the reinforcement.

Figure 14-4 CRC Pavement Full-depth Repair Layout



14-2.5.6 Matching Joints.

Matching joints in adjacent lanes (typically for roadways) is not necessary as long as a debonding material (e.g., fiberboard) has been placed along the longitudinal joint to separate the lanes. However, if the distressed areas in both lanes are similar and both lanes are to be repaired at the same time, it is a good practice to align repair boundaries to avoid small offsets and maintain continuity.

14-2.6 Removal of Existing Concrete.

Do not use procedures for removal that spall or crack adjacent concrete or significantly disturb the base or subgrade. There are two basic methods to remove concrete pavement, as discussed below.

14-2.6.1 Breakup and Cleanout Method.

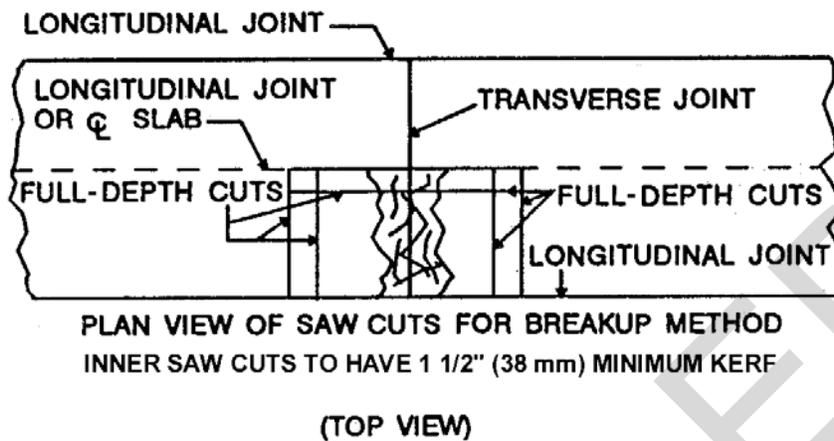
Concrete breakup is accomplished using a pavement breaker with removal by a backhoe (Figure 14-5). This method disturbs the base and requires base replacement or filling with concrete. It also has the potential to damage the adjacent slab if proper sawing procedures are not followed. This is not a preferred method for concrete removal.

After the repair is isolated by full-depth saw cuts, additional saw cuts using a wheel saw with at least 1.5-inch (38-millimeter) kerf, are made within the repair area, parallel and approximately 1.5 feet (450 millimeters) from each perimeter saw cut or joint (Figure 14-6). Begin breakup in the center of the removal area within the inner saw cuts. After breakup of the inner area, a backhoe can be used to gently pull the outer region free of the adjacent slab, or this strip can be broken up with light hand-held jackhammers.

Figure 14-5 Concrete Removal Using Backhoe



Figure 14-6 Additional Saw Cuts (Breakup Method)



14-2.6.2 Lift-out Method.

This is a recommended practice as it results in little damage to the base and the subgrade. This procedure is accomplished using a crane or front-end loader to lift the deteriorated concrete from its in-place position (Figure 14-7). Closely control lift-out operations to prevent accidents. After the repair area is isolated by full-depth saw cuts, holes are drilled through the slab and fitted with lift pins and the slab is then lifted in one or more pieces. If it is necessary to decrease the load, the slab may be saw cut into smaller pieces.

Figure 14-7 Lift-out Method

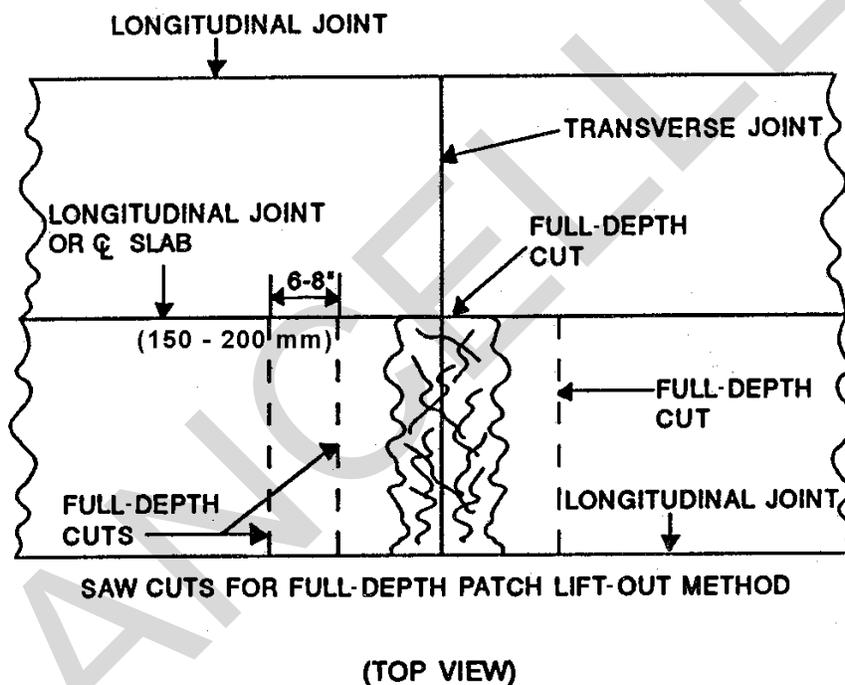


During hot weather, the sawing equipment may bind during initial transverse sawing procedures. It may be necessary to perform sawing at night when the temperatures are lower and the slabs are contracting. Another solution is to use a

carbide-tipped wheel saw to provide a pressure relief cut within the patch area prior to the perimeter sawing (Figure 14-8). It is strongly recommended that the carbide-tipped wheel saw cut be made no closer than 6 to 8 inches (150 to 200 millimeters) from the proposed patch boundary due to the possibility of damage and micro-cracking in adjacent concrete. The same procedures may be used for the removal of CRC. Carefully remove concrete in the two reinforcing lap areas by jackhammering so as not to damage the reinforcing.

For CRC pavements, after the concrete between the two full-depth saw cuts is removed, remove the concrete between the full-depth saw cuts and the partial-depth saw cuts by jack-hammering to expose the steel reinforcement.

Figure 14-8 Pressure Relief Cuts for Lift-out Method



14-2.7 Subgrade and Base Preparation.

After the deteriorated and loose concrete has been removed, examine the base course. Remove all excess disturbed material. Compact the patch area using a plate compactor (Figure 14-9). If excessive moisture exists in the repair area, remove it or dry the repair area before re-grading and compacting the base. It is difficult to adequately compact granular material along the perimeter and the corner areas of the patch, which may result in settlement of the patch under future traffic loading. Replacing some or all disturbed base material with lean concrete or flowable fill is a very good alternative for critical operational areas.

Figure 14-9 Patch Area Compaction



14-2.8 Dowel and Tie-Bar Placement.

In full-depth repair of jointed concrete pavements, good load transfer across the transverse repair joints is a critical factor affecting the performance of the full-depth repairs. Load transfer is best achieved by properly installed dowel bars of sufficient size and number. For dowel bar size and spacing, follow the recommendations provided in Table 18-1.

Deformed tie-bars along longitudinal joints in new construction are used to restrict movement at these joints. These bars are typically #5 or #6 in size and spaced at about 30 inches (750 millimeters). For roadway full-depth repairs, tie-bars along interior joints (e.g., centerline joint) are necessary for repair lengths exceeding 40 feet (12 meters) to prevent drifting of the full-depth patch.

For full-depth repair of airfield pavements, incorporate dowel bars along longitudinal joints within the patch and dowel all edges to the existing pavement (longitudinal and transverse).

14-2.8.1 Smooth Dowel Bars.

Use of smooth dowel bars at the joints provide load transfer across these joints while allowing the joint to open and close as the surrounding pavement expands and contracts in response to temperature and moisture changes.

14-2.8.2 Deformed Dowel Bars.

In contrast to smooth dowel bars, deformed dowel bars are used along certain repair joints to provide both load transfer and prevent movement at the specific joints. Since in repair both smooth and deformed dowel bars have a load transfer role, select their dimensions and spacing based on the design loading for that facility.

14-2.9 Drilling Dowel and Tie-Bar Holes.

Installation of smooth or deformed dowel bars and deformed tie-bars requires drilling holes at specified locations into the exposed (saw cut) face of the existing slab. Gang drills are available to drill multiple holes simultaneously (Figure 14-10). The gang drill maintains the drills in a rigid frame to prevent the drill bits from wandering and holds them in a horizontal position at the correct height (typically, one-half the slab thickness). Make the depth of the holes approximately one-half the length of the dowel or tie-bar. Do not use hand-held drills to drill holes for dowel bars as the required dowel alignment cannot be easily achieved.

Figure 14-10 Drilling Multiple Holes at Mid-depth for Dowel Bars



Hole diameters exceeding the bar diameter by 0.125 inch (3 millimeters) or less are recommended when using epoxy materials. Clean the drilled holes using air blasting before injecting the epoxy grout into the hole. Take care during the drilling to ensure that spalling around the drilled hole at the joint face is kept to a minimum. Ensure spalling does not exceed the diameter of the retainer ring used to keep the epoxy from flowing out of the drilled hole. In case of such minor spalling, the epoxy is used to patch the spalls. For larger spalls around the drilled holes, the spalled area needs to be repaired before installing the dowel bars.

14-2.10 Dowel and Tie-Bar Installation.

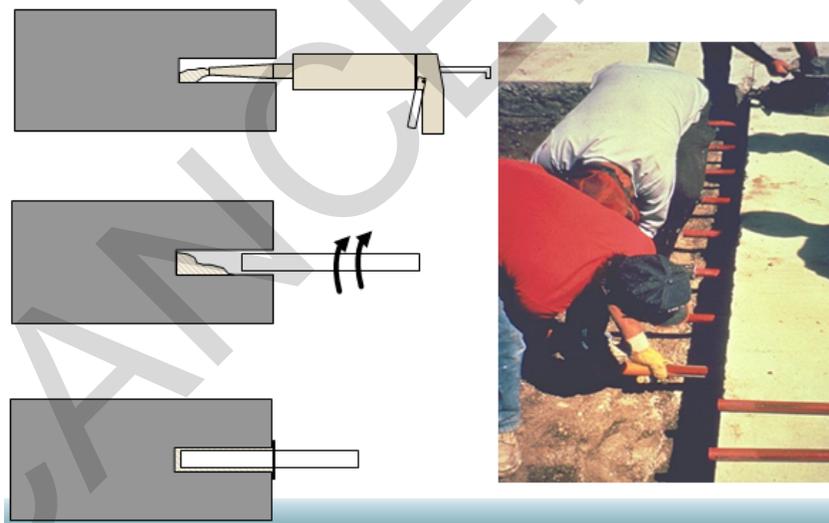
Use dowels, tie-bars, or reinforcement that are clean and free of flaking rust. Specify appropriate sizes of dowels (at least matching the size of dowel bars used in the existing pavement) for different thicknesses of pavements (refer to UFC 3-260-02,

Pavement Design for Airfields, for required sizes). Exercise care in epoxy grouting dowels or tie-bars to ensure complete coverage and support of the bars. Use grout retention devices that fit tightly over the dowel or tie-bar and seal the hole to prevent loss of epoxy. The steps for correctly installing dowel bars after air-blasting the holes are illustrated in Figure 14-11.

The proper installation of the smooth dowel bars is very important. Misaligned dowels can lead to early joint failure (spalling around the dowel bars) or cracking in the slab panel adjacent to the joint. The smooth dowels allow movement of the adjoining slabs. Oil or treat with a debonding material the portion of the bars that extend into the repair when using dowels to prevent bonding of the bars with the repair concrete. Cap one end of dowels used at expansion joints, in addition to oiling or treating with a debonding material, to permit further penetration of the dowels into the concrete when these joints close during warm weather.

Deformed tie-bars with surface ridges provide a locking anchorage with surrounding concrete. These tie-bars are placed in joints that are not intended to have movement.

Figure 14-11 Dowel Bar Installation



- A. Injecting the epoxy into the back of the hole in sufficient amount to ensure full coverage around the inserted dowel bars
- B. Inserting dowel bars into the hole with a slight twisting motion
- C. Using a retainer ring to stop the epoxy from flowing out of the hole

14-2.11 Continuous Reinforced Concrete (CRC) Pavement Repair.

Successful performance of CRC pavements requires good load transfer across all transverse cracks and repair joints. Failure to provide adequate load transfer will cause the repair and the surrounding pavement to fail due to excessive deflection at the joints.

For conventional full-depth repair of CRC pavements, the longitudinal reinforcing is generally carried through the repairs by carefully removing the old concrete to allow the appropriate length of steel (lap length) from the existing pavement to extend into the repair area. This steel is then tied, welded, or mechanically connected to new reinforcing steel that extends through the repair area. When replacing reinforcing steel in the patch area, match the original rebar in size (diameter), grade, and number. Place the new bars on bar supports to ensure proper position and cover. Do not extend bars closer than 2 inches (51 millimeters) to the patch/slab interface.

14-2.11.1 Tied Splices.

Lap tied splices the proper length that provides full bar strength. The recommended lap length for tying longitudinal steel is a minimum of 25 times the diameter of the steel bars.

14-2.11.2 Welded Splices.

Use the proper length for the welding procedure chosen when using welded splices. Lap bars at the center of the repair area to avoid the potential buckling of bars on hot days.

14-2.11.3 Mechanical Splices.

Use mechanical splices in accordance with the supplier's instructions.

14-2.12 Expansion Joints.

Expansion joints are placed in concrete pavements to provide relief for expansion of the concrete pavement due to temperature changes. Generally, expansion joints are installed at all intersections of pavements with structures or when a pavement ends near a structure but are rarely required within pavement features.

Expansion joints may be required if longer-length full-depth repairs are made during cool weather when adjacent concrete is in a contracted state or crushing and spalling of concrete at the joints may occur during subsequent hot weather when the concrete expands. Keep expansion joints in pavements to the minimum necessary to minimize future maintenance issues. The types of expansion joints commonly used by the military are the thickened-edge expansion joint (Figure 14-12) and the doveled type expansion joint (Figure 14-13).

Figure 14-12 Thickened-edge Expansion Joint

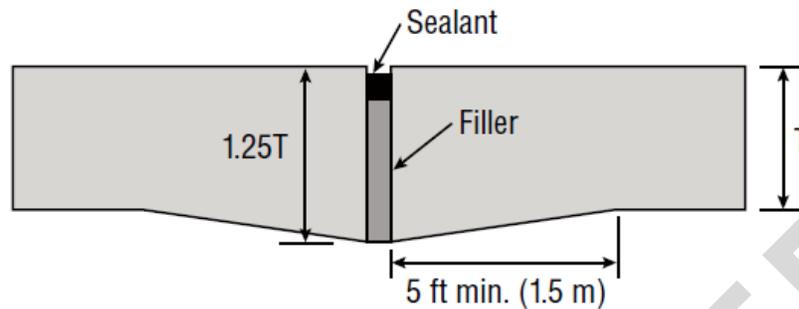
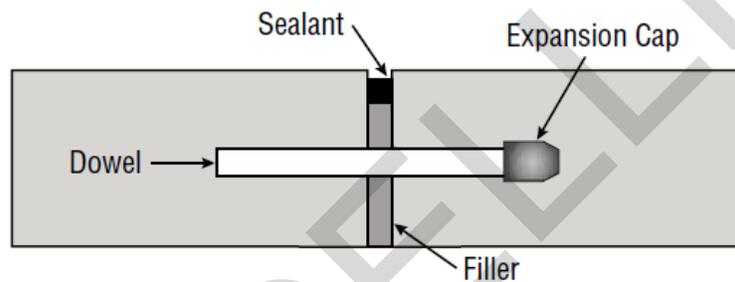


Figure 14-13 Doweled Expansion Joint



14-2.12.1 Thickened-edge Longitudinal Expansion Joint (Without Dowels).

The thickened-edge type is suggested for longitudinal expansion joints (slip joints) within airfield pavements. Dowels are not used in thickened edge longitudinal expansion joints because differential expansion and contraction parallel with the joints may develop undesirable localized stresses and possibly failure of the existing concrete or the full-depth patch, especially near the corners of existing slabs at transverse joints.

14-2.12.2 Thickened-edge Isolation Joint (Without Dowels).

The thickened-edge isolation joint (without dowels) is the expansion joint best suited to surround or separate any structure that projects through, into, or against the pavement (approaches to buildings, drainage inlets, roadway bridges, and hydrant refueling outlets).

14-2.12.3 Doweled Transverse Expansion Joints.

Use doweled transverse expansion joints within roadway pavements. However, at the angular intersection of pavements, it might be desirable to allow some slippage in the transverse joint to prevent the expansion of one pavement from distorting the other. In such instances, design the transverse expansion joint as a thickened-edge expansion joint.

14-2.13 Filler Material.

Use non-extruding type material for filler material for the thickened-edge and doweled-type expansion joint. The type and thickness of the filler material will depend upon the particular project. Usually, a preformed material of 0.75-inch (20-millimeter) thickness will be adequate, but in some instances a greater thickness may be required, depending on the geometric design of the facility and temperature at the time of full-depth repair. Use a heavy coating of bituminous material not less than 0.25 inch (6 millimeters) in thickness or a standard non-extruding type material not less than 0.25 inch (6 millimeters) in thickness for filler material for thickened-edge slip joints.

Filler material at expansion joints where dowels are used require that the dowels be securely placed and properly aligned. Drill or punch the non-extruding filler material to the exact diameter at the location of the dowels. Furnish it in lengths equal to the width of the placement. When more than one length of the filler board is used along a joint, hold the abutting ends of the filler in alignment. Hold the filler boards firmly in place and extend downward completely to the bottom of the slab and hold the top edge about 0.5 inch (13 millimeters) below the surface of the pavement. Protect the top edge of the filler material while the concrete is being placed. Use a zip strip to accomplish this, where available.

14-2.14 Concrete Placement.

Conventional concrete is typically used for full-depth repairs. The concrete mixture selection depends on the curing time available to reach required strength before the repair area is opened to traffic. If it is acceptable for the concrete to cure for several days (similar to new construction), regular concrete mixtures using Type I or Type II cement can be used. If an earlier opening time (12 hours to 3 days) is needed, a high early-strength concrete, incorporating a higher volume of Type I or Type II cement or using Type III cement, can be used. However, carefully consider the use of a higher volume of cement in areas subject to ASR in concrete. Follow standard concrete placement procedures, including concrete consolidation procedures.

Place the concrete when the ambient temperature is between 40 and 90 degrees F (4 and 32 degrees C).

14-2.14.1 Vibration Adjacent to Edge.

Give extra attention to ensure that the concrete is vibrated well around the edges and beneath the reinforcement.

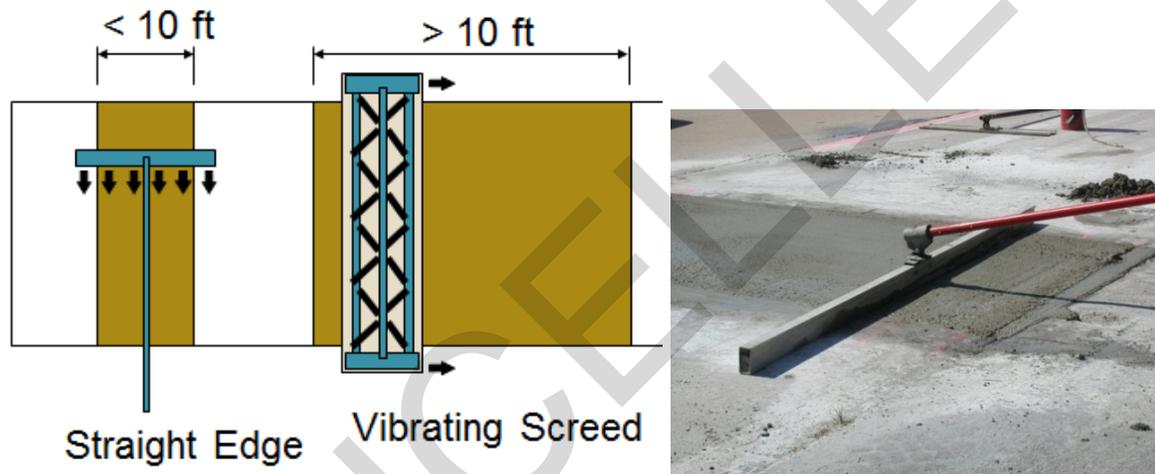
14-2.14.2 Rapid-set Proprietary Cementitious Materials.

Rapid-set proprietary cementitious materials that attain sufficient strength for opening to traffic in as little as four hours are available. Use rapid-set proprietary materials in compliance with the manufacturer's recommendations. These recommendations typically include mixture proportioning, placing, consolidation, curing, time required before opening to traffic, and allowable placement temperature ranges.

14-2.15 Concrete Finishing and Texturing.

Follow standard procedures when finishing. For repairs less than 10 feet (3.048 meters) in length, strike off the surface of the concrete with the screed parallel to the centerline of the pavement. For repairs more than 10 feet (3 meters) in length, strike off the surface with the screed perpendicular to the centerline of the pavement. Give extra attention to ensure the concrete is not over-finished. Before the concrete becomes non-plastic, give the surface a burlap drag or broom finish to approximately match the surface finish of the existing adjacent concrete pavement unless a grinding operation is to follow the repair work. Typical finishing techniques are illustrated in Figure 14-14.

Figure 14-14 Typical Finishing Techniques for Full-depth Repairs



14-2.16 Curing.

There are many ways to cure concrete. Wet burlap (with or without sand) or white pigmented curing membranes are commonly used for full-depth repairs. Although ponding and constant spraying are the best curing methods, it is generally not practical to do so. Use of white pigmented curing membrane is better for indication of proper coverage and minimizes heating from solar radiation on warm, sunny days. Start curing as soon as the concrete has set sufficiently and the bleed water, if any, has evaporated, but typically no later than 45 minutes after concrete finishing. In hot weather conditions, curing may need to be initiated earlier to minimize the risk of plastic-shrinkage cracking. Proper concrete curing is crucial to achieving a good repair.

14-2.17 Joint Sealing.

Seal any longitudinal or transverse joints around the perimeter of the repair area and any intermediate joints within the repair area. This reduces the entry of water, which may cause pumping and faulting, and reduces the incidence and severity of spalling along the joints. Saw, do not form, the transverse and longitudinal joint sealant reservoirs at the repair area.

14-2.17.1 Inspection of Saw Cuts.

After joint sawing for sealing purposes, inspect the saw cuts for spalling. Repair spalls that extend more than 0.25 inch (6 millimeters) horizontally from the sidewall of the saw cuts. Patch void areas caused by honeycombing of the concrete to provide a solid joint sidewall for the sealant to bond.

14-2.17.2 Cleaning Joints.

Following the sawing operation, clean the joint by sandblasting to remove laitance, sawing dust, and other foreign debris from the joint sidewalls and from the pavement surface adjacent to the joint to a width of approximately 1 to 2 inches (25 to 50 millimeters). A multiple-pass technique has proven very successful in removing foreign debris. When using the multiple-pass technique, the nozzle is directed at one of the joint faces and that face is sandblasted the entire length of the slab. After one face has been completed, the nozzle is directed at the other joint face and it is sandblasted for the entire length of the slab. The pavement surface adjacent to the joint is then sandblasted to remove all surface debris. If water-blasting is used instead of sandblasting, employ a multiple-pass technique and dry the joints before starting the sealing operation. Cleaning the joint is one of the most important steps in obtaining high-quality sealed joints. If the joints are not clean and dry before the sealant is installed, the sealant will usually prematurely fail.

After the joint has been cleaned by sandblasting, clean it again with compressed air to remove any remaining sand or dust. However, complete the final air cleaning of the joint immediately before sealing to prevent sand and dust from blowing back into the joint. A vacuum sweeper can be used to clean around the joints, which will help reduce the amount of debris that blows back into the joints.

14-2.17.3 Installing Backer Rod.

After the joint is cleaned, install the backer rod or separating material. Do not leave the backer materials in the joint for an extended period of time before sealing. These materials may work loose and move up or down in the joint or may even come completely out. Do not twist, stretch, or otherwise damage these materials when they are installed in the joint. Damaging the backer material can cause sealant failure or a poor-quality finished product. Inspect the backer rod or separating material after installation to ensure it has been placed at the proper depth and has not been damaged. After installation of the backer or separating material, the joint is ready for the sealant material. However, seal the joint only if all steps have been properly performed.

14-2.17.4 Sealant Specifications.

Special considerations for the sealant material are jet fuel and jet blast resistance. The full-depth repair may be located in an area where fuel or lubricating or hydraulic fluid spillage may occur or in an area subjected to high temperature from jet blast or exhaust from APUs. Provide and use sealant material that conforms to UFGS 32 01 19 or to ASTM specifications designated for joint and crack sealants for use in these areas.

14-3 PRECAUTIONS.

Comply with the following precautions when performing full-depth repairs:

- Avoid undercutting spalled areas at bottom of remaining existing slab; saw back into adjacent slab until sound concrete is encountered.
- Avoid damaging remaining concrete when lifting out damaged concrete pieces.
- Keep repair areas dry before concrete application.
- Ensure dowel bars are properly aligned.

Although not a common practice for roadway full-depth repairs, consider reinforcement (about 0.2 percent of the cross-sectional area) along the long direction of the full-depth patch at the mid-width location for airfield applications. The reinforcement will keep any crack that may develop tight.

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CHAPTER 15 CONCRETE PAVEMENT SLAB JACKING

15-1 INTRODUCTION.

The purpose of slab jacking is to raise one or several adjacent slabs in place permanently as a result of settlement of the support under the pavement. Concrete pavement settlements sometimes occur in areas of poor foundation support. Such settlements not only provide riding discomfort, they also can create large stresses in the slab that can lead to cracking and shattered slabs.

Caution: Slab jacking involves injection of a grout or polyurethane foam under the settled slab and raising the slabs slowly under pressure to the desired elevation. Use only experienced contractors to perform the slab jacking work due to the complexity and specialized equipment required for the work. The risk of over-stressing the slab being raised is high if the work is not performed with care. Slab jacking is not recommended for repairing faulted joints. Correct faulted joints using a combination of subsealing and diamond grinding of the faulting. Subsealing is also called slab sealing, slabsealing, slab subsealing, slab stabilization, undersealing, and pavement grouting.

15-2 NEED FOR SLAB JACKING.

Consider slab jacking for any condition that has resulted in slab settlement, such as embankment settlement, settlement of approach slabs, settlement over culverts or utility cuts, voids under the pavements, differences in elevation of adjacent pavements, and pavement slabs that rock under traffic.

The effectiveness of slab jacking is highly dependent on closely monitoring the amount of lift being performed at any one location. It is very important that the slab not be lifted more than 0.25 inch (6 millimeters) at a time to prevent the development of excessive stresses in the slab. Care is required to get the slab to initially move as the grout applied under pressure can cause the slab to move unexpectedly and more than intended. Where careful monitoring during the uplift has been conducted, slab jacking has been effective at leveling out isolated depressed areas

15-3 SLAB JACKING GROUT MATERIALS.

A variety of grout materials have been successfully used for slab jacking and subsealing (Chapter 16). These materials include the following:

15-3.1 Cement-Fly Ash Grout.

The grout typically consists of one part portland cement (typically Type I or Type II cement) three parts Class F or Class C fly ash, three to seven parts fine aggregates, water in sufficient amount to produce the desired consistency, and wetting agents or other additives may also be used to increase the flowability. The use of a wetting agent

lubricates the grout, permitting runs of up to 6 feet (1.8 meters). It also tends to reduce “pyramiding.” (A stiff grout may form a pyramid under the slab, leaving unfilled cavities.)

Use a repeated and consistent method of proportioning the grout mixture to ensure uniform consistency. The proper consistency to be used for any given condition is best determined by experience. Generally, a mix of stiff consistency is used to raise the pavement slabs. Check the consistency by a flow cone (CRD-C-611, *Test Method for Flow of Grout Mixtures (Flow-Cone Method)*, ASTM C939, *Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)*) at least twice each day. Typical flow-cone times vary between 16 to 30 seconds, depending on the type of materials used in the grout mix. Specify strength requirements of the grout mixture consistent with the location of the grout and the design loads on the pavement. A common requirement is 600 psi (4,134 kilopascals) at seven days as determined by ASTM C39, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*. The grout mixing equipment is shown in Figure 15-1.

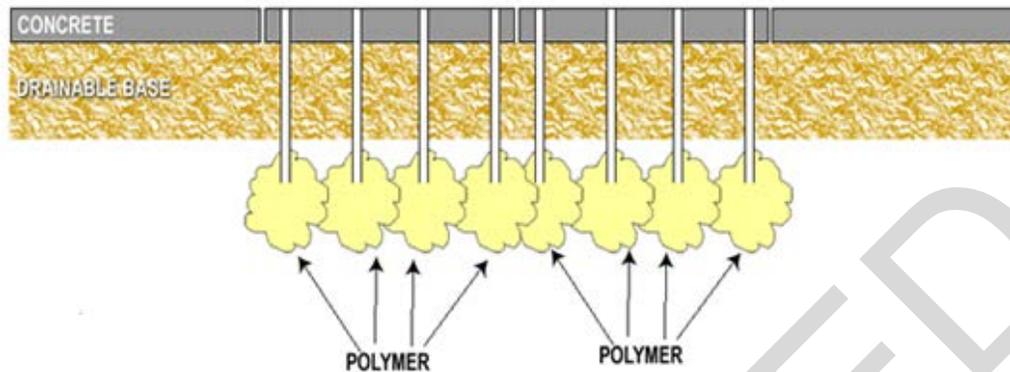
Figure 15-1 Grout Mixing Equipment



15-3.2 High-density Polyurethane Polymer Deep Injection.

High-density polyurethane polymer materials are made of two specially formulated liquid chemicals that combine to form a strong, light-weight, foam-like substance. After being injected beneath the pavement into the soil mass, the low-viscosity polymer flows into the voids and weak zones in the soil mass. As the polymeric reaction occurs, the expanding polymer compacts the surrounding soils (Figure 15-2). As more polymer material is injected, the compacted soil mass lifts upwards and raises the profile of the settled slab. The polymer injection process is controlled to ensure the desired uplift of the slab. Because of the complexity of the operation, only use a qualified contractor to perform this process. When using this process, store, proportion, and blend all material within a self-contained pumping unit. Handle and use these materials in accordance with the material manufacturer’s instructions and specifications.

Figure 15-2 The Polymer Deep Injection Process



In this chapter, only the generic process using the cement-fly ash grout is presented. Information on the polymer injection process is not presented here because of the proprietary nature of the process. Information can be obtained from contractors on a project-by-project basis.

15-4 INJECTION HOLE LOCATIONS.

Identify the location of injection holes in the field. The slab jacking crew superintendent normally locates the holes, taking into consideration the size or length of the pavement area to be raised, the elevation differences, subgrade and drainage conditions, location of joints or cracks, and the manner in which the slabs will be tilted or raised.

As a general rule, do not place holes less than 12 inches (300 millimeters) or more than 18 inches (450 millimeters) from a transverse joint or slab edge. Do not place the holes more than 6 feet (1.8 meters) center to center so that not more than approximately 25 to 30 square feet (2.33 to 2.79 square meters) of slab is raised by pumping any one hole. Additional holes may be required if the slab is cracked. Where the pavement has settled and the slabs are in contact with the subbase, a single hole located in the middle of the panel may be sufficient.

15-5 DRILLING INJECTION HOLES.

Holes that are 1.25 to 2 inches (32 to 50 millimeters) in diameter are drilled by pneumatic drills, core drills, or other devices capable of drilling grout injection holes through the concrete pavement and base material. Provide and use equipment that is in good condition and operated in such a manner that the holes are vertical and round. Do not exceed 200 psi (1,379 kilopascals) of down-feed pressure. Where the concrete pavement is tight against the base material, the use of an airline or blow pipe may be necessary to form a cavity under the pavement slab for the grout pressure to take effect.

Where the pavement is placed and bonded to a cement-treated or other stabilized base material, drill grout holes completely through the base material. Inject

the grout below the base material rather than between the pavement and base material. Do not leave grout holes ungrouted overnight and grout holes within four hours.

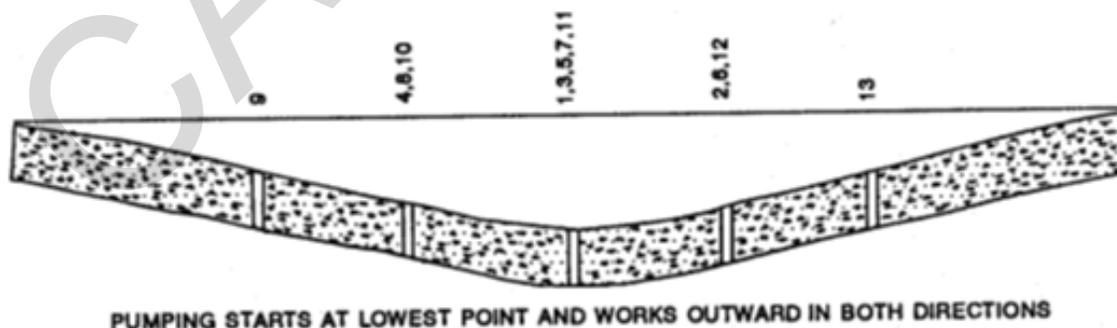
15-6 GROUT PUMPING.

Start pumping and jacking operations at the lowest point in a depressed area and work outward in both directions (Figure 15-3). Pumping progresses by lowering into successive holes an injection pipe connected to the discharge hose of the grout pump. An expanding rubber packer is used to seal the open space between the pipe and the drill hole. Do not extend the injection pipe below the bottom of the pavement. Provide and use an injection pipe equipped with a return line to circulate the grout while no grout is being placed. Lift in increments of about 0.25 inch (6 millimeters), with frequent changes in injection locations to minimize slab stresses and avoid cracking.

Use a rate of grout injection that is uniform and as slow as possible, usually a minimum of 0.5 cubic foot (0.014 cubic meter) per minute to a maximum of 2 cubic feet (0.056 cubic meter) per minute. Initial pumping is normally at the lower rate and is increased as lifting progresses. As the desired elevation is approached, reduce the lifting rate. When grout is extruded from joints, cracks, or from the pavement edge before the target elevation is reached, regrouting in new drill holes and additional slab jacking will be necessary. Applied pressures for slab jacking are normally in the range of 75 to 200 psi (517 to 1,379 kilopascals), with short pressure surges up to 600 psi (4,134 kilopascals) to initiate lifting of bonded slabs.

Constant observation and monitoring of the applied pressure is the most important single factor affecting the successful application of slab jacking. A rapid increase in the applied pressure can signal a stoppage of flow that could be followed by excessive lifting of the slab and slab cracking if pumping continues. A sudden reduction of pressure could indicate a loss of lift due to subsurface leakage of the grout.

Figure 15-3 Grout Pumping

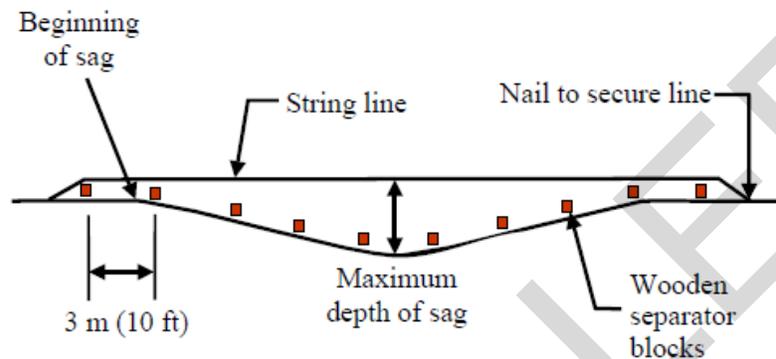


15-7 ELEVATION CONTROL DURING SLAB JACKING.

Before slab jacking operations are started, establish a method of controlling the amount the slab is to be raised and establish the finished elevation of the pavement. For short dips up to approximately 50 feet (18.3 meters) in length, a tight stringline is adequate,

provided the joints are true and plane with those of the adjacent pavement (Figure 15-4). For dips in excess of 50 feet (18.3 meters) in length, use an engineer's level and rod or a laser-based elevation control system to check the profile well beyond the dip; this will avoid building a localized bulge into the pavement.

Figure 15-4 Elevation Control

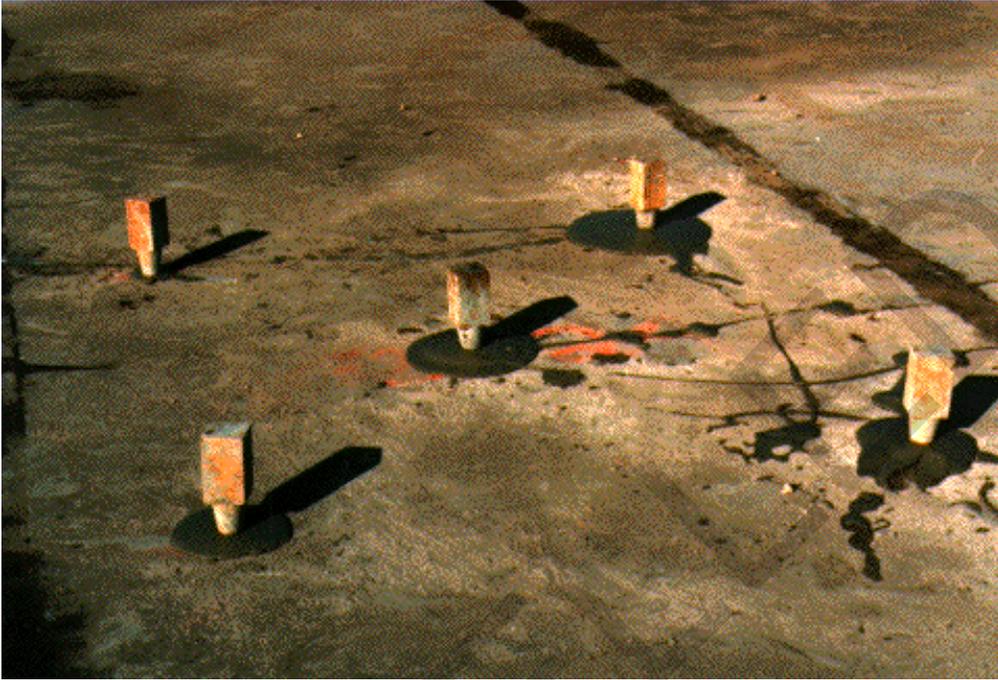


15-8 PLUGGING AND CLEANUP.

After completing slab jacking at a hole and the discharge pipe is removed, plug the hole immediately. Place temporary tapered wooden plugs into the injection hole to retain the grout pressure and stop any mixture return flow (Figure 15-5). Once the slab is jacked to the desired elevation, the temporary plugs are removed and the injection holes are filled with a stiff one-part-water, three-part-cement grout, or an approved concrete mixture, or a proprietary patching product. These areas are then finished flush with the existing pavement surface. Keep surfaces adjacent to the grouting operation clean of excess grout and other materials. Broom and wash off grout on the pavement to avoid unsightly discoloration and to remove the grout before it bonds to the concrete surface.

Caution: The primary concern with slab jacking is excessive raising of the slab, which can induce stress concentrations in the slab and produce cracking. Therefore, it is critical to raise the slab slowly and no more than 0.25 inch (6 millimeters) at a time when pumping grout at each hole.

Figure 15-5 Temporary Plugs



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CHAPTER 16 SUBSEALING JOINTED CONCRETE PAVEMENTS

16-1 INTRODUCTION.

The purpose of subsealing is to stabilize the pavement slab by restoring support under the slab, typically at joint and crack locations. Subsealing is also called slab sealing, slabsealing, slab subsealing, slab undersealing, slab stabilization, undersealing, and pavement grouting. Pumping at joints and cracks with subsequent loss of support under the slab can occur beneath concrete pavements due to the presence of an erodible base or subbase, presence of moisture under the pavement, or significant slab deflections due to heavy traffic loadings.

Poor support conditions can lead to joint or crack faulting and corner breaks. Loss of support (voids) is indicated by signs of pumping at joints or by means of nondestructive deflection testing at joints. Subsealing involves the injection of a cementitious grout through holes drilled in the slab. The cementitious grout will, without raising the slab, fill the voids under it, displace water from the voids, and reduce the damaging pumping action caused by excessive pavement deflections. Subsealing reduces deflections at joints and cracks and retards the development of additional pavement deterioration.

16-2 NEED FOR SUBSEALING.

For jointed concrete pavement, accomplish subsealing as soon as significant loss of support is detected at slab corners. Symptoms of loss of support include increased deflections under vehicular loading, transverse joint faulting, corner breaks, and the accumulation of fines in or near joints or cracks on traffic lanes or shoulders. Consider subsealing at all existing repairs that show evidence of pumping or settlement. To be effective, perform subsealing before the voids become so large that they cause pavement failure.

Caution: To be most effective, it is important that slab undersealing be performed prior to the onset of pavement damage due to loss of support. Also, before considering undersealing of the slabs exhibiting loss of support, it is important that the cause(s) of the condition that led to the slab loss of support be addressed. This may require improving subsurface drainage conditions and/or restoration of load transfer at joints and cracks. Undersealing slabs where loss of support does not exist may be detrimental to pavement performance.

16-3 PAVEMENT SUBSEALING KEY STEPS.

The key steps for effective undersealing include the following:

1. Void (loss of support) detection
2. Selecting the grout material
3. Establishing the grout hole pattern

4. Drilling holes
5. Grout injection
6. Testing effectiveness of grouting
7. Grinding, if necessary, to restore profile at affected joint and crack location

16-4 SUBSEALING GROUT MATERIALS.

A variety of grout materials have been successfully used for slab jacking and subsealing. These materials are described in paragraph 15-3. The difference between slab jacking and subsealing is that when subsealing, the cementitious or polymer injection process is stopped at the point where all voids are filled to ensure there is no raising of the slab.

16-4.1 Polyurethane Polymer Subsealing.

The application of high-density polyurethane polymer material is similar to the application using cementitious grout. The polymer is injected directly into the void under the slab so as to fill the void with the high-density polymer foam (Figure 16-1).

Figure 16-1 Polymer Subsealing Process



In this chapter, only the generic processes using the cement-fly ash grout and polymer foam to directly fill the voids are presented. Information on the polymer deep injection process is not presented here because of the proprietary nature of the process. Information can be obtained from contractors on a project-by-project basis. Also note that in the past, asphaltic materials were used to underseal concrete pavements. This practice is no longer widely used and therefore not discussed.

16-5 VOID DETECTION.

Conduct a comprehensive survey to determine void locations beneath concrete pavement. Take void detection measurements during the preliminary evaluation and the repair process. Void detection can be a complicated process as natural wetting and

drying cycles and thermal variations can cause slab curling. Interpretation of field conditions by experienced personnel is always desirable. Suggested methods follow.

16-5.1 Visual Inspection.

The simplest method is a visual inspection of the pavement to locate areas of distress. The presence of ejected subgrade or base material, staining of pavement surfaces adjacent to joints, excessive vertical movement at joints or cracks under traffic, and faulting of joints are evidence of possible voids under the slab.

16-5.2 Proof Rolling.

A common method of determining the presence of voids is called “proof rolling.” In this procedure a heavily loaded vehicle (minimum 18,000-pound [80-kilonewton] axle load) drives slowly over a transverse joint while observing deflection of the slabs. If deflection is visually observed, under-seal the joint. Deflections during proof rolling can be measured by devices equipped with sensitive dial gauges that contact the pavement. Gauges are attached to a firm base located off the pavement or at a sufficient distance from the test locations. The dial gauges are read visually or recorded electronically. Under-seal any slab showing deflection in excess of 0.015 inch (0.38 millimeter).

16-5.3 Nondestructive Deflection Testing.

On large critical projects, the most effective method to locate voids under the pavement slab is the falling-weight deflectometer (FWD). The device measures deflections at a joint under several load levels and the deflection data is analyzed to determine the extent of void at the test location (Figure 16-2).

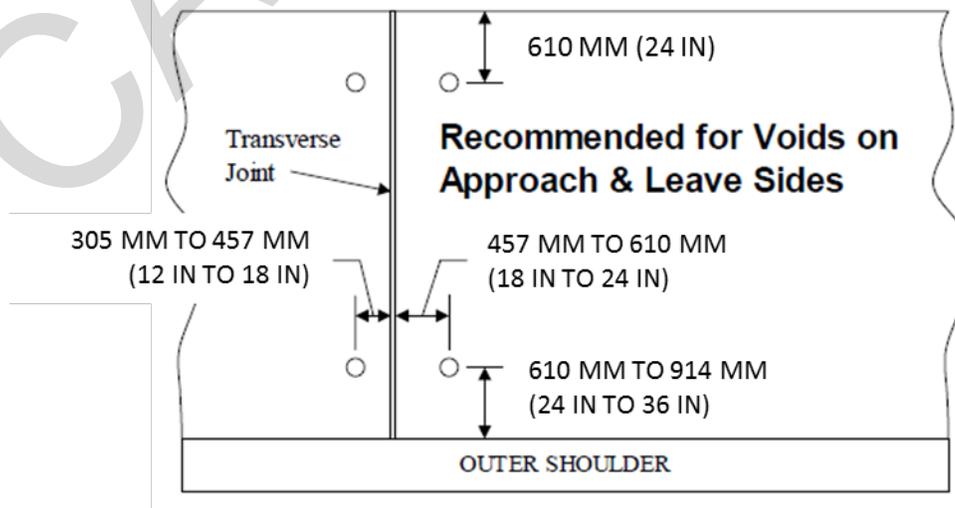
Figure 16-2 Falling Weight Deflectometer



16-6 INJECTION HOLE LOCATIONS.

Subsealing injection hole locations are similar to slab jacking (paragraph 15-4), the exception being to locate subsealing at pavement joints where the most common hole pattern is a four-hole pattern with two holes on each side of a transverse joint. The holes are located in the wheel tracks, with the approach slab holes nearer the joint than the leave slab holes. Typical distances from the joint are 12 to 18 inches (305 to 457 millimeters) for the approach slab and 18 to 24 inches (457 to 610 millimeters) for the leave slab (Figure 16-3). It is noted that in some cases the slab undersealing may be needed only on the leave (exhibiting void) side of the joint. Also, additional holes may be required for voids under the longitudinal joints or along the shoulder edge.

Figure 16-3 Four-hole Pattern at Joint for Grout Injection



16-7 DRILLING HOLES.

Drilling holes is identical to paragraph 15-5.

16-8 GROUT INJECTION.

Grout injection proceeds by lowering into successive holes a pipe connected to the discharge hose of the grout pump. The grout hole is sealed by a device called a packer. Two types are commonly used, as described below. The drive packer consists of a tapered pipe tapped into and out of the grout hole. Drive packers are used with 1-inch (25-millimeter) -diameter holes, and the expanding rubber packer consists of a threaded inner pipe, a thin-walled steel outer sleeve, and a short rubber sleeve at the bottom. This type of packer is used with 1.5-inch (33-millimeter) -diameter and larger holes.

Monitor movement (uplift) of the slabs during the grouting operation. To properly monitor movement of the slabs, gauges capable of reading movement of 0.001 inch (0.025 millimeter) must be used. Place the base for the gauge 3 to 4 feet (0.91 to 1.22 meters) off the slab being monitored. The gauges are set up at the joint corner locations and are not moved until grouting of the joint is completed. Typical pumping pressure are in the range of 40 to 60 psi (275 to 413 kilopascals) range. Always start grout injection with a low pumping rate and pressure. Stop pumping if the slab begins to rise or when no material is being injected at the maximum allowable pressure of 100 psi (689 kilopascals). Pumping of short surges up to 200 psi (1,378 kilopascals) are allowable for the grout to penetrate the void structure. If grout returns through an adjacent hole, stop pumping and insert the packer into another hole. If water or diluted grout is observed flowing from joints or cracks in the pavement, continue pumping until undiluted grout is observed.

Generally, when pumping the four-hole pattern at a joint, begin pumping first at the centerline and then continue with the holes closest to the shoulder. This sequence will drive any trapped water to the outside of the slab and through the transverse and shoulder joints. Where there is also void along the shoulder and extra holes are required, the sequence of grout injection becomes more complicated. Usually, the shoulder joint locations are pumped last.

Caution: To ensure that the slab is not raised, place straightedges with gauges attached over the slab to measure any upward movement of the slab. At the first indication of movement, stop the grout-injecting procedure. If the slab is raised, high slab stresses may develop, leading to slab cracking.

16-9 RETESTING SLAB CORNERS.

After a minimum of 24 hours has elapsed following completion of subsealing, test the grouted slabs for stability at the same points as previously tested. Conduct this testing using the same procedure used for the pre-grouting test. Include other joints that were not grouted in this test for use as a control. If loss of support still exists after grouting, re-grout the slab. In each regrouting, new holes will be needed. It is recommended that

if voids are still present after three attempts to stabilize the slab, do not attempt any further regrouting and consider other repair methods such as full-depth repair in lieu of regrouting.

16-10 PLUGGING AND CLEANUP.

Plugging and cleanup is identical to paragraph 15-8.

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CHAPTER 17 PCC PAVEMENT DIAMOND GRINDING

17-1 INTRODUCTION.

Diamond grinding, using closely spaced diamond saw blades mounted on a rotating shaft, removes a thin layer of the concrete surface to correct for faults at joints and crack locations and correct for surface defects, such as wheel path rutting. Diamond grinding results in re-profiling the pavement and improves the pavement's ride quality.

Note that diamond grinding is a different process than diamond grooving. Diamond grooving is a process in which parallel grooves in the transverse direction are cut into new airfield runway pavements using diamond saw blades with a typical center-to-center blade spacing of 0.75 inch (19 millimeters). The principal objective of grooving is to provide escape channels for surface water, thereby reducing the incidence of hydroplaning that can cause wet weather crashes. Diamond grooving is typically not used for roadway pavements except at sharp curves.

17-2 NEED FOR GRINDING.

Consider diamond grinding when a pavement survey reveals surface defects such as faulted joints and cracks in excess of 0.125 inch (3 millimeters), roughness in excess of 0.125 inch (3 millimeters) in a 10-foot (3-meter) length, or rutting up to 0.375 inch (10 millimeters). If skid resistance is to be examined, examine it on the areas not scheduled for grinding for any of the previously mentioned defects. If a large area requires grinding to improve skid resistance, economics may favor grinding the entire pavement surface.

Caution: Note that diamond grinding primarily improves the pavement's ride quality and does not directly improve the structural condition of the pavement. Diamond grinding is frequently used in combination with other concrete pavement repair techniques that improve the structural condition of the pavement. Diamond grinding may not be effective over the long term if the pavement exhibits significant deterioration or if causes of faulting are not addressed. Do not consider diamond grinding for pavements exhibiting concrete materials-related distress, such as D-cracking and ASR. Perform any partial-depth and full-depth patching before grinding.

17-3 GRINDING PROCESS.

The diamond grinding process is free of impact and does not damage joints. The pavement grinder is similar to a wood plane. The front wheels are designed to pass over a fault or bump, the cutting head shaves off the fault or bump, and the rear wheels ride in a smooth path left by the cutting head.

Diamond grinding requires heavy, specially designed equipment (Figure 17-1) that uses diamond saw blades gang-mounted on a cutting head (Figure 17-2). Spacers are placed between the saw blades to reduce the amount of cutting to be done. This

combination of saw blades and spacers gives the pavement the characteristic corduroy texture that also improves skid resistance (Figure 17-3).

Because the hardness of the aggregate will influence the grinding operation, identify the type of aggregate in the PCC pavement when contracting the work. Grinding a pavement with extremely hard aggregate (such as trap rock, river gravel, or quartzite) takes more time and effort than grinding a pavement with a softer aggregate (such as limestone) and will cost more.

Figure 17-1 Grinding Equipment



Figure 17-2 Gang-mounted Diamond Saw Blades

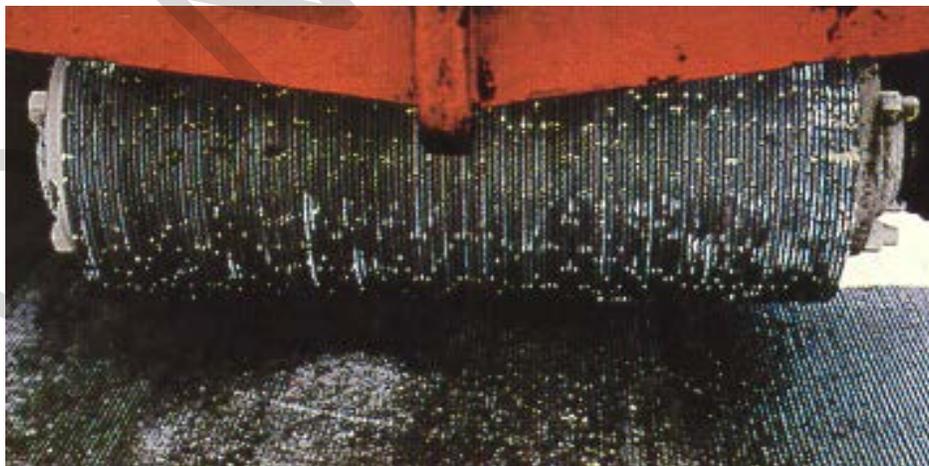
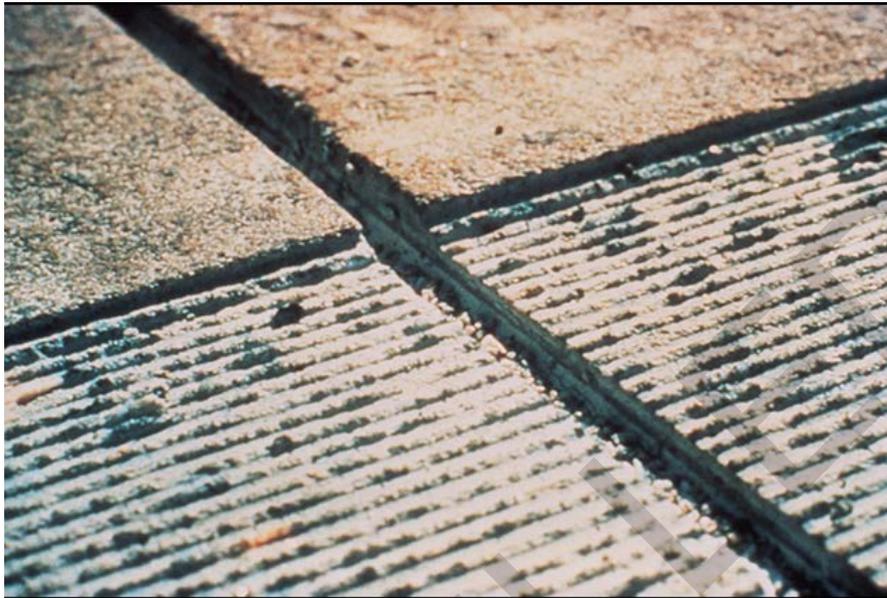


Figure 17-3 Diamond-ground Surface



17-4 TEST SECTION.

Before work begins, test the equipment on a small section of the pavement to ensure that proper blade spacing is being used for the specific aggregate on the project. The width of the spacers between the saw blades is varied depending on the hardness of the aggregates. Use a thinner (smaller) spacing between the blades with harder aggregate. As the diamond grinding head cuts the surface of the pavement, thin fins of concrete are left between the cutting blades. These fins typically break off during the grinding process. If these fins do not break off, use a grinding head with thinner spacers. When grinding aggregate susceptible to polishing, provide more area between the blades.

Use a fin depth (land area thickness) measured at the thickest point of 0.08-inch (2-millimeter) minimum and have an average thickness of 0.1 inch (2.5 millimeters). For harder aggregates not subject to polishing, use a minimum fin depth of 0.065 inch (1.7 millimeters) and an average thickness of 0.08 inch (2 millimeters).

17-5 GRINDING PROCEDURE.

Grinding equipment uses diamond blades mounted in series on a cutting head. The cutting head typically has a width ranging from 48 to 50 inches (1.22 to 1.27 meter). The desired corduroy texture is produced using a spacing of 50 to 60 blades per foot (164 to 197 blades per meter). New, improved grinding machines and grinding blades have greatly increased the capability to provide extremely smooth profiles. Always start and end grinding perpendicular to the pavement centerline and consistently maintain the grinding parallel to the centerline.

The grinding and grooving operation produces slurry consisting of ground concrete and the water used to cool the blades. This slurry is picked up by onboard wet-vacuums. Continuously remove the slurry residue. Do not permit grinding slurry to flow across adjacent lanes into gutters or other drainage facilities. Dispose of grinding slurry in accordance with local environmental regulations.

The following grinding procedures are for roughness and fault removal.

17-5.1 Roughness Removal.

For areas identified as being too rough, establish a level of restoration and grind the nominated sections. Following grinding, test the roughness again. Testing is typically accomplished using equipment such as the California profilograph (Figure 17-4). Prior to grinding, establish the grade. Do not use the old pavement surface as the reference unless using a long beam or skid. Where sags in the pavement are encountered, first remove the sags by slabjacking. Grinding at a sag point will not remove roughness. Reinvestigate the pavement following slabjacking to revise the grinding requirements, if necessary.

Figure 17-4 California Profilograph



17-5.2 Fault Removal.

Prior to grinding the faulted joints (and cracks), underseal the slabs to prevent the fault from recurring. Cut in to the faulted joint during grinding to produce smoother joints and a more efficient operating surface. Feather the fault back some distance into the slab. The distance required depends on the allowable roughness. The American Concrete Pavement Association has a general guideline of 1 foot (300 millimeters) for every 0.1 inch (2.5 millimeters) of faulting. This is slightly rougher than 0.125 inch (3 millimeters) in 10 feet (3 meters). Feathering distances necessary to meet straight-edge requirements of 0.125 inch (3 millimeters) in 10 feet (3 meters) are shown in Table 17-1. If the entire slab is to be ground, feather out the depth of the cut to the next joint to remove the fault.

Table 17-1 Feathering Distances

Fault Height Inches (Millimeters)	Feathering Distance Feet (Meters)
0.125 (3)	2.5 (0.76)
0.25 (6)	5.0 (1.52)
0.375 (10)	7.5 (2.29)
0.5 (13)	10.0 (3.04)
0.625 (16)	12.5 (3.81)
0.75 (19)	14.0 (4.27)

17-5.3 Skid Resistance.

Grinding can improve skid resistance. Grind only those lanes needing treatment. Feather the edges of the ground areas into the adjoining areas to eliminate a sharp drop-off. Grind the pavement in a longitudinal direction that begins and ends at a line marked perpendicular to the pavement centerline. A successful grinding operation produces a uniformly finished surface that is free of joint or crack faults and provides positive lateral surface drainage.

17-6 ACCEPTANCE TESTING.

After completing grinding and texturing, test the pavement for smoothness. Accept only pavement which meets the surface tolerance for a new pavement as required by the specifying agency. Specify use of the same test equipment in the acceptance testing as used in the initial evaluation along with the procedures to be followed in acceptance testing. Do not reduce the thickness of the pavement through grinding by an amount that reduces the nominal load-carrying capability of the pavement without prior approval of the Pavements DWG or their designated representative.

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CHAPTER 18 CONCRETE PAVEMENT LOAD TRANSFER RESTORATION

18-1 INTRODUCTION.

New pavement joints typically exhibit good load transfer, particularly if the joints are doweled. However, repeated heavy loads over time can cause an elongation of the dowel sockets and result in dowel looseness and a reduction of load transfer efficiency. As the load transfer efficiency decreases, the load-related deflections along the joints, especially at corner locations, increase. This can accelerate the development of joint-related distresses, such as pumping, spalling, faulting, and slab corner cracking. For non-doweled concrete pavements, aggregate interlock at joints is relied upon to provide load transfer across a joint. However, under traffic loading and due to concrete drying shrinkage over time, aggregate interlock becomes less effective. If the non-doweled pavement continues to carry heavy traffic, the non-doweled joints may be good candidates for load transfer restoration (LTR).

For many years, the typical way to transfer shear at a construction joint was with a keyed joint. Many steel bulkhead forms are available with a keyed profile. However, most experts no longer recommend keyed joints since they seldom stay tight enough to provide positive shear transfer. In accordance with ACI 360R-10, *Guide to Design of Slabs-on-Ground*, the male and female components lose contact when the joint opens due to drying shrinkage, which can lead to breakdown of the joint edges and failure of the top side portion of the key.

Restoration of load transfer is used to retard further deterioration of the concrete pavement by reducing the potential for joint-related distresses. Restoration of load transfer can improve pavement performance by reducing pumping, faulting, and corner breaks, and also by retarding the deterioration of transverse cracks. In most instances, the pumping and faulting distresses can be corrected by installing joint load transfer devices. Diamond-grinding the pavement surface is often done in conjunction with LTR to restore rideability.

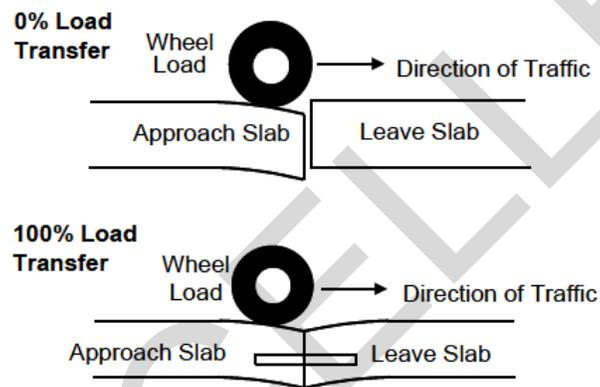
Caution: LTR is not used for heavily trafficked airfield concrete pavements. The shear stresses caused by the heavy loading may be greater than the bond strength between the slot patch material and the existing concrete. This can cause dowel bars in the slots to break out of the slots under repeated aircraft loadings.

18-2 NEED FOR LOAD TRANSFER RESTORATION.

Transverse joints or cracks that would benefit from improved load transfer can be identified by measuring the existing load transfer efficiency using a nondestructive deflection testing device such as the FWD. Conduct these tests during periods of cooler temperatures (less than about 80 degrees F [27 degrees C]) when the slab joints and cracks are not tightly closed. Consider LTR for joints or cracks having a measured load transfer efficiency (ratio of the deflection on the unloaded side of a joint or crack divided by the deflection of the loaded side) of less than 50 percent.

For thicker airfield pavements being considered for LTR, use the heavier version of the FWD, commonly called the heavy weight deflectometer (HWD). The HWD can apply loading up to 50,000 pounds-force (222 kilonewtons) that better simulates the loading of the heavier aircraft. For concrete pavements 12 inches (300 millimeters) or less in thickness, a standard FWD meets the testing needs and test loads of up to 20,000 pounds-force (89 kilonewtons) can be applied. The concept of load transfer at a joint is illustrated in Figure 18-1. Take deflection measurements as near as possible to the joint or crack. Take deflection measurements in the center of the load plate, positioned tangentially along the joint, and at 12 inches (300 millimeters) across the joint (from the center of the load plate).

Figure 18-1 Load Transfer at a Joint



18-3 LOAD TRANSFER RESTORATION (LTR) KEY STEPS.

The key steps in performing LTR include the following:

1. Correct causes of poor load transfer
2. Create slots at the joints being treated by saw-cutting and chipping concrete
3. Place load transfer devices, typically dowel bars, into the slots and properly align the bars
4. Use compressible inserts
5. Place repair material into the slots, ensuring good coverage under the dowel bars
6. Restore the joint at the slot locations and seal the joints
7. Grind at joint locations or over the full pavement width and length to improve ride quality

18-4 CORRECTION OF DEFICIENCIES.

Before load transfer devices are installed, it is necessary to determine the cause of the joint or crack distress. Attempt to correct the cause(s) of these deficiencies prior to LTR. Slabs exhibiting extensive distress along a joint may require portions of or the entire slab to be replaced. Also, successful installation of load transfer devices requires sound concrete adjacent to the joint or crack. If the concrete near the joint or crack is significantly deteriorated, perform full-depth repair (with provisions for load transfer) in lieu of LTR. Perform the following additional work if required prior to LTR. Subsealing (essential if loss of support exists) to fill voids in the pavement structure and to restore support to the pavement slabs, and full-depth and spall repairs to replace highly distressed joints and slabs with corner breaks, “D” cracking, etc.

18-5 DOWEL LOAD TRANSFER RESTORATION (LTR) PROCESS.

Installing round dowel bars is the primary method of restoring load transfer at existing joints or cracks. In the past, use of proprietary devices was attempted but has fallen out of favor because of cost and uneven performance in the field. Field experience indicates that round dowel bars can effectively transfer loads across joints and cracks.

18-5.1 Dowel Size Requirement.

Specify different size dowels for different thicknesses of pavements. Dowel size and spacing for construction, contraction, and expansion joints are shown in Table 18-1.

Table 18-1 Dowel Size Requirements

Pavement Thickness, inches (millimeters)	Dowel Length, inches (millimeters)	Dowel Spacing, inches (millimeters)	Dowel Bar Diameter, inches (millimeters)
8 to 11.5 (200 - 290)	16 (400)	12 (300)	1 (25)
12 to 15.5 (300 -395)	18 (450)	15 (380)	1.25 (32)
16 to 20.5 (400 - 520)	20 (500)	18 (450)	1.5 (38)
21 to 21.5 (530 - 550)	24 (600)	18 (450)	2 (50)
>26 (660)	30 (762)	18 (450)	3 (75)

For roadway pavements, four dowel bars are typically used for each wheel path. The bars are typically spaced at 12 inches (300 millimeters).

18-5.2 Cutting Slots for Dowel Installation.

Slots for installing dowels are cut using diamond-blade saws. Gang-mounted multiple blade saws are recommended to speed operations (Figure 18-2). Cut the slots so the

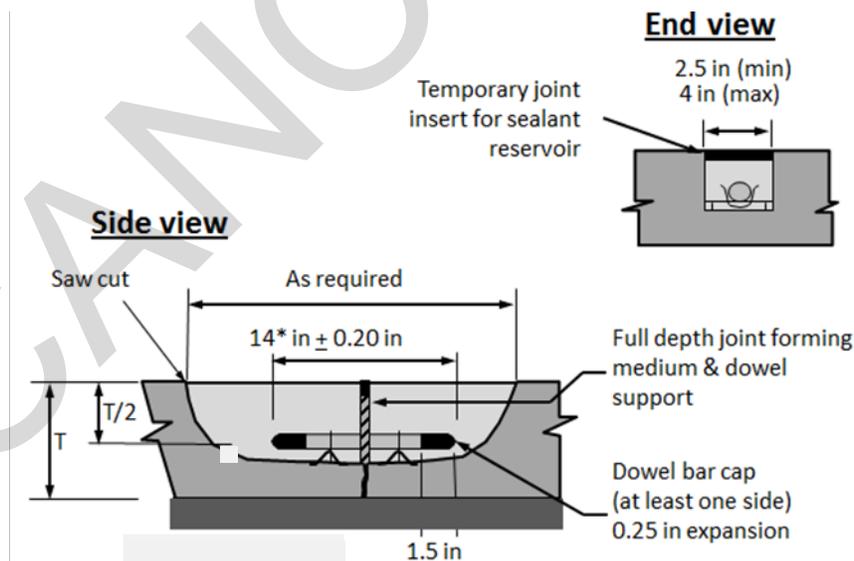
dowels can be placed horizontally parallel to the pavement surface, perpendicular to the joint, and at mid-depth of the slab (Figure 18-3).

Figure 18-2 Gang-Mounted Multiple Saw Blades for Slot Cuts



Where slab movement at the crack/joint location is required, cut slots to allow dowel placement parallel to the pavement surface at mid-depth and perpendicular to the orientation of the crack/joint.

Figure 18-3 Dowel Placement in Slot



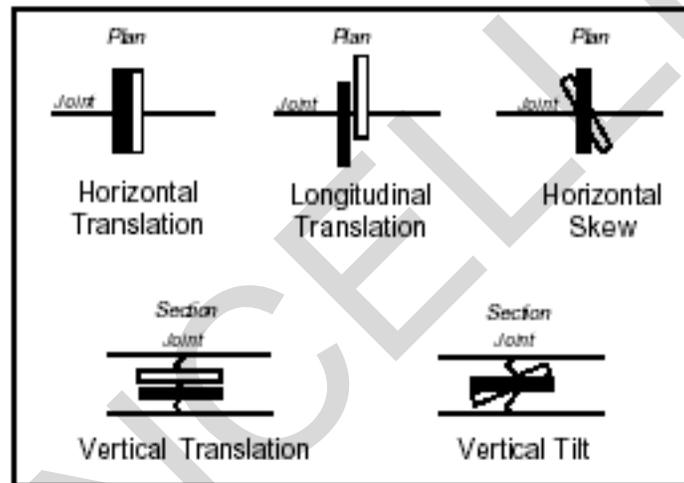
* Actual dowel bar length is dependent on design load

Take care to ensure the dowel bars are correctly aligned in the slots. Poor dowel alignment, as shown in Figure 18-4, can cause joint locking (or a working crack), spalling in the patch material, and poor load transfer efficiency.

Figure 18-4 Types of Dowel Bar Misalignment and Effect on Performance

Type of Misalignment	Effect on Spalling	Cracking	Load Transfer
Horizontal Translation	—	—	yes
Longitudinal Translation	—	—	yes
Vertical Translation	yes	—	yes
Horizontal Skew	yes	yes	yes
Vertical Tilt	yes	yes	yes

Categories of dowel misalignment are illustrated below.



Misalignment categories.

18-5.3 Concrete Removal & Dowel Installation.

Light-weight (10 to 17 pounds [4.5 to 7.7 kilograms]) chipping hammers are used to remove the concrete within the saw cuts (Figure 18-5). Take care not to punch through the slot bottom. The slot is then cleaned by sandblasting or any method that will ensure removal of all sawing residue, dirt, or oil that may prevent bonding of the patch material to the slot faces.

Figure 18-5 Use of Chipping Hammers to Remove Concrete



Each dowel is placed upon a support chair to allow the patch material to surround the dowel. One end of the dowel is oiled and painted and an expansion cap placed at the end of the dowel bars (Figure 18-6). Provide and use the dowels with a filler board or Styrofoam material at mid-length to prevent intrusion of the patch material into the joint or crack (causing point bearing and compression failure during warm weather) and to form the joint in the slot (Figure 18-6).

Before installing the dowel bar, caulk the perimeter of the joint within each slot to prevent the intrusion of the patch material into the joint (Figure 18-6).

Figure 18-6 Use of Compressible Insert



18-5.4 Patching Material.

High early-strength concrete or proprietary cementitious materials extended with small-sized aggregate have been used to fill the slot at most installations to date. The patch material used with load transfer devices is a critical factor in performing this technique. It is necessary to ensure there is thermal compatibility between the patch material and the existing concrete; therefore, use aggregates in the patch material that have a coefficient of thermal expansion (CTE) property similar to that of the aggregates used in the existing concrete.

It is important that a laboratory evaluation be made of any patch material utilized for patching the slots. Evaluate the following key factors: working time, rapid early-strength gain, thermal compatibility with existing concrete, and shrinkage property.

18-5.5 Placing Patch Material.

After properly cleaning the patch area, apply a bonding agent if required by the patching material manufacturer. The type of bonding agent depends on the bond development requirements for opening to traffic and type of patching material used. Follow the manufacturer's recommendations with all patching materials. Use bonding agents recommended by the manufacturer for the placement conditions. Bonding agents or grouts may not be needed when using high-early-strength concrete.

Place and consolidate the patch material to eliminate all voids at the interface of the patch and the existing concrete and at the load transfer device and the patch material (Figure 18-7). Each slot requires two to four short, vertical penetrations of a small-diameter spud vibrator. Place the patch material flush with the adjacent concrete and take care to prevent intrusion of the patch material into the adjacent joint areas. However, the patch material is finished slightly "humped" (no more than 0.125 inch [3.175 millimeters]) if diamond grinding is to be employed.

Figure 18-7 Placing and Consolidating Patch Material



After consolidation and finishing, place a curing compound on the patching material to minimize rapid patch material shrinkage. Depending upon the type of repair material, the pavement may be opened to traffic in as little as a few hours. The minimum compressive strength required to open a repair to traffic is about 2,000 psi (13.7 megapascals) for slabs 8 inches (200 millimeters) or thicker.

18-5.6 Finishing Activities.

LTR may result in increased roughness at joint locations if the patch materials are not properly finished. This is typically due to differences in elevation between the finished repair area and the existing pavement, or perhaps due to shrinkage or settlement of the repair material. Consequently, the joint locations or the entire pavement project being rehabilitated is often diamond-ground to provide a smooth-riding surface. Complete grinding as soon as is feasible after the patch material has attained the specified strength, typically 4,000 psi (27.4 megapascals) compressive strength.

After the patch material has cured and the surface diamond-ground, re-establish the transverse joint at the affected joints by sawing over the length of the joints and through the filler board then prepare and seal the joint.

18-6 KEYED JOINTS LOAD TRANSFER RESTORATION PROCESS.

Although not recommended for new construction, keyed construction joints (Figure 18-8) are still found in existing airfield pavements. In addition to the loss of load transfer due to shrinkage, the female keyed flanges are prone to spalling. For this reason, keyed joints are recommended to be removed and replaced with a doweled joint.

Figure 18-8 Keyed Joint



18-6.1 Keyed Joint Key Steps.

Restoration of keyed joints is identical to full-depth repair of concrete pavements (Chapter 14), with the following exceptions.

18-6.1.1 Keyed Joint Concrete Removal.

Depending on the joint stress severity, remove the complete keyed joint for the entire edge of the slab. The male end of the keyed joint needs to be removed with a concrete saw, leaving the joint flush, vertical, and ready to accept new dowels. The female end needs to be cut far enough back to allow the use of a dowel drill. This can be as much as 4 feet (1.2 meters) for the typical gang-operated concrete dowel drill (Figure 18-9).

Figure 18-9 Gang-operated Dowel Drill



18-6.1.2 Dowel Bar Placement and Installation.

Install dowels along the face where the keyed joint male end has been removed. Place and install the dowel bars in accordance with paragraph 18-5.

18-6.1.3 Tie Bar Placement and Installation.

Secure the newly cut joints other than the existing keyed joint with tie bars. Install tie bars in the same manner as the dowel bars (paragraph 14-2.10), but both ends are permanently secured.

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CHAPTER 19 CONCRETE PAVEMENT RETROFITTED EDGE DRAINAGE

19-1 INTRODUCTION.

The presence of moisture under pavement, if not removed quickly, leads to poorly performing pavement or failure. One of the most critical considerations for pavement design is how to control water entering the pavement. The primary source of water under the pavement is rainwater that infiltrates into the pavement due to poorly sealed transverse and longitudinal joints and cracks. Many older concrete pavements have non-drainable bases and subbases with no provision to quickly remove water from the pavement system. The infiltration of water through the pavement causes saturation of the base and subbase. Without drainable layers, traffic loads cause pumping at joints and crack locations. Over time, repeated traffic loading leads to a loss of support along joints and cracks, resulting in high deflections and slab cracking.

19-2 NEED FOR PAVEMENT-EDGE DRAINAGE.

- The following conditions may warrant the addition of pavement-edge drainage:
- Inadequate surface drainage facilities (shallow ditches or absence of ditches)
- Water table may rise within the pavement system
- Surface water entering the pavement system at joints or cracks, surface edges, or percolating through the shoulders
- Water in the subgrade rising vertically via capillary action

19-3 DRAINAGE SYSTEM CLASSIFICATIONS.

Pavement drainage is grouped into two major classifications: surface and subsurface. When both types are required for efficient maintenance and protection of the pavement, it is generally a good practice for each system to function independently.

19-3.1 Surface Drainage.

Surface drainage keeps surface water (rain) out of the pavement system, typically by incorporating adequate cross-slopes and longitudinal grades and properly designed and maintained ditches.

19-3.2 Subsurface Drainage.

Subsurface drainage quickly removes water that has entered the pavement system. These systems are designed so the outflow capacity is greater than the long-term maximum inflow into the pavement system. These systems may consist of drainage layers discharging to daylight or in conjunction with built-in edge drains. One way to

provide for subsurface drainage for an existing system without an effective subsurface drainage system is to retrofit edge drainage along the shoulder.

19-4 EDGE DRAINAGE REQUIREMENTS.

Edge drainage in an existing pavement is required where seasonal fluctuations of ground water are expected to rise in the subgrade water table to less than 1 foot (0.305 meter) below the bottom of the base course or seeping water in a pervious stratum will raise the ground water table to a depth of less than 1 foot (0.305 meter) below the bottom of the base course.

19-5 EDGE DRAINAGE CANDIDATES.

A good candidate project for retrofitted edge drainage is a pavement showing early signs of moisture-related damage. Additionally, projects with acceptable surface geometrics (longitudinal grades and transverse cross-slopes) and adequate depth and condition of roadside ditches are good candidates for retrofitted edge drainage.

Retrofitted edge drainage is not effective at extending the service life of concrete pavements already experiencing significant moisture-related deterioration. Concrete pavements in which the following conditions are present are poor candidates for retrofitted edge drainage:

- More than 15 percent of the slabs exhibit full-depth cracking, all of which require extensive corrective work to return the pavement to an adequate level of service
- A high number of transverse joints are spalled
- Pumping has occurred
- A cement-treated base exists that is no longer intact
- The existing base contains greater than 15 percent fines (material passing the 0.075-millimeter [No. 200] sieve). Base materials with these characteristics may be too impermeable for effective use of a retrofitted edge drainage system.

19-5.1 Edge Drainage Key Steps.

The key steps in providing retrofitted edge drainage include the following:

1. Select edge drainage system and materials
2. Locate the edge drainage
3. Dig a trench
4. Place edge drainage material (e.g., filter fabric [geotextile], perforated flexible drainage pipe [or fin drain], backfill filler material, outlet pipes)

5. Finish the surface of the edge drainage system

Note: Consider retrofitting edge drainage by itself or in combination with other repair techniques, such as full-depth repairs and dowel bar retrofit.

19-6 EDGE DRAINAGE MATERIALS.

While this chapter discusses edge drainage systems using perforated pipes, most of the steps discussed are also applicable to fin drain systems. Edge drainage systems require the following materials:

19-6.1 Drainage Pipe.

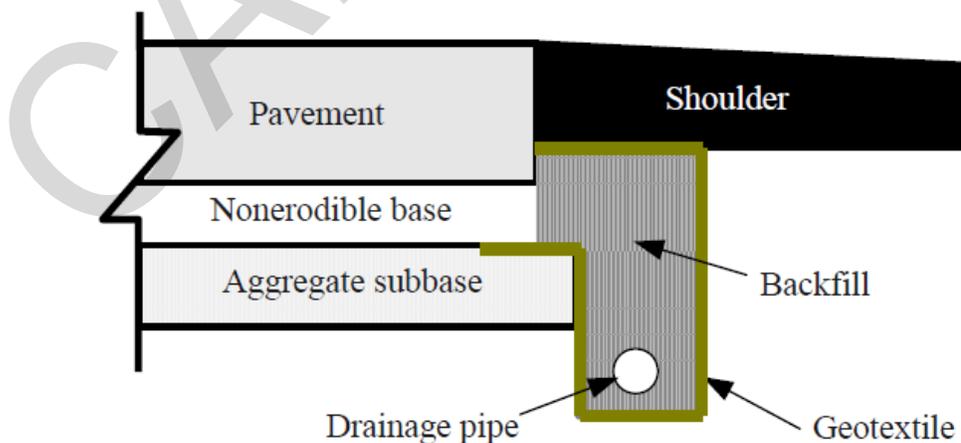
Although in the past several different types of pipe of various materials, lengths and diameters have been used in edge drainage systems, the pipe that is currently widely used is the perforated corrugated plastic pipe. These pipes are flexible. Select the type of pipe based on local requirements, such as the condition of the soil, loading and amount of cover, cost, and availability of pipe. Most highway agencies use flexible, corrugated polyethylene (CPE) adhering to AASHTO M252, *Standard Specification for Corrugated Polyethylene Drainage Pipe*.

19-6.2 Perforated Drainage Pipe.

A typical retrofitted edge drainage system is illustrated in Figure 19-1. Such an edge drainage system incorporates a perforated drainage pipe.

Aggregate trench drains (drainable aggregate material) constructed along pavement edges are not generally recommended because they have poor stability, a relatively low hydraulic capacity, and are difficult to maintain.

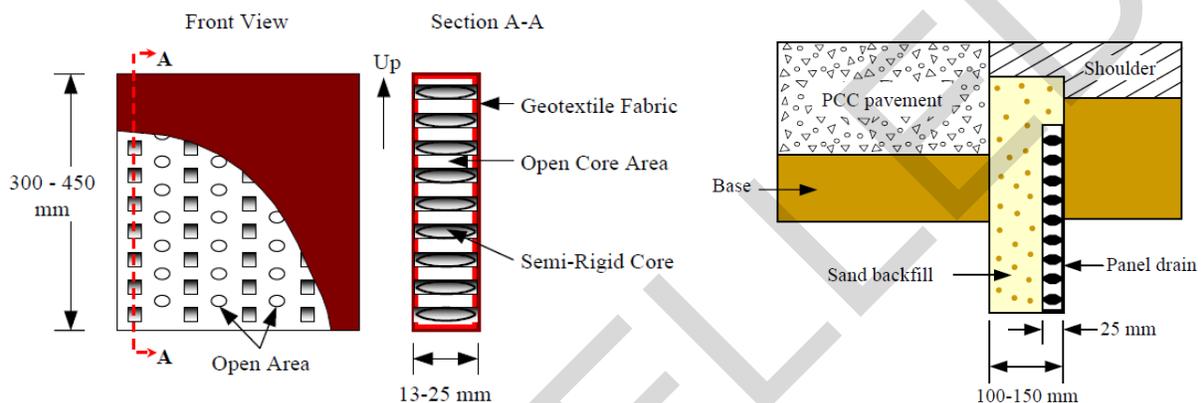
Figure 19-1 Typical Retrofitted Edge Drainage System



19-6.3 Fin Drains.

Fin (geocomposite) drains are another acceptable type of edge drainage system. This system comprises an extruded plastic drainage core wrapped with a geotextile filter. Figure 19-2 shows details of a typical geocomposite edge drain and recommended installation details. Geocomposite edge drains are typically 0.5 to 1 inch (13 to 25 millimeters) thick and manufactured in long strips coiled into rolls.

Figure 19-2 Geocomposite Edge Drain Features & Installation Details



19-6.4 Filter Material.

19-6.4.1 When possible, for economic reasons, use locally available processed sands and gravels. Use filter material that is more permeable than the material being drained. Provide and use only filter materials with a grain size curve that is smooth (no gap grading) and parallel to or flatter than that of the protected material. Standard concrete aggregates can be used as a filter, but provide and use aggregates that meet the filter criteria. Provide and use filter material fine enough to prevent infiltration of the material from which drainage is occurring. To avoid contamination of the filter by fines by the material in the layer being drained, the required ratio of d_{15} percent passing size of filter material / d_{85} percent passing size of material being drained is < 5 , where d_{15} is the equivalent grain diameter (millimeters) at which 15 percent of the material is finer by weight and d_{85} is the equivalent grain diameter (millimeters) at which 85 percent of the material is finer by weight. The required ratio of d_{50} percent passing size of filter material / d_{50} percent passing size of material being drained is < 25 , where d_{50} is the equivalent grain diameter (millimeters) at which 50 percent of the material is finer by weight. Use these criteria when protecting all soils, except for nondispersive lean clay (CL) or fat clay (CH) soils without sand or silt particles, whereupon disregard the d_{50} percent size relationship.

19-6.4.2 It is essential to use well-graded filter material. The required coefficient of uniformity equates to d_{60} percent passing size of filter material / d_{10} percent passing size of filter material having a value less than or equal to 20, where d_{60} is the equivalent grain diameter (millimeters) at which 60 percent of the material is finer by

weight and d_{10} is the equivalent grain diameter (millimeters) at which 10 percent of the material is finer by weight.

19-6.4.3 To prevent clogging of perforated pipe or screens, the required ratio of d_{85} percent passing size of filter material / slot width or hole diameter slot or hole diameter is > 1.2 .

19-6.4.4 To prevent clogging of the openings in porous pipe the ratio of d_{15} percent passing size of aggregate in porous pipe / d_{85} percent passing size of filter material is < 5 .

19-6.5 Dispersive Clays.

If dispersive clays are encountered, obtain the services of a geotechnical expert having experience detecting and determining the best way to handle these clays. Dispersive clays normally deflocculate when exposed to water with a low salt content. This behavior is the opposite of aggregated clays that remain flocculated in the same soil-water systems. Generally, dispersive clays are highly erosive, are subject to high shrink-swell potential, and have lower permeability rates than aggregated clays.

19-6.6 Filter Fabrics.

The use of woven or nonwoven geotextile materials meeting the requirements of AASHTO M288, *Standard Specification for Geotextile Specification for Highway Applications*, are widely accepted as filters in pavement edge drainage systems. In some instances, these materials may replace one or more components of a graded filter. Filter fabrics may be used to wrap the collector pipe, thus permitting use of a relatively fine backfill material; or line the trench (most common), allowing use of a relatively coarse backfill material. Filter fabrics are rarely used without the entire granular backfill. The only instance where a geotextile can completely replace a granular system is when the subgrade soil is a clean, granular material.

19-6.6.1 Filter Fabric-wrapped Collector Pipe.

When a geotextile is used to wrap the collector pipe, the required ratio of d_{85} percent passing size of granular filter material (millimeters) / apparent opening size (AOS) of geotextile (millimeters) is > 1.0 , where apparent opening size is a property that indicates the approximate largest particle that will effectively pass through the geotextile. This is for a gradient ratio < 3 , where gradient ratio is the ratio of the hydraulic gradient through a soil-geotextile system to the hydraulic gradient through the soil alone. For woven geotextiles, do not use a cloth with an open area that is less than 4 percent or greater than 36 percent of the total area. Where these criteria are met, the criteria given for perforated pipe or screens are no longer applicable.

19-6.6.2 Filter Fabric-lined Drainage Trench.

Where geotextiles are used to line a drainage trench and the geotextile adjacent to granular materials containing 50 percent or less by weight of fines (minus No. 200

materials) the required ratio of d85 percent size of the material (millimeters) / apparent opening size (AOS) (millimeters) is > 1 and a gradient ratio < 3 . For woven geotextiles, do not use cloth with an open area that is less than 4 percent or greater than 36 percent.

19-6.6.3 Filter Fabric and All Other Soil Types.

For geotextiles adjacent to all other types of soil and an AOS no larger than the opening in U.S. Standard Sieve No. 70 and gradient ratio < 3 , do not use cloth with an open area that is less than 4 percent or greater than 10 percent. Where these criteria are met, the criteria for stability and permeability are no longer applicable and the backfill may be selected based on the criteria for perforated pipe or screens.

19-6.6.4 Filter Fabric Clogging.

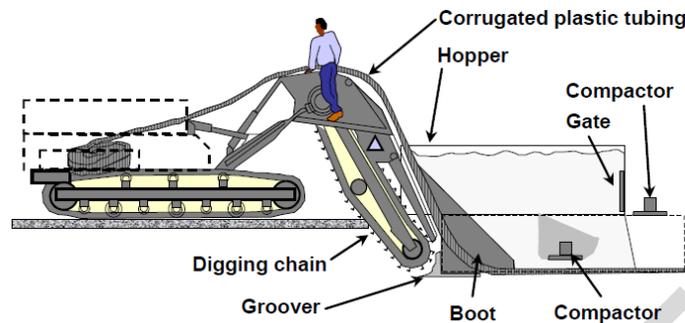
To reduce the possibility of clogging, specify no geotextile with an AOS smaller than the openings of U.S. Standard Sieve No. 100. When possible, it is preferable to specify a geotextile with openings as large as allowed by the above criteria. Do not use geotextiles for soils with 85 percent or more passing the No. 200 sieve.

Methods for determining the AOS and gradient ratio of geotextiles are given in ASTM D4751, *Test Method for Determining Apparent Opening Size of a Geotextile*, and ASTM D5101, *Standard Test Method for Measuring the Filtration Compatibility of Soil-Geotextile Systems*, respectively. Percent open area is defined as the summation of the open areas divided by the total area of the geotextile (refers to woven geotextiles only).

19-7 SUBSURFACE DRAIN INSTALLATION.

Subsurface drains are typically installed using trenchers or other suitable equipment (Figure 19-3). Grade control and elevations are normally obtained from the pavement surface. A minimal slope of 0.15 foot (0.04 meter) in 100 feet (30.4 meters) is recommended for subsurface drains. Cap or plug the upstream end of drainage pipes not terminating in a structure.

Figure 19-3 Trenching Equipment for Installing Pipe Edge Drains



19-7.1 Filter Material Placement.

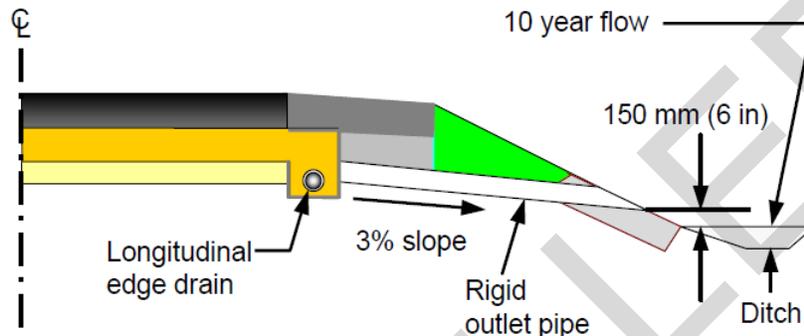
Place a minimum thickness of 6 inches (152 millimeters) of filter material around all types of subsurface drains. Place the backfill material using chutes or other means to avoid dumping the material onto the pipe from the top of the trench. To prevent displacement of drainage pipes during compaction, do not compact the filter material until the trench is backfilled above the level of the top of the pipes. Do not allow the filter material to become segregated or contaminated prior to, during, or after installation. Segregation results in zones of material too fine to meet the permeability requirements and other zones too coarse to meet the stability requirements. Contamination can clog voids in the material and render the drainage system useless. Nominally compact filter material in trenches and cover up with an appropriate material.

19-7.2 Drainage Pipe Outlets.

Where practicable, feed outlets from drainage pipes into existing storm drainage manholes. Protect outlets 12 inches (304 millimeters) in diameter and smaller, not terminating in a manhole with rodent screens, and locate them to prevent surface water from entering the system. The outlet pipe is typically a 4-inch (100-millimeter) -diameter stiff, non-perforated, smooth-walled PVC or high-density polyethylene (HDPE) pipe, installed with minimum slope of about 3 feet in 100 feet (0.03 meter/meter) (Figure 19-

4). Good compaction control of the backfill below, around, and above the outlet pipe is required to avoid transverse shoulder sags. Place the outlet end at least 6 inches (150 millimeters) above the 10-year ditch flow line and protect with a headwall and splash block that is blended into the slope. Mark the outlet end (headwall) to prevent damage by mowers or other equipment.

Figure 19-4 Outlet Pipe Design



19-7.3 Drainage Pipe Access.

Provide manholes or other access points for inspection and cleaning approximately every 250 to 500 linear feet (75 to 150 linear meters), depending on grades, and at the upper ends of runs. If elbows are used instead of manholes, provide and use pipes with a radius and diameter of the pipe of sufficient size to allow cleaning and inspection equipment to pass.

19-7.4 Caution.

Caution: Take care to ensure that construction equipment does not track over the completed edge drainage system as it can damage the drain pipe. Also, monitor the drainage system regularly by checking the functioning of the drains at outlet ends or by using a video-based pipe inspection system. A damaged edge drainage system that retains water within the trench is more damaging to pavement performance than having no edge drainage system.

CHAPTER 20 MAINTENANCE OF HEAT-RESISTANT CONCRETE

20-1 INTRODUCTION.

Concrete pavement damage resulting from high temperatures of jet blast includes spalling, delamination, aggregate popouts, scaling, cracking, and loss of joint sealant (Figure 20-1). Such damage can result in FOD that can damage aircraft engines.

Figure 20-1 Heat-damaged Concrete



Spalling and Scaling

Delamination and Blistering

Conventional PCC rapidly loses free moisture around 212 degrees F (100 degrees C) and starts to lose its chemically combined water at around 250 degrees F (121 degrees C). The highest rate of dehydration occurs around 350 degrees F (177 degrees C). At temperatures above 350 degrees F (177 degrees C), pavement damage increases exponentially. In accordance with this UFC and UFGS 32 13 13.43, *High Temperature Concrete for Airfields with Applied Pavement Temperatures of 482 Degrees C (900 Degrees F) or Higher Using Lightweight and Traprock Aggregates*, use of high-temperature concrete is mandatory where operations apply temperatures at the surface of the concrete from 900 degrees F to 1700 degrees F (482 degrees C to 926 degrees C), even for durations of a fraction of a second. Operations that apply temperatures at the surface of the concrete from 300 degrees F to 900 degrees F (148 degrees C to 482 degrees C) for longer durations may use this UFC and UFGS 32 13 11. If using UFGS 32 13 11, modify the specification to require only traprock for the coarse aggregate for durations greater than 1 minute.

High-temperature concrete (HTC) has been used in vertical landing zones (VLZ), aprons, forward arming and refueling pads (FARP), taxiway hold points, trim pads, and engine warm-up or run-up pads. The pads are usually associated with the operations of MV-22, CV-22, F-35B, and AV-8 aircraft but have also been used in parking areas affected by APUs on B-1 and F-18 aircraft.

20-2 MAINTENANCE AND REPAIR.

Material and construction requirements are intended to provide the longest performance available. Periodic maintenance is required at installations subject to high heat scenarios as described below.

20-2.1 Pavement Markings.

Commonly available pavement marking paints are not expected to maintain a bond or survive repeated heat applications from vertical landing (VL) operations from aircraft on the high-temperature range. Markings are on the perimeter of the VL pad so they will experience damage only when aircraft land near the safety zone. Paint may not adhere to pavement surfaces coated with sodium silicate. Avoid over spraying areas treated with surface sealers.

20-2.2 VL Pad Surface Grinding.

Tests indicate the HTC used for the VL pad may need 0.125 to 0.25 inch (3.2 to 6.4 millimeters) ground off the surface after about 500 landings in the same location. The time required for 500 landings in the exact same location is a function of the operational tempo of the VL pad and landing accuracy. It is reasonable to expect that grinding will be required every three to seven years to reduce spalling and potential FOD. Grinding removes damaged HTC and maintains the slope for required surface drainage. Add an additional 0.5 inch (12.7 millimeters) to the VL pad design thickness to allow future grinding.

20-2.3 Frequency and Depth.

Visually determine frequency and depth of grinding by examining the VL pad pavement surface. Do not exceed 2 inches (50 millimeters) total depth of grinding during the lifetime of the VL pad pavement. Beyond this depth, the concrete cover over the continuous reinforcement is too thin for proper performance. Distresses (e.g., additional cracking or spalling) may begin to develop. The surface area to be ground includes the VL pad plus a limited portion of the adjacent safety zone. Grinding of the remainder of the safety zone or the shoulder areas is not required. Pavement markings and the isolation joint sealant will need to be replaced in areas affected by grinding.

20-2.4 Diamond Grinding Procedures.

20-2.4.1 Pre-Planning.

Prior to grinding, consult the as-built drawings to determine the surface grades and better plan the grinding depth and area to maintain drainage. In the absence of as-built drawings, field-survey the pad using conventional survey equipment. A survey grid of 10 feet by 10 feet (3 meters by 3 meters) is adequate; however, use a grid that matches the width of the grinding machine cutting head for enhanced control of final surface elevations.

20-2.4.2 Diamond Grinding Equipment.

Use concrete grinding machines, not milling machines with hardened teeth. Provide and use grinding machine saw blades impregnated with an industrial diamond abrasive. Assemble saw blades in a cutting head mounted on a machine designed specifically for diamond grinding, which will produce the required texture and smoothness level without damage to the concrete pavement or joint faces.

Provide and use saw blades 0.125 inch (3 millimeters) wide, with a minimum of 60 blades per 12 inches (300 millimeters) of cutting head width, depending on the hardness of the aggregate. Provide and use machines capable of cutting a path 3 feet to 4 feet (0.9 meter to 1.2 meters) wide. Grinding equipment that causes ravels, aggregate fractures, spalls, or disturbance to the joints is prohibited. Ensure finished surfaces are free of raised slivers (commonly referred to as “fins”).

20-2.5 Water Cutting.

It may be possible to remove the recommended 0.125 to 0.25 inch (3 to 6 millimeters) using special high-pressure water-cutting machines fitted to pavement surface scrubbers. These are substantially more advanced machines than a conventional pressure washer, and are typically trailer-mounted with a pressure rating of approximately 10,000 psi (68.9 megapascals). This procedure requires validation by USACE (CEMP-ET), the AFCEC pavements SME, or NAVFAC EXWC for up-to-date guidance.

20-2.6 Surface Sealing.

Re-apply sodium silicate solution after grinding. Prior to application, clean the VLZ concrete areas (including the VL pad and safety zone, at a minimum) using a rotary power washer/scrubber. To remove tire rubber and, to the extent possible, fuel and oil spills, use a rotary power washer/scrubber. Apply the sealer as described for a new installation. Ensure all joint seals are in good condition prior to any application of surface sealers. Replace any damaged, cracked, debonded, or missing joint seals in accordance with UFC 3-250-08FA, *Standard Practice for Sealing Joints and Cracks in Rigid and Flexible Pavements*, before applying any surface sealer.

20-2.7 HTC Patching and Materials.

Do not design or construct partial-depth patches on areas subject to vertical take-off or landing or short take-off operations of the F-35B or located on a VLZ without prior approval of the Pavements DWG. Partial-depth patches are allowed on pavement that is continuously reinforced in both directions provided the partial-depth patching uses hydro-demolition to remove material within 2 inches (50 millimeters) of the rebar and the bottom of the repair is at least 2 inches (50 millimeters) below the bottom of the rebar. If the remaining concrete is cracked or less than 2 inches (50 millimeters), continue to remove all the concrete and treat as a full-depth repair. Patches of areas not subject to vertical take-off or landing or short take-off operations of the F-35B and not located on

VLZs can be design and constructed as a partial-depth repair when full-depth cracks are not present in the repair area. Otherwise, a full-depth patch must be designed and constructed in these areas.

Design and construct partial-depth patches with a minimum 3 inches (75 millimeters) deep, ± 0.25 inch (± 6 millimeters), instead of the standard 2-inch (50-millimeter) minimum used for conventional concrete pavements. Shallower repairs separate from the rest of the pavement due to thermal expansion cycles. Partial-depth patches deeper than 3 inches (75 millimeters) in reinforced areas are not recommended, as the depth of cover of the longitudinal reinforcement is 4 inches (100 millimeters) unless hydro-demolition is used to excavate the patch area at least 2 inches (50 millimeters) below the bottom of the rebar.

Provide and use materials for patching HTC surfaces that match the materials used to originally construct the pad. If the original HTC materials are not available, specify and use only materials that will survive high-temperature applications and are approved by the contracting officer or for in-house work by the Pavements DWG. Some prepackaged rapid-repair materials that will survive high-temperature applications are available on the GSA schedule at the time of the publication of this UFC.

20-2.8 PCC Patching.

Applying high temperatures to a PCC safety area may generate spalling. The surface sealer may allow the PCC to survive a few landings per location. Landing on PCC may also result in very thin delamination, which can be corrected by brooming and resealing with sodium silicate. Repeated landings at the same PCC location or over-exposure to high temperatures generates more severe spalling. Repair the PCC with HTC patching materials or conventional PCC. Do not use rapid spall repair materials (e.g., epoxy-based or activated fly-ash products) if sited near the VL pad due to the risk of future high-temperature exposures.

20-3 SUMMARY OF MITIGATION TIPS.

20-3.1 Water/Cement Ratio.

Use concrete with a low water/cement ratio (below 0.42). Properly cure the concrete. Leaner concrete mixes (low cement to aggregate ratio) perform better than richer mixes.

20-3.2 PCC Mix.

Use of hydrated portland cement that has lower calcium hydroxide content is preferable to those with higher calcium hydroxide content for high-temperature applications. For temperatures of 1,500 degrees F (816 degrees C) or more, high alumina cement provides superior performance.

20-3.3 Construction Quality.

Proper consolidation of concrete and proper finishing is critical. Minimize the amount of paste on the surface to minimize scaling.

20-3.4 Proper Material.

Aggregate selection is the most important single material-related factor; however, there is no standard specification for heat-resistant aggregate. Aggregates with low coefficients of thermal expansion (CTE) are desirable. The optimal aggregate is formed at a temperature higher than the expected exposure temperature, such as igneous trap rock. Lightweight aggregates, such as expanded shale and expanded slate, tend to perform better than conventional natural concrete aggregates subject to high temperature. Air-cooled slag aggregates also provide good results.

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CHAPTER 21 REPAIR OF PCC DAMAGED BY POL

21-1 INTRODUCTION.

Engine exhaust combined with petroleum, oil, and lubricant (POL) contamination can damage ordinary PCC pavements. Damage occurs in the form of scaling or spalling of the top 1 to 2 inches (25 to 50 millimeters) of the pavement. Pavement fragments from these surface scales can cause FOD to aircraft engines. High exhaust temperatures, coupled with spilled fluids (POL), damage ordinary PCC airfield pavements. Damage occurs progressively to the pavement surface under repeated thermal cycling and chemical reaction of the spilled aircraft fluids with the cement paste.

PCC surface treatments reduce or eliminate spalling, scaling, and other surface damage caused by heat and POL. These treatments are suitable for repairing PCC damaged by POL and heat from B-1, F-18, F-35, CV-22, and MV-22 operations. Apply these treatments prior to POL contamination, where possible. When in doubt as to the length or number of operations, treat the affected area.

Do not use this UFC to deny or restrict operations of any aircraft, including CV-22s and MV-22s. Use it to identify and establish projects and protocols to effectively support air operations.

21-2 PRIMARY DAMAGE MECHANISMS.

Testing has revealed three primary damage mechanisms: thermal fatigue, vapor pressure, and chemical degradation. Thermal fatigue has produced failures without the presence of POL. Vapor pressure damage has been observed when the water vapor pressure cannot be relieved fast enough during the heating phase. Chemical degradation results in a significant loss of strength—up to 50 percent in some cases—which accelerates failure. Chemical degradation by itself can result in raveling of the concrete, which has been observed under APUs for the B-1 and F-18; it does not produce scaling, but accelerates scaling.

21-3 REPAIR TECHNIQUES/MATERIALS.

The following techniques can reduce damage from combined exhaust heat and POL.

21-3.1 Sodium Silicate Application.

Applying sodium silicate dramatically improves a concrete pavement's ability to resist damage from exhaust temperatures below 500 degrees F (260 degrees C). Applying sodium silicate is the most affordable way to reduce damage to existing undamaged pavement where reconstruction is not required.

21-3.2 Multifilament Fibers.

Multifilament polypropylene fibers at a dosage of 3 pounds per cubic yard (1.8 kilograms per cubic meter) of concrete further improves concrete durability when subjected to exhaust heat.

21-3.3 Polymer Coatings.

The US Army Corps of Engineers, Engineering Research and Development Center Geotechnical and Structures Laboratory performed laboratory test and field demonstrations with two polymer coats which, when combined with a sealer, provided results equal to or greater than coal tar emulsions. If polymer coatings are used on the airfield pavements, specify or use materials and methods recommended in ERDC/GSL Technical Report TR 03-24. Do not specify or use any materials or methods other than those included in this report without prior approval of the Pavements DWG. Do not specify or use polymer coating on any areas used for landing or take-off of jet, turbo-prop, CV 22, or MV-22 aircraft. These products have been used on parking aprons and FARPs.

21-3.4 Surface-Applied Penetrating Chemically Reactive Silicates.

Surface-applied penetrating water-soluble, chemically reactive silicates migrate through micropores and chemically bond with calcium hydroxide and calcium chlorides in cements to form calcium silicates which inhibit hydrolysis with POL esters. They also fill micropores, reducing the permeability of concrete. If surface-applied penetrating water-soluble, chemically reactive silicates are used on the airfield pavements, specify or use materials and methods that do not leave a surface film or coating and cannot be scraped or removed from the surface using mechanical means. Specify and use only those products and methods that reduce the chloride ion penetration in PCC by at least 60 percent, as determined by ASTM C1202, AASHTO T277, or AASHTO T259, and that penetrate at least 0.75 inch (19 millimeters) into the surface of the concrete. Materials and methods proven effective on airfield pavements are documented in "Auxiliary Power Unit (APU) Resistant Concrete: State-Of-The-Art," by Anderson, John R., et al, 1 March 2000. Do not specify or use any materials or methods other than those included in this report without prior approval of the Pavements DWG.

21-3.5 Magnesium Phosphate Cement (MPC)

MPC is a different cement formulation than conventional PCC. MPC is less sensitive to reaction with acids than PCC. It can be extended with any normal aggregate; however, for applications under B-1 aircraft, using aggregate that is not reactive with acids (limestone is reactive) is necessary. MPC is a fast-setting cement that reaches high strength (above 5000 psi [34.5 megapascals]) in less than one hour, with an ultimate strength after several hours of approximately 8000 psi (55.1 megapascals). It is more resistant to the types of aviation fluids that have caused damage to pavement under Navy F/A-18 Hornet fighter aircraft (TDS NAVFAC EXWC-CI-1403, *Mitigating Concrete Damage Caused by Engine Exhaust Surface Temperature Below 500 °F*).

21-4 REQUIREMENTS.

21-4.1 Cleaning.

Before applying surface sealants, remove all contaminants such as POL, dust, curing compound, and moisture. If water is used to clean the pavement, dry the pavement and keep it dry for at least 24 hours prior to any surface application.

21-4.2 When to Seal.

Initiate steps to protect the pavement within six months of commencing operations; however, apply surface sealants, such as sodium silicate, no earlier than 70 days after placing pavement.

For locations subject to less than two operations per week, this time may be extended to 12 months. Surface treatments are most effective when placed prior to the application of heat loads and prior to any contamination by POL. Damage to PCC has been observed as early as six months and as late as 60 months after operations commence.

21-4.3 Distress Repairs.

When possible, repair the following distresses within the treatment area prior to the placement of surface treatments: damaged joint and crack seals, spalls, and medium- and high-severity patches as defined by ASTM D5340. Surface treatments can be applied before completing these repairs; however, retreatment of the surface within 6 inches (150 millimeters) of the repair area is recommended after completing the repairs. If the repair includes the placement of concrete or magnesium phosphate-based cements, do not reseal the surface of the repair during the first 70 days after placement.

21-4.4 Existing Distress Effects.

There are some distresses that, if present, reduce the effectiveness of the surface treatment; therefore, if you have shattered slabs, medium- or high-level durability cracking (D cracking), medium- or high-severity scaling, or medium- or high-level ASR as defined in ASTM D5340, the surface treatment can be omitted because they are not effective. In rare cases where older pavements have had their entire surfaces scaled and additional scaling or surface cracking has ceased, surface treatments can increase the life span of the pavement and can be effectively applied. Parking/operating the CV-22 or MV-22 on pavements with these types and levels of distresses increases the rate of deterioration under the nacelles. Applying surface treatments to pavements with low-severity distresses of these types increases the service life of the pavement.

21-4.5 Where to Seal.

Seal those areas most susceptible to POL and direct exhaust, a circular area with a minimum 15-foot (4.5-meter) radius, centered where the engine exhaust is directed at

parking, maintenance, and preflight check areas, including parking/maintenance ramps, forward area refueling points (FARP), and hot refuel/re-arm pads.

21-4.6 High-Temperature Aggregates.

If constructing new or replacing existing pavement to support CV-22, MV-22, or F-35A/B parking, maintenance, FARP, or hot refuel/re-arm operations, a high-temperature aggregate such as an igneous trap rock, expanded shale, or expanded slate may be used as the coarse aggregate in the concrete mix design. Unlike a concrete mix for a vertical landing pad, the fine aggregate can be a natural sand. If the cost of the pavement using high-temperature aggregates is more than twice the cost of standard PCC then construct/repair the pavement using standard PCC. Apply sodium silicate. However, do not apply the sealant any earlier than 70 days after placement of the concrete repair material. Where practical, include multifilament polypropylene fibers at a dosage of 3 pounds per cubic yard (1.8 kilograms per cubic meter) of concrete in any PCC or PCC with high-temperature aggregates.

21-5 PCC SODIUM SILICATE SURFACE SEALING.

The sodium silicate surface sealer is absorbed into the top 0.125 inch (3 millimeters) of the concrete, providing resistance to high exhaust temperatures and POL stains. Sodium silicate requires reapplication if surface wear occurs. Do not apply sodium silicate surface sealers to asphalt pavement.

21-5.1 Sodium Silicate Solution.

Provide and use a sodium silicate surface sealer that is a colorless, water-based solution containing 9 percent sodium silicate. While many manufacturers provide a product with this concentration, it often comes in 40 percent solutions. Higher-concentration products can be diluted to 9 percent sodium silicate. The 9 percent sodium silicate provides optimum concrete penetration with three applications. In order to dilute a 40 percent solution of sodium silicate to 9 percent, add 3.5 parts of water to 1 part of the 40 percent solution, i.e., for every gallon of 40 percent solution add 3.5 gallons of water. The sodium silicate sealer is applied to PCC subject to heat and POL, such as from F-35B, MV-22, and CV-22 engines. Use of concentrations higher than 9 percent results in an excess buildup that will bubble and discolor under the heat load of the nacelles. If this occurs, remove the excess material by washing the area with warm water. Use a scrub brush and/or a high-pressure pump to speed removal. In extreme cases, use ultra-high-pressure rubber removal equipment. The portion of the sodium silicate that has combined with the concrete surface remains in place.

21-5.2 Surface Cleaning.

Before application, clean the concrete with a rotary power washer/scrubber to remove tire rubber, curing compound, and POL. If heavy POL contamination is present or if the sodium silicate will not penetrate the surface, follow the procedures in paragraph 21-6 before applying the pavement sealant.

21-5.3 When to Seal.

Do not apply the sodium silicate earlier than 70 days after the pavement has been placed. Testing has determined that sodium silicate applications prior to 70 days result in surface flaking of the PCC. Ensure all curing compound has been removed prior to sealing the PCC.

21-5.4 Joint Sealing.

Properly seal the pavement joints before applying the sodium silicate. If the joint seals are not in good condition then repair or replace them before applying the sodium silicate.

21-5.5 Paint Markings.

Ensure all paint markings (including shadow markings) are in place, in good condition, and contain no cracks or chips before applying the sodium silicate. Repair or replace damaged markings before applying the sodium silicate.

21-5.6 Environmental Conditions.

Do not apply the sodium silicate until the concrete surface has been dry for at least 24 hours and the pavement markings have been applied. Do not apply the sodium silicate until the air temperature is 40 degrees F (4.4 degrees C) or higher and relative humidity is 80 percent or less, both during application and for 48 hours after application. It is acceptable to apply the sodium silicate over pavement markings and glass beads.

21-5.7 Surface Seal Application.

Apply three coats of the sodium silicate solution with low-pressure airless spraying equipment to ensure uniform application or use a roller with a 0.25-inch to 0.5-inch (6-millimeter to 13-millimeter) nap. Start applying the solution at the highest point in the pavement and continue downgrade. Each coat will cover no more than 200 square feet per gallon (4.9 square meters per liter). Avoid excessive application, as it may cause efflorescence and reduce friction. Allow the sodium silicate to penetrate for two hours then wash off any visible excess (ponded) solution. Allow the area to dry for at least 24 hours between each coat.

21-5.8 Final Evaluation.

After allowing the last coat to dry for 24 hours, evaluate the surface for any excess silica or dusting. Wash off any excess silica or dusting as needed. Protect the application from any pedestrian or vehicular traffic until the last coat has dried.

21-6 CLEANING POL CONTAMINATION FROM PCC AND PCC JOINTS.

21-6.1 Stains.

If POL stains are present, treat the entire stain before sealing the pavement. Several methods to remove POL stains and, in the case of POL stains on joints, improve the bond to the joint surface are described below. Most stains require several applications and may require the use of more than one treatment method. By implementing all of these steps maximum removal will be achieved; however, one or more of the steps can be omitted to achieve acceptable results. Steam may be used; however, steam alone will provide some cleansing of the immediate surface but not penetrate deep enough to provide a long-term result. Properly collect and dispose of any POL-contaminated water, paste, or solids.

21-6.2 Dawn (or Simple Green) Dishwashing Detergent and Hot Water.

Apply to the stained area and scrub to develop a thick lather. Let set for five minutes then rinse with warm/hot water. Use of steam to pretreat the area and rinse may aid removal.

21-6.3 Tri-Sodium Phosphate (TSP).

TSP (also called sodium orthophosphate) is available in hardware stores.

Note: Some states have banned this product because phosphate can cause problems with waterways. Check with the environmental office before using.

Mix one measure of TSP with six measures of water. Apply over the stain with a paintbrush and allow to dry completely before scraping off the dried paste. Rinse the surface and scrub with a stiff brush and clean water.

Caution: DO NOT MIX TSP WITH ANY ACID! A violent reaction can occur and release noxious gas. You can use both products but use them separately, with a thorough rinsing with water between applications.

Alternate application method: Dissolve 1 pound, 6 ounces of TSP in a gallon of water. Add enough finely ground calcium carbonate (also called whiting or agricultural lime) to make a thick paste. Agricultural lime is available at garden supply stores. Spread the paste over the stain and allow it to dry for a day, if possible. Brush off the dry paste with a stiff brush and scrub the concrete with water. Provide and use PPE and keep the paste away from aircraft due to the high pH of the paste. If it is windy, protect the treated area until the area is cleaned and rinsed to keep the caustic material from blowing around the apron.

21-6.4 Sodium Hydroxide.

If TSP is not available or not allowed, use sodium hydroxide. Prepare and use a solution of 5 percent sodium hydroxide (caustic soda: NaOH). Apply it over the stain with a

paintbrush and allow to dry for at least 24 hours. Rinse and scrub with clean water then repeat as required. Provide and use PPE and keep the solution away from aircraft due to the high pH of the solution. If it is windy, protect the treated area until the area is cleaned and rinsed to keep the caustic material from blowing around the apron.

21-6.5 Super Washing Soda.

Washing Soda or Super Washing Soda, sodium carbonate, can be used as a substitute for TSP or sodium hydroxide; however, it does not work as well and may take more applications to remove the POL. Apply in accordance with manufacturer directions. Rinse well with water. This is an organic salt. If it is windy, protect the treated area until the area is cleaned and rinsed to keep the salt from blowing around the apron.

21-6.6 Phosphoric Acid Cleaner.

Apply phosphoric acid cleaner in accordance with manufacturer directions. Rinse well with water and sodium carbonate (washing soda or soda ash) to neutralize the pH then rinse with clear water. This product will etch the concrete so do not leave it on too long and ensure the area is rinsed well to ensure no acid is left on the concrete. Acid deteriorates ordinary Portland cement.

21-6.7 Bacteria and Enzymes that Remove Oil Stains in Concrete.

Biological materials (bacteria and enzymes) that consume POL can also help to remove stains. Use a biologic product as a final treatment prior to sealing. The bacteria stay in the concrete and help eliminate any remaining POL over time. Follow the product directions.

21-6.8 Replacement.

If the contamination is too extensive, consider removal/repair.

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APPENDIX B BEST PRACTICES

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APPENDIX C GLOSSARY

C	degrees Celsius
F	degrees Fahrenheit
AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
AFCEC	Air Force Civil Engineer Center
AFJMAN	Air Force joint manual
AOS	apparent opening size
APU	auxiliary power unit
ASR	alkali-silica reaction
ASTM	American Society for Testing and Materials
CRC	continuously reinforced concrete
CTE	coefficient of thermal expansion
DBST	double bituminous surface treatment
DOD	Department of Defense
DWG	Discipline Working Group
ETL	Engineering Technical Letter
FAA AC	Federal Aviation Administration Advisory Circular
FARP	forward area refueling point
FOD	foreign object damage
FWD	falling-weight deflectometer
gal/yd ²	gallon per square yard
HCA	hot compressed air
HMA	hot-mix asphalt

HMAC	hot-mix asphalt concrete
HTC	high-temperature concrete
in.	inch
JPCP	Jointed Plan Concrete Pavement
kg/m ²	kilogram per square meter
kPa	kilopascal
l/m ²	liter per square meter
lb/yd ²	pound per square yard
LTR	load transfer restoration
M&R	maintenance and repair
mm	millimeter
MMA	methyl methacrylate
MPC	magnesium phosphate cement
MS	medium-setting emulsion
NAVFAC EXWC	Naval Facilities Engineering Command Engineering and Expeditionary Warfare Center
NCS	neoprene compression seal
PFC	porous friction course
PFS	porous friction surface
OSHA	Occupational Safety and Health Administration
PCC	Portland cement concrete
pH	numeric scale to specify the acidity or alkalinity of an aqueous solution
PM	preventive maintenance
POL	petroleum, oil, lubricants
PPE	personal protective equipment

psi	pounds per square inch
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
QS	quick-setting emulsion
RPM	revolutions per minute
RS	rapid-setting emulsion
SBST	single bituminous surface treatment
SMA	stone mastic asphalt
SME	subject matter expert
SS	slow-setting emulsion
TDS-NAVFAC EXWC	TechData - Sheet Naval Facilities Engineering Command Engineering and Expeditionary Warfare Center
TM	Army technical manual
TSMCX	Transportation Systems Center
TSP	trisodium phosphate
TSPWG	Tri-Service Pavements Working Group
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specifications
USACE (CEMP-ET)	United States Army Corps of Engineers, Directorate of Military Programs
VL	vertical landing
VLZ	vertical landing zone comprising the imaginary airspace, VL pad, safety zone, shoulders, and connecting taxiway
WMA	warm mix asphalt