

DRAFT

**UFC 3-270-07
30 JUNE 2003**

UNIFIED FACILITIES CRITERIA (UFC)

AIRFIELD DAMAGE REPAIR



APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

UNIFIED FACILITIES CRITERIA (UFC)

CRITERIA FORMAT STANDARD

Any copyrighted material included in this UFC is identified at its point of use. Use of the copyrighted material apart from this UFC must have the permission of the copyright holder.

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

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

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

Change No.	Date	Location

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007, provides planning, design, construction, sustaintment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the Department of Defense (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 more 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 Support Agency (AFCEA) 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 \(CCR\)](#). The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following sources:

- Unified Facilities Criteria (UFC) Index http://65.204.17.188/report/doc_ufc.html.
- USACE TECHINFO Internet site <http://www.hnd.usace.army.mil/techinfo/index.htm>.
- NAVFAC Engineering Innovation and Criteria Office Internet site <http://criteria.navfac.navy.mil>.
- Construction Criteria Base (CCB) system maintained by the National Institute of Building Sciences at Internet site <http://www.nibs.org/ccb>.

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.

AUTHORIZED BY:

Dwight A. Beranek, P.E.
Chief, Engineering and Construction Division
U.S. Army Corps of Engineers

Dr. James W. Wright, P.E.
Chief Engineer
Naval Facilities Engineering Command

Kathleen I. Ferguson, P.E.
The Deputy Civil Engineer
DCS/Installations & Logistics
Department of the Air Force

Frank Lane
Director of Analysis & Investment
Deputy Under Secretary of Defense
for Installations and Environment
Department of Defense

CONTENTS

	<u>Page</u>
CHAPTER 1 INTRODUCTION	
Paragraph 1-1 PURPOSE AND SCOPE	1
1-2 APPLICATION.....	1
CHAPTER 2 PAVEMENT REPAIR CRITERIA	
Paragraph 2-1 DESCRIPTION OF ENGINEER ACTIVITIES.....	2
2-2 BOMB DAMAGE ASSESSMENT	2
2-3 SELECTION OF THE MOS.....	2
2-4 SAFING AND DISPOSAL OF EXPLOSIVE ORDNANCE	3
2-5 BOMB DAMAGE REPAIR	3
2-6 DEFINITIONS.....	3
2-6.1 Spalls.....	3
2-6.2 Craters.....	3
2-7 EXPEDIENT REPAIR.....	4
2-8 SUSTAINMENT REPAIR	4
2-9 PERMANENT REPAIR.....	5
2-10 SELECTION OF REPAIR METHOD	5
2-11 REPAIR QUALITY CRITERIA (RQC).....	6
2-12 REPAIR EVALUATION METHODS.....	7
2-12.1 Acceptance Criteria	7
2-12.2 Airfield Certification.....	9
CHAPTER 3 SPALL REPAIR	
Paragraph 3-1 DEFINITION OF SPALL	10
3-2 REPAIR CONCEPT.....	10
3-2.1 Purpose	10
3-2.2 Concerns	10
3-3 MATERIALS	10
3-3.1 Conventional Cement/Grout.....	10
3-3.2 Cold Mix Products	11
3-3.3 Proprietary Products.....	11
3-3.4 Technical Representatives	11
3-4 SPALL REPAIR/ACCEPTANCE PROCEDURES	11
3-5 SPALL REPAIR ACCEPTANCE CRITERIA.....	12
CHAPTER 4 EXPEDIENT REPAIR METHODS	
Paragraph 4-1 EXPEDIENT REPAIR CONCEPT	13
4-1.1 Purpose	13
4-1.2 Assumptions.....	13

4-2	SELECTION OF REPAIR METHOD	13
4-2.1	Aircraft Type and Load	13
4-2.2	Available Material	13
4-2.3	Available Equipment.....	13
4-2.4	Repair Quality Criteria (RQC).....	13
4-2.5	Existing Pavement Structure	13
4-2.6	Time Constraints	13
4-2.7	Repair Crew Capability/Equipment/Manpower	14
4-3	CRUSHED STONE REPAIR	14
4-3.1	Materials	14
4-3.2	Types of Repair Methods	15
4-3.3	Procedures	16
4-4	SAND-GRID REPAIR	18
4-5	FOREIGN OBJECT DAMAGE (FOD) COVERS	20
4-5.1	Army FOD Cover Assembly Procedures	20
4-5.2	Navy-Marine Corps FOD (FRP)	21
4-5.3	Air Force Folded Fiberglass Mat (FFM).....	28
4-6	AM-2 MAT REPAIR.....	34
4-6.1	Army.....	34
4-6.2	Navy/Marine Corps.....	41
4-6.3	Air Force.....	42
4-7	RAPID SET MATERIAL REPAIR	45
4-8	SEMI-PREPARED SURFACES	45
4-8.1	Unsurfaced Repair.....	45
4-8.2	Stabilized Surface Repair	45

CHAPTER 5 SUSTAINMENT REPAIR METHODS

Paragraph 5-1	SUSTAINMENT REPAIR CONCEPTS.....	46
5-1.1	Purpose	46
5-1.2	Assumptions.....	46
5-2	SELECTION OF REPAIR METHOD	46
5-3	STONE AND GROUT REPAIR	46
5-3.1	Stone and Grout Repair (Above Freezing Temperatures).....	46
5-3.2	Stone and Grout Repair (Below Freezing Temperatures)	48
5-4	AM-2 MAT REPAIR.....	49
5-5	RAPID SET MATERIAL.....	49
5-6	CONCRETE CAP REPAIR.....	49
5-7	ASPHALT CONCRETE REPAIR.....	52
5-8	SEMI PREPARED SURFACES.....	52
5-8.1	Unsurfaced Repair.....	52
5-8.2	Stabilized Surface Repair	52

CHAPTER 6 PERMANENT REPAIR

Paragraph 6-1	PERMANENT REPAIR.....	53
---------------	-----------------------	----

CHAPTER 7 SUMMARY AND LESSONS LEARNED

Paragraph 7-1	Summary	54
7-2	Lessons Learned	54
GLOSSARY		58
APPENDIX A CRATER PROFILE MEASUREMENT WITH STANCHIONS.....		62
APPENDIX B EQUIPMENT AND MANPOWER REQUIREMENTS.....		77
APPENDIX C	REFERENCES	89
APPENDIX D	BIBLIOGRAPHY	91
APPENDIX E AIRFIELD DAMAGE REPAIR LOG		93

FIGURES

Figure Title

2-1	Spall.....	3
2-2	Craters	4
2-3	Repaired Crater	6
2-4	Profile Measurement of Filled Crater	7
2-5	Five Percent Change of Slope	8
4-1	Debris Backfill	15
4-2	Choke Ballast over Debris	15
4-3	Choke Ballast.....	16
4-4	Sand Grid Repair	18
4-5	Sand Grid Repair Detail	18
4-6	FRP Panel Bushing Detail	22
4-7	Typical Navy-Marine Corps FRP Mat Layout.....	23
4-8	Mat Assembly Sequence	24
4-9	Mat Assembly	25
4-10	Small FRP Cover Towing System.....	26
4-11	Large FRP Cover Towing System.....	26
4-12	FFM Configuration	29
4-13	Attaching Nylon Straps	30
4-14	Mat Unfolding Procedure	30
4-15	Joining Panel Attachment	31
4-16	Joining Second Mat Using Pivot Point	31
4-17	Concrete Pavement Anchoring.....	33
4-18	Asphalt-Overlaid Concrete Anchoring.....	33
4-19	Attachment of Towing Tubes	35
4-20	Towing Tube and Keylock.....	36
4-21	Towing Mandrel and Mandrel Fittings.....	37

4-22	Comparison of Standard and Reverse Towing Tubes	39
4-23	Standard Towing Tube and Keylock Assembly.....	39
4-24	Reverse Towing Tube and Keylock Assembly	40
4-25	Assembled Patch Towing Tube	41
4-26	Use of Locking Bar in Assembly Patch and Correction of Misalignment.....	42
4-27	AM-2 Aluminum Mat	44
5-1	Stone and Grout Repair	46
5-2	Concrete Cap Repair	49
5-3	Pedestal Designs	51

TABLES

<u>Table</u>	<u>Title</u>	
2-1	Repair Suitability for Airfield Surfaces and Aircraft Type.....	5
4-1	Specifications for Ballast Rock.....	14
4-2	Specifications for High Quality, Well-Graded Crushed Stone	14
4-3	Army FRP Panel Types	20
4-4	Navy-Marine Corps FRP Panel Types	22
5-1	Stone and Grout Mix Proportions.....	48

CHAPTER 1

INTRODUCTION

1-1 **PURPOSE AND SCOPE.** This document describes the various services' (Army, Navy, Marine Corps, Air Force) airfield damage repair (ADR) concept of operations. Recent operations identified the lack of familiarity and consistency in ADR procedures, equipment, material, and unified pavement specifications. This document is the first effort toward developing unified ADR guidance in the context of recent operations.

ADR encompasses more than just pavement repair. Damage assessment, explosive ordnance reconnaissance, minimum operating strip (MOS) selection, repair quality criteria (RQC), aircraft arresting system installation and utility system repairs are just a few of the areas that must also be considered. These areas are only briefly addressed. **This document only addresses airfield pavement repairs.** All branches of service accomplish pavement repair in a similar manner. The major differences occur in the final 457 to 610 mm (18 to 24 in.) of crater repair and capping due to mission differences, team configuration, and available resources. Understanding the various services' repair procedures will expedite the re-repair and/or upgrade of those repairs by follow-on forces, regardless of branch of service. Extensive efforts are still required to find the ultimate answers to pavement repair problems and compatibility issues with new aircraft.

Note: The use of the name or mark of any specific manufacturer, commercial product, commodity, or service in this publication does not imply endorsement by the Department of Defense.

1-2 **APPLICATION.** All Department of Defense (DoD) organizations are responsible for ADR planning, design, construction, maintenance, repair, evaluation, and training. The current international situation dictates a flexible force capable of ADR. Both the initial and follow-on force, regardless of branch of service, must be familiar with each service's repair procedures, techniques, and materials in order to keep an airfield operational. Familiarity with the different repair procedures will significantly expedite maintenance, upgrades, and permanent repairs.

CHAPTER 2

PAVEMENT REPAIR CRITERIA

2-1 **DESCRIPTION OF ENGINEER ACTIVITIES.** After an air base is attacked, engineer personnel will respond with four activities to provide adequate launch and recovery surfaces for mission aircraft. These engineer activities are as follows: damage assessment, identification of candidate minimum operating strips, safing and disposal of explosive ordnance, and repair of bomb damage. However, it should be noted that in this era of new global strategies the wartime scenario is often different from that anticipated in the past. Instead of repair of a damaged airfield in friendly territory, the engineer is faced with the task of restoring airfields formerly occupied by hostile troops, damaged during forcible entry, and subsequently sabotaged and booby trapped by departing unfriendly forces. Lines of communication are longer and acquisition of materials more difficult. Thus, more emphasis is placed on force protection and sustainment engineering.

2-2 **BOMB DAMAGE ASSESSMENT.** Bomb damage assessment activities are categorized into two distinct areas: airfield damage repair assessment and facility and utility damage assessment. In this manual, only airfield damage repair assessment is addressed. Airfield damage repair assessment includes evaluation of damage involving runway surfaces, taxiway surfaces, and other facilities that directly support aircraft operations. Since major recovery tasks cannot be started until damage assessment and MOS selection are completed, speed and accuracy during damage assessment are essential. The damage assessment teams (DATs) determine and report the location, types, and numbers of unexploded ordnance, and the location, types, and quantity of airfield pavement damage to the survival recovery center (SRC). A qualified team from the SRC, known as the MOS selection team, uses this information to select the MOS, which must be cleared and repaired in order to launch and recover aircraft.

2-3 **SELECTION OF THE MOS.** After an air base attack, the base commander's immediate problem is to launch and recover mission aircraft as soon as possible. The base engineer must recommend the best airfield surfaces to repair; i.e., those that require the least repair time but still provide adequate launch and recovery surfaces for mission aircraft. The launch and recovery surface selected for repair is called the minimum operating strip or MOS. The MOS is the area from which aircraft take off and land. When a MOS is combined with access taxiways from aircraft staging areas such as shelters and parking aprons, the entire area becomes the minimum airfield operating surface (MAOS). The length of the MOS will depend on the take-off or landing distance of the mission aircraft, whichever is greater. Typical MOS dimensions for various aircraft are as follows: fighter aircraft—1,524 m long by 15.2 m wide (5,000 ft long by 50 ft wide); C-130 Hercules—1,067 m long by 18.3 m wide (3,500 ft long by 60 ft wide); P3 Orion—1,920 m long by 27.4 m wide (6,300 ft long by 90 ft wide); and C-17 Globemaster III—at least 1,067 m (3,500 ft) long (but may be longer depending upon altitude, surface type, and runway condition rating of the airfield) and 27.4 m (90 ft) wide. These do not include the requirement for 91.5 m (300-ft) overruns. See Reference 1.

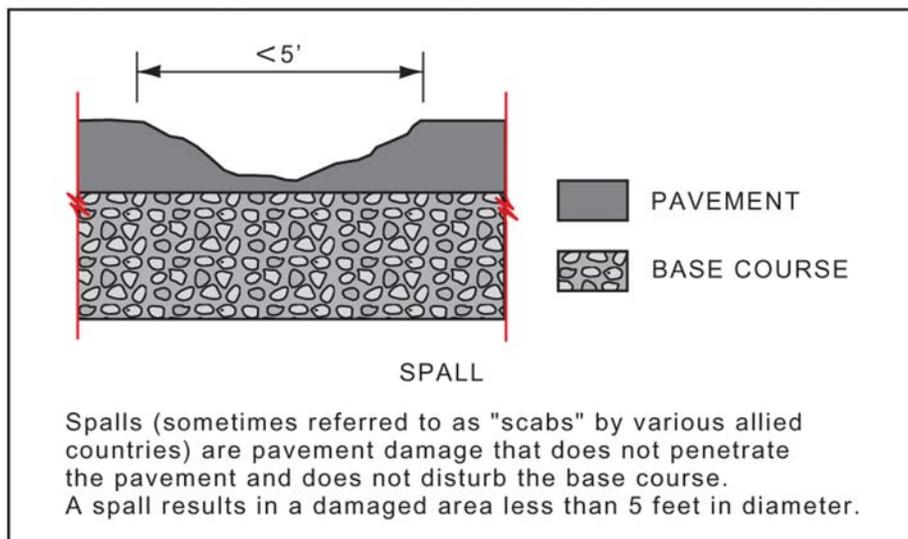
2-4 **SAFING AND DISPOSAL OF EXPLOSIVE ORDNANCE (UXO).** During damage assessment, Damage Assessment Teams (DAT) must gather two types of information—location of pavement damage caused by bombs, cannon fire; etc., and UXO data. The UXO data should include information regarding type, location, and number. Unexploded ordnance that may influence aircraft operations must be accurately located, reported, and recorded in sufficient detail for the Survival Recovery Center (SRC) explosive ordnance disposal representative to determine the risk to aircraft operations. The following information should be obtained: location, quantity, size, shape, color, distinctive markings, and fuse type and condition. All UXO within 91.5 m (300 ft) of repair operations or aircraft operating surfaces must be identified. Holes of entry for subsurface UXO and camouflaged craters must also be reported. Once an MOS site has been selected, the Damage Control Center (DCC) will be notified so that Airfield Damage Repair (ADR) teams can be dispatched. At the same time, the SRC will direct the Explosive Ordnance Disposal (EOD) technician to dispatch the UXO safing and bomb removal teams to clear the ADR team's route to the MOS and the MOS itself of munitions.

2-5 **BOMB DAMAGE REPAIR.** After selection of the MOS and removal of UXO, debris can be removed and repairs initiated. Damage to runways, taxiways, and other aircraft operating surfaces is classified as spalls or craters based on severity of damage. Repair categories are termed expedient, sustainment, or permanent.

2-6 DEFINITIONS.

2-6.1 **Spalls.** A spall is damage that does not penetrate through the pavement surface to the underlying layers. Spalls may be up to 1.52 m (5 ft) in diameter. See Figure 2-1.

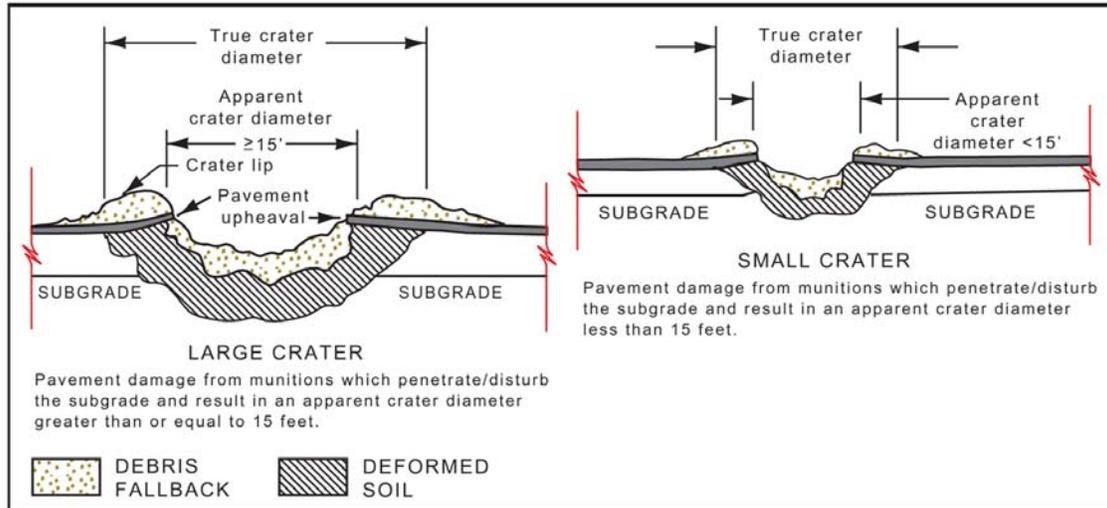
Figure 2-1. Spall (To convert feet to meters, multiply by 0.3048)



2-6.2 **Craters.** Craters represent damage that penetrates through the pavement surface into the underlying base and subgrade soil uplifting the surrounding pavement

and ejecting soil, rock, and pavement debris around the impact area. Craters represent much more severe damage than spalls. Large craters have an apparent diameter equal to or greater than 4.57 m (15 ft). Small craters have an apparent diameter less than 4.57 m (15 ft). Typical crater configurations are shown in Figure 2-2.

Figure 2-2. Craters (To convert feet to meters, multiply by 0.3048)



2-7 **EXPEDIENT REPAIR.** Expedient repairs are defined as airfield pavement repairs that create an initial operationally capable MOS/MOAS, based on projected mission aircraft requirements, in the most expeditious manner possible. Ideally, where sufficient equipment and materials are available, individual crater repairs should be completed within four (4) hours. Austere bases where required equipment and materials are not readily available will require additional time for crater repair. Criteria have been established for an expedient repair to provide an accessible and functional MOS/MAOS that will sustain 100 C-17 passes with a gross weight of 227,707 kg (502 kips), or 100 C-130 passes with a gross weight of 79,380 kg (175 kips), or 100 passes of a particular aircraft at its projected mission weight if other than the C-17 or C-130, or the number of passes required to support the initial surge mission aircraft.

2-8 **SUSTAINMENT REPAIR.** Repair efforts designed to upgrade expedient repairs for increased aircraft traffic are known as sustainment repairs. Sustainment repairs should be initiated as soon as the operational tempo permits, considering that expedient repairs are only designed to support 100 aircraft sorties. Sustainment repairs to an MOS/MAOS are expected to support the operation of 5,000 C-17 passes with a gross weight of 227,707 kg (502 kips), or 5,000 C-130 passes with a gross weight of 79,380 kg (175 kips), or the number of passes required to support mission aircraft at the projected mission weights throughout the anticipated operation, if other than the C-17 or C-130. "Expected to support..." means that these numbers of passes can be conducted before additional maintenance is required. While construction time is important for conducting sustainment repairs, quality control is even more important so that further maintenance will be minimized.

2-9 **PERMANENT REPAIR.** Once the conflict is over, permanent repairs will return the air base to its original conditions. Permanent repairs are designed to sustain 50,000 or more C-17 passes with a gross weight of 263,008 kg (580 kips), or 50,000 C-130 passes with a gross weight of 79,380 kg (175 kips), or to support a service-defined airfield design type, depending upon mission aircraft, in accordance with References 4 and 9.

2-10 **SELECTION OF REPAIR METHOD.** (Note: This section covers selection of methods for crater repair. A repair matrix is presented in Table 2-1. Shown are expedient and sustainment repair methodologies for runways, taxiways and aprons, and taxiway and apron expansions. The matrix indicates repair options, applicability of FOD covers, and use of unsurfaced and stabilized soils. Notes at the bottom of the table indicate constraints based on aircraft type. Details of the various repair methodologies and considerations of other factors influencing selection of the optimum repair technique are presented in Chapters 4 and 5.

Table 2-1. Repair Suitability for Airfield Surfaces and Aircraft Type

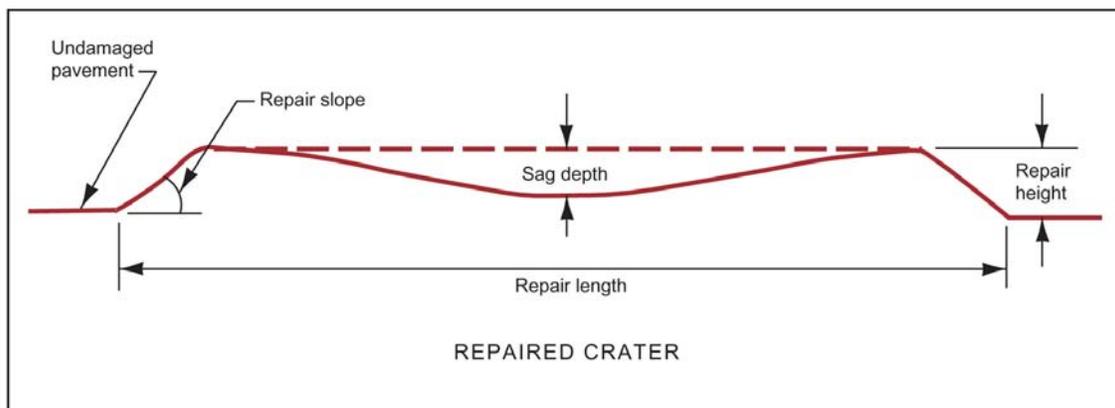
ADR Methods						
Current Repair Methods	Runway Repair		Taxiway/Apron Repair		Taxiway/Apron Expansion	
	Expedient	Sustain	Expedient	Sustain	Expedient	Sustain
Crater Repair						
Crushed stone with FOD cover	X (1)		X (1)			
Crushed stone without FOD cover	X (2)		X (2)			
Sand grid with FOD cover	X (1)		X (1)			
Stone and grout		X		X		
AM-2 mat	X (3)	X (3)	X	X	X	X
Rapid-set materials	X	X	X	X	X	X
Concrete cap		X		X		X
Asphalt		X		X		X
FOD Covers						
FRP (Army)	X (1)		X (1)			
FRP (Navy)	X (1)		X (1)			
FFM (Air Force)	X (1)		X (1)			
Semi-prepared Surfaces						
Unsurfaced					X (4)	X (4)
Stabilized surface	X (4)		X (4)		X (4)	X (4)
<p>Notes:</p> <p>(1) Folded fiberglass mat (FFM)/fiberglass reinforced polyester (FRP) foreign object damage (FOD) covers are suitable only for fighter aircraft and C-130 operations. These FOD covers are not approved for C-17, C-5 Galaxy, C-141 Starlifter, KC-10 Extender, and KC-135 Stratotanker operations.</p> <p>(2) Crushed stone repairs without FOD covers are approved for C-17, C-5, C-141, and KC-10 operations only as a last alternative due to potential FOD damage to the aircraft.</p> <p>(3) AM-2 mat is suitable as a runway surface only for fighter aircraft and C-130 operations, and then only if accomplished as a flush repair and installed and certified in accordance with References 5, 6, and 7. AM-2 is not an approved runway surface for C-17, C-5, C-141, KC-10, and KC-135 operations.</p> <p>(4) Unsurfaced and/or stabilized surfaces are suitable for C-130 and C-17 operations.</p> <p>(5) KC-135s may not operate on any crushed stone or sand grid repairs, with or without FOD covers. They may only operate on permanent repaired surfaces that demonstrated reduced FOD potential.</p>						

2-11 **REPAIR QUALITY CRITERIA (RQC).** Runway repair teams will attempt to make repairs flush with the original pavement surface; however, flush repairs are difficult to achieve in the required time. Repair Quality Criteria (RQC) provides guidance for determining whether nonflush repairs are usable. RQC also provides limits to indicate when repair maintenance is required.

2-11.1 The RQC system is a set of charts and tables that allow quick and accurate determination of allowable crater repair roughness. Different aircraft can withstand varying levels of runway roughness. Weather and runway conditions may affect an aircraft's performance. Aircraft operations may also affect RQC since different operations call for different procedures and aircraft configurations. Detailed instructions for calculation of RQC are provided in Reference 3.

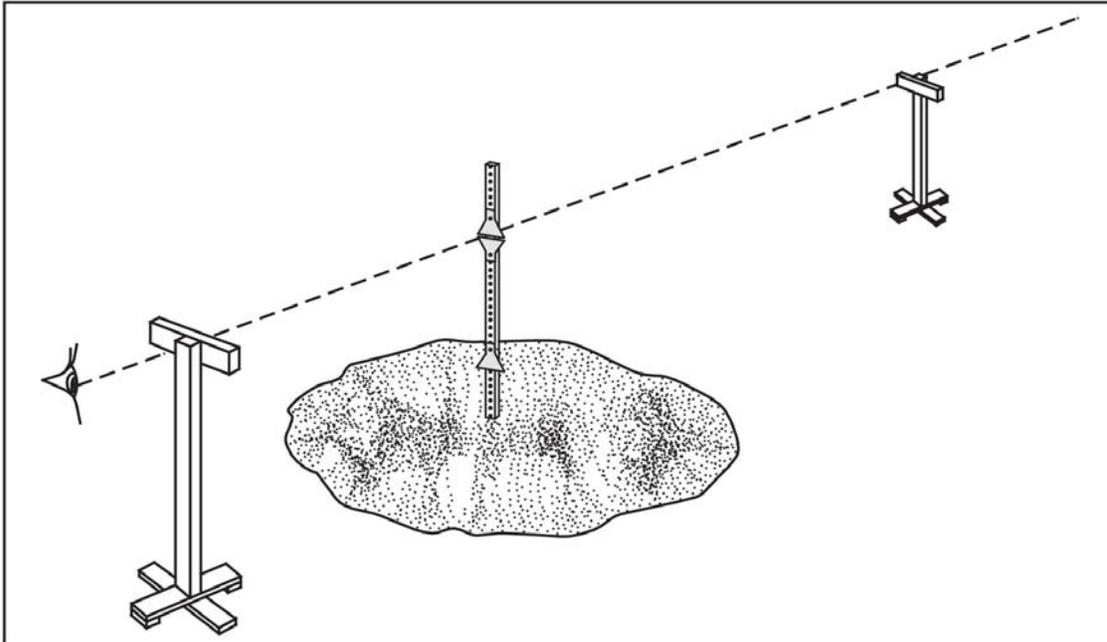
2-11.2 Pertinent RQC features of a repaired crater are shown in Figure 2-3. Critical values are: repair height, sag depth, and repair slope. The allowable repair height is determined from a specific RQC chart for a specific aircraft under specific operating and weather conditions. The actual crater repair height, measured as the difference between the height of the crater repair surface and the undamaged pavement surface, cannot exceed the maximum allowable value. The allowable crater repair height is generally a single number 25 to 152 mm (1 to 6 in.); however, an "F" or "FF" may be designated which indicates that the crater (or two successive craters, if FF is designated) must be a flush repair. The "F" indicates the requirement for a flush repair for a single crater, and an "FF" designation indicates the requirement for a flush repair for each of two successive craters. A flush repair cannot exceed ± 20 mm (± 0.75 in.) from the original undamaged pavement surface. All spall repairs are considered to be flush repairs. An expedient method of determining the height of a crater repair above the undamaged pavement is the use of stanchions and an elevation target as shown in Figure 2-4. The crater height is the difference between the elevation rod readings at the top of the repair and on the undamaged pavement. Detailed guidance for the assembly and use of stanchions for establishing the extent of pavement upheaval around the crater and repair quality are provided in Appendix A.

Figure 2-3. Repaired Crater



2-11.3 Sag is defined as the maximum amount, in inches, that a repair surface drops below the maximum repair height. Allowing sag permits a repair to degrade with aircraft traffic without requiring excessive maintenance during sortie operations. Allowable sag depth is 50 mm (2.0 in.) for craters except for flush repairs for which the allowable sag

Figure 2-4. Profile Measurement of Filled Crater



depth is only 20 mm (0.75 in.) since by definition flush means ± 20 mm (0.75 in.). Sag depth can also be measured using line of sight stanchions.

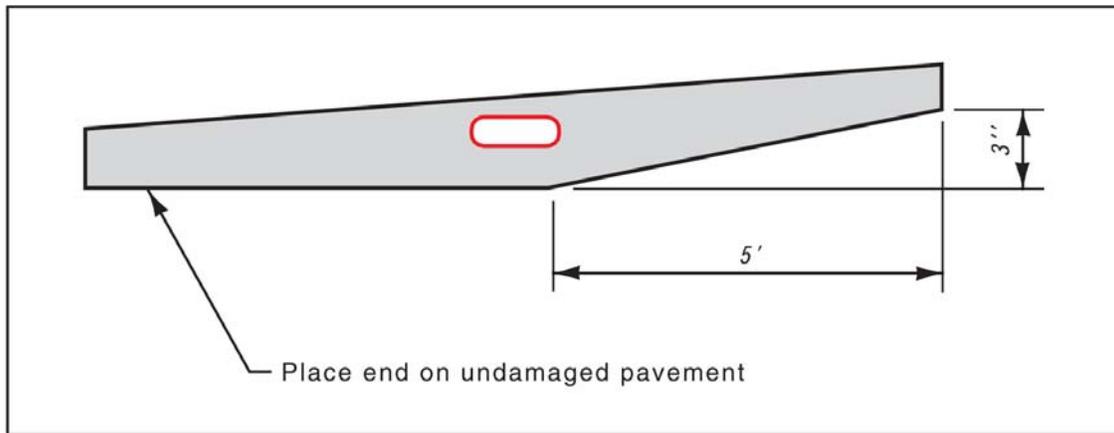
2-11.4 The maximum allowable repair slope is 5.0 percent change with respect to the undamaged pavement surface except when located in the landing touchdown zone where the maximum allowable repair slope is 3.4 percent. The device shown in Figure 2-5 may be used to determine change in slope.

2-12 REPAIR EVALUTION METHODS.

2-12.1 **Acceptance Criteria.** Crater repairs must be evaluated before acceptance for aircraft operations. The following areas should be considered:

2-12.1.1 **Repair Compaction.** The strength of the backfill, debris, or subgrade materials must be verified. Depending upon the repair method used, the thickness and strengths of all surface and/or base course materials must also be verified. The soil structure should be tested using a dynamic cone penetrometer (DCP) to determine CBRs of each layer. These tests must be accomplished before placing the FOD covers, AM-2 matting, stone and grout, asphalt, concrete, or other surface materials that would prevent the use of the DCP. DCP measurements conducted according to procedures described in Appendix J of Reference 8b and Reference 12.

Figure 2-5. Five Percent Change of Slope (To convert feet to meters, multiply by 0.3048. To convert inches to centimeters, multiply by 2.54)



2-12.1.2 Surface Roughness. The final grade of the repair must be checked using line-of-sight profile measurement stanchions, upheaval posts, or string lines to ensure the repair meets surface roughness criteria contained in Reference 3. Procedures are described in T.O. 35E2-5-1, Crushed-Stone Crater Repair and Line-Of-Sight Profile Measurement for Rapid Runway Repair. In the case of a crushed stone repair without a FOD cover, the repair surface should be checked for loose aggregate or FOD objects.

2-12.1.3 FOD Covers

2-12.1.3.1 FOD covers should be no more than 5 degrees off parallel with the runway centerline.

2-12.1.3.2 Check connection bolts and verify that all connections between panels are tight and secure.

2-12.1.3.3 Check anchor bolts and verify that all bolts are secure and that the FOD cover is held snugly against the pavement surface. In taxiway and apron applications, the leading and trailing edges of the FOD cover must be anchored. The side edges must also be anchored if the cover is located in an area where aircraft will be required to turn.

2-12.1.4 Setting/Curing. If the repairs are capped with concrete, stone and grout, or rapid-set materials, verify that the surface material has set and that adequate cure time is allowed prior to aircraft operations. Verification that the material has set can be accomplished by probing the repair with a heavy object to ensure solidification of the repair material. Recommended curing times should be strictly followed to ensure adequate strength improvement prior to applying aircraft traffic.

2-12.1.5 Clean-up. For all repair methods, verify that the repair and adjacent area is cleared of any excess repair materials.

2-12.2 Airfield Certification

2-12.2.1 The on-site engineer responsible for the repair will certify that the repair was accomplished in accordance with the procedures in this ETL.

2-12.2.2 The repair procedures will be documented on an ADR log similar to the one provided in Appendix D. This form will then be updated to reflect subsequent aircraft traffic and required maintenance throughout the history of the repair. If another team replaces the initial repair team, this form should be given to the follow-on team. This information will be useful in planning or performing any further maintenance and/or upgrade of the repairs.

2-12.2.3 Upon completion of repairs, the status of the airfield/repairs should be provided to the airfield manager or other individual authorized to monitor and control on-site aircraft operations. This individual can then issue a NOTAM to change the airfield status. If questions arise, the following contacts may be useful:

2-12.2.3.1 **Navy/Marine Corps Operations.** Contact the Marine Corps Airfield Service Officer. All AM-2 mat airfield installations on which aircraft operate under their own power require certification in accordance with NAWCADLKE-MISC-48J200-0011. AM-2 mat expanses on which aircraft are towed only do not require certification. The inspector must use the instructions and procedures in NAWCADLKE-MISC-48J200-0011 to ensure the structural and functional integrity of AM-2 mat and accessories. Annual certifications will be accomplished after the initial certification.

2-12.2.3.2 Air Force Operations

For questions regarding the suitability of paved airfields, contact Headquarters Air Mobility Command, Airfield Analysis (HQ AMC/DOVS), DSN 779-3112.

For questions regarding the suitability of semi-prepared airfields, contact Headquarters Air Mobility Command, Directorate of Operations (HQ AMC/DOK), DSN 779-3727.

If information on a particular airfield is not available from HQ AMC/DOVS or HQ AMC/DOK, or if a site survey is required, contact Headquarters Air Mobility Command, Tanker Airlift Control Center, Mission Support Cell (HQ AMC TACC/XOPM), DSN 779-4015, who tasks Tanker Airlift Control Elements (TALCE) and/or Air Mobility Operations Groups (AMOG) to perform suitability surveys of paved airfields; or Headquarters Air Force Special Operations Command, Operations and Training (HQ AFSOC/DOO), DSN 579-4073, who tasks Special Tactics Teams (STT) through the 720th Special Tactics Group, Operations and Training (STG/DOO), DSN 579-4250, to perform semi-prepared airfield or landing zone surveys.

CHAPTER 3

SPALL REPAIR

3-1 **DEFINITION OF SPALL.** A spall is damage that does not penetrate through the pavement surface to the underlying layers. Spalls may be up to 1.6 m (5 ft) in diameter. See Figure 2-1.

3-2 **REPAIR CONCEPT.** Repair of a spall requires few procedures: squaring of the edges, cleaning out and removing debris, apply bonding agent if required, placing the fill material, finish the surface to provide a smooth structural bearing surface for aircraft traffic.

3-2.1 **Purpose.** This section provides guidance on repair of spalls. Although spalls are relatively small, they can be numerous. Thus, planning for spall repair should receive close attention.

3-2.2 **Concerns.**

3-2.2.1 **Manufacturer's instructions.** Insure that the manufacturer's instructions, or rules of common practice, are strictly followed.

3-2.2.2 **Bonding.** The spall area must be prepared thoroughly. Sides should be vertical, loose material removed, and the repair surface clean or coated with a bonding agent if applicable. Bad bonding will result in the patch coming loose.

3-2.2.3 **Compaction of cold mix products.** Failure to achieve density can result in rutting of the patch.

3-2.2.4 **Joints.** For all spall repairs, an attempt should be made to maintain continuity of existing pavement joints through the repair by using a spacer, such as a piece of backer rod or plywood, that is the width of the existing joint to maintain the joint across the repair.

3-2.2.5 **Safety.** Follow all safety precautions. Some of the rapid setting materials are toxic and flammable. Wear protective clothing. Dispose of excess material properly.

3-2.2.6 **Debris.** Sweep all areas to be trafficked by aircraft even if debris appears minimal.

3-3 **MATERIALS**

3-3.1 **Conventional Cement/Grout.** A conventional cement grout mixture similar to that indicated for Stone and Grout crater repair may be used in spall repair with pea gravel substituted for 76-mm (3-in.) stone as the aggregate. A rapid setting cement (proprietary) must be used to obtain a compressive strength of 10.3 MPa (1500 psi) in 4 hr. Consult the technical representatives for information on rapid setting cements.

3-3.2 **Cold Mix Products.** Tests conducted on a variety of cold mix patching products have met with limited success. Conventional cold mix asphalt is suitable for small repairs up to 0.61 m (2 ft) in diameter and 1.83 mm (6 in.) deep. Proprietary patching products can be used for both small and large spall repair; however, both types of materials tend to rut easily.

3-3.3 **Proprietary Products.** Numerous commercial-off-the-shelf (COTS) materials are available. Some of these materials, particularly some rapid setting cements, have been tested and approved for DoD use while others have not. Before any material can be used on DoD airfields, it must be certified for use. Contact your service technical representative for the appropriate material and installation procedures for your particular application.

3-3.4 **Technical Representatives**

3-3.4.1 **Army.** U.S. Army Engineer Research and Development Center, Geotechnical and Structures Laboratory, Airfields and Pavements Branch, Internet <http://pavement.wes.army.mil/>, DSN 446-2731, commercial (601) 634-2731.

3-3.4.2 **Navy.** Naval Facilities Engineering Service Center, Code ESC63, Internet <http://www.nfesc.navy.mil/>, DSN 551-1447, commercial (805) 982-1447, FAX (805) 982-1074.

3-3.4.3 **Marine Corps.** Expeditionary Airfields (EAF) Aircraft Rescue and Firefighting (ARFF), HQMC ASL-38, DSN 224-1835, commercial (703) 614-1835/1028/2742, FAX (703) 697-7473.

3-3.4.4 **Air Force.** Headquarters Air Force Civil Engineer Support Agency, Technical Support Directorate (HQ AFCESA/CES), Internet <http://www.afcesa.af.mil/>, DSN 523-6334, commercial (850) 283-6334.

3-4 **SPALL REPAIR/ACCEPTANCE PROCEDURES**

3-4.1 Locate and mark spall areas. The remaining pavement around the spall should be sounded to identify delaminated pavement layers adjacent to the existing spall. Sounding can be accomplished by using a heavy object to strike the pavement surface and identifying changes in the acoustic response.

3-4.2 Square the edges of the spall as vertically as possible and remove loose debris and pavement pieces.

3-4.3 If the surface of the spall is smooth, it may be desirable to groove the bottom crater surface to increase interface friction between the patch and crater surfaces and to reduce the likelihood of the repair slipping out under aircraft traffic.

3-4.4 Prepare the surface of the spall as appropriate for the repair method. For proprietary materials follow the manufacturer's instructions. For cold mix asphalt repairs, the surface should be primed with liquid asphalt if possible.

3-4.5 Prepare proprietary repair materials per the manufacturer's instructions. Cement grout should be mixed following conventional procedures for grout and concrete. Cold mix asphalt needs no preparation.

3-4.6 Place the repair material in the spall area. For grouts, simply screed off the surface even with the surrounding pavement. For cold mix materials place the material in 50-mm- (2-in.-) thick layers compacting each layer with a plate compactor. Overfill the repair 38 mm (1.5 in.) and finish compacting with a vibratory roller. On small repairs a plate compactor can be used. The finished surface should be flush with these existing pavements.

3-5 **SPALL REPAIR ACCEPTANCE CRITERIA.** RQC specify that spall repairs should be flush with the surrounding undamaged pavement with a tolerance of ± 20 mm (0.75 in.).

CHAPTER 4

EXPEDIENT REPAIR METHODS

4-1 EXPEDIENT REPAIR CONCEPT

4-1.1 **Purpose.** Expedient repairs represent the minimum effort required to restore the MOS to a specified operational condition as described in para. 2-7. Desired time to complete expedient repairs is 4 hr after recovery efforts are initiated. However, the actual time to repair individual craters depends upon the availability of personnel, equipment, and proper materials.

4-1.2 **Assumptions.** Equipment and manpower requirements for the various services are shown in Appendix A. Although these requirements are not presented in terms of repair category, policy has been that the Air Force will conduct expedient repairs and the Army will be largely involved in semi-permanent repairs. However, repair effort beyond expedient may involve assets of both services depending on mission requirements. Navy/Marine Corps guidance is that Naval Mobile Construction Battalions have the primary responsibility for airfield repair based on mission requirements. It is assumed that the appropriate assets will be available for any scenario. Time to repair could be affected by the presence of unfriendly elements.

4-2 SELECTION OF REPAIR METHOD

4-2.1 **Aircraft Type and Load.** Each aircraft has distinct characteristics (e.g., wing span, tire pressure, load capacity, braking mechanism) that must be known when choosing the type of repair to accomplish.

4-2.2 **Available Material.** The type and quantity of material (e.g., backfill, crushed stone, fiberglass mat, spall, repair material, soil stabilization agents) available for a repair.

4-2.3 **Available Equipment.** The type and quantity of various pieces of construction equipment (e.g., dozer, front-end loader, roller, concrete mixing equipment) available for a repair.

4-2.4 **Repair Quality Criteria (RQC).** A single number representing the maximum allowable repair height in inches that various aircraft can tolerate on an MAOS. See Reference 3. See para. 2-11.

4-2.5 **Existing Pavement Structure.** The configuration of the current pavement layers (e.g., concrete, asphalt over concrete, asphalt, compacted earth, etc.).

4-2.6 **Time Constraints.** The time allotted to accomplish the repairs before the first aircraft arrival or departure.

4-2.7 **Repair Crew Capability/Equipment/Manpower.** The repair crew’s capacity for the task (e.g., experience, number of repair people, resource availability). Guidance on Equipment and Manpower Requirements is provided in Appendix B.

4-3 CRUSHED STONE REPAIR

4-3.1 **Materials.** Three types of repair methods are presented. Each involves the use of a combination of crushed stone, ballast rock, or debris. Gradation specifications for the ballast rock and crushed stone are shown in Tables 4-1 and 4-2, respectively. Procedures for testing the gradation of materials are detailed in Reference 13. If the repair materials fail to meet the gradation requirements in Tables 4-1 and 4-2, the repair team should consider using an unsurfaced repair (Section 4-8.1), chemically stabilizing the materials (Section 4-8.2 and Ref. 11), or mechanically stabilizing the material with sand grid (Section 4-4).

Table 4-1. Specifications for Ballast Rock

U.S. Standard Sieve Size	Allowable Range (Weight % Passing)
3 in.	100
2-1/2 in.	90 – 100
2 in.	35 – 100
1-1/2 in.	0 – 70
1 in.	0 – 15
3/4 in.	0 – 10
1/2 in.	0 – 5

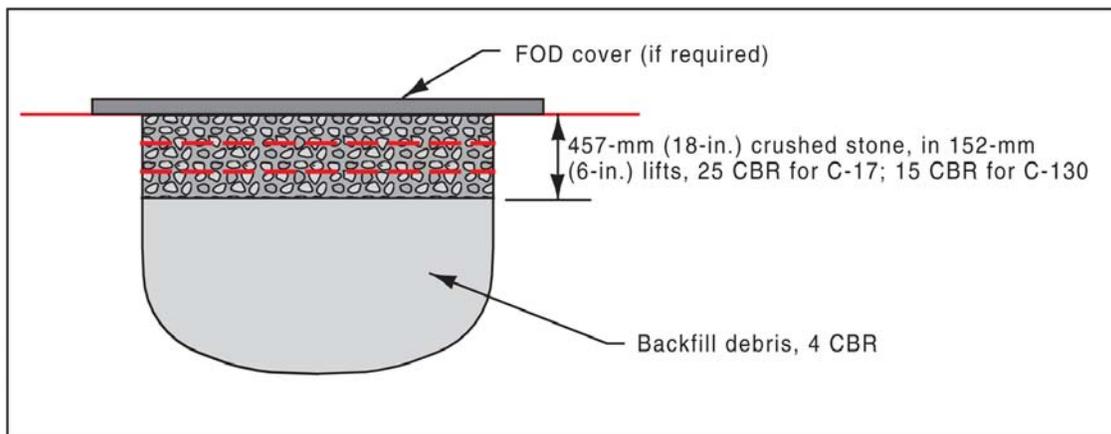
**Table 4-2. Specifications for High Quality,
Well-Graded Crushed Stone**

Sieve Designation	Crushed Stone		
	No. 1	No. 2	No. 3
76 mm (3 in.)	--	--	--
64 mm (2.5 in.)	--	--	--
50 mm (2 in.)	100	--	--
37.5 mm (1.5 in.)	70-100	100	--
25 mm (1 in.)	45-80	60-100	100
19.1 mm (3/4 in.)	--	--	--
12.5 mm (1/2 in.)	30-60	30-65	40-70
4.75 mm (No. 4)	20-50	20-50	20-50
2.0 mm (No. 10)	15-40	15-40	15-40
0.425 mm (No. 40)	5-25	5-25	5-25
0.075 mm (No. 200)	0-8	0-8	0-8

4-3.2 Types of Repair Methods.

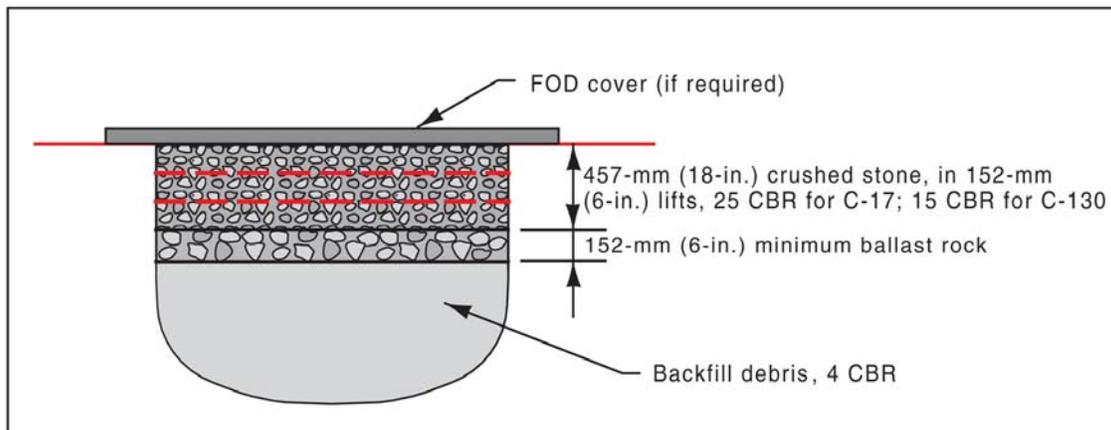
4-3.2.1 **Debris Backfill.** Use when subsurface debris is plentiful and suitable for filling the crater. Fill the crater with debris up to 457 mm (18 in.) below the surface. Fill the remaining portion of the crater with crushed stone meeting the gradation requirements shown in Table 4-2. See Figure 4-1.

Figure 4-1. Debris Backfill



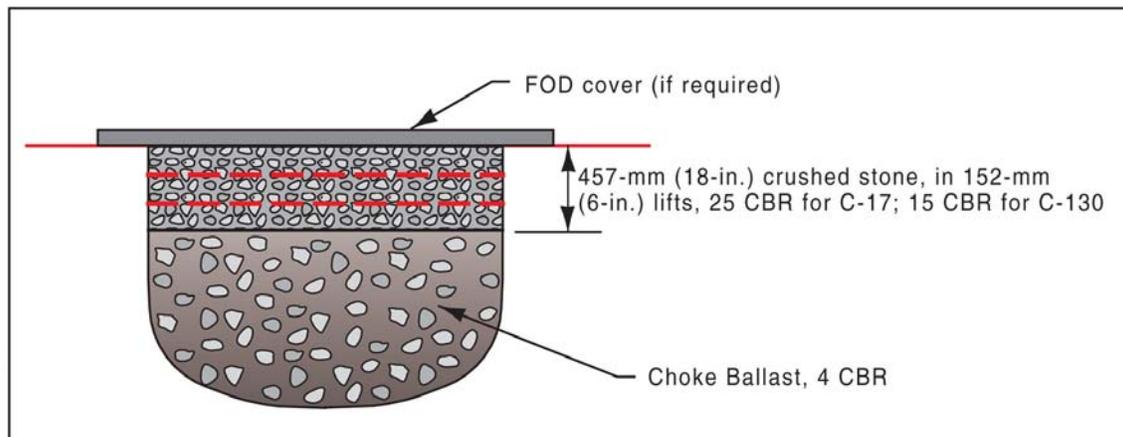
4-3.2.2 **Choke Ballast over Debris.** Use when subsurface debris is suitable for fill, but limited. Fill the crater with useable debris up to a maximum of 609 mm (24 in.) below the pavement surface. Continue to fill the crater up to 457 mm (18 in.) below the surface with ballast rock meeting the requirements shown in Table 4-1, and fill the remaining portion of the crater with crushed stone meeting the requirements shown in Table 4-2. See Figure 4-2.

Figure 4-2. Choke Ballast over Debris



4-3.2.3 **Choke Ballast Repair.** Use when water is standing in the crater or if subsurface material is unsuitable for filling the crater. Fill the crater with ballast rock meeting the requirements shown in Table 4-1 up to 457 mm (18 in.) below the pavement surface. Fill the remaining portion of the crater with crushed stone meeting the requirements shown in Table 4-2. See Figure 4-3.

Figure 4-3. Choke Ballast



4-3.3 Procedures.

4-3.3.1 Clear debris from around the crater at least 9.1 m (30 ft) in all directions to allow identification of the upheaved pavement surface. Identification and removal of all upheaval or damaged pavement is critical. **It cannot be rolled down flush with the existing pavement and left.** The upheaved pavement will eventually break up and create additional problems adjacent to the crater repair.

4-3.3.2 Perform profile measurement and visual inspection to identify and mark upheaval around the crater.

4-3.3.3 Remove upheaved pavement using an excavator with bucket or moil point attachment, and a front-end loader. A dozer may also be used, depending on the runway surface.

4-3.3.4 All debris material in excess of 304 mm (12 in.) in diameter must be removed or reduced in size. Breaking the pavement into smaller pieces will minimize the potential for voids and settling problems in the future.

4-3.3.5 Push unusable debris at least 9 m (30 ft) off the MOS and pile no higher than 0.9 m (3 ft).

4-3.3.6 Place backfill material (debris and/or ballast rock) into the crater in accordance with the repair procedure chosen. Note: If settling problems are anticipated, placement of a geotextile fabric between dissimilar backfill materials is recommended to prevent intermingling. The use of a medium weight geotextile is

recommended for separation applications in pavements and the National Stock Number for the DOD recommended products is NSN: 5675-01-471-2647. Appropriate geotextile products are not included in some ADR kits. This backfill should have a minimum strength of 4 CBR for a depth ranging from 18 to 30 inches below the pavement surface. The maximum CBR reasonably attainable should be achieved for backfill below 30 in. from the surface. Generally this can be achieved by normal traffic of the construction equipment used to fill, spread, and roll down the backfill. For small craters (less than 20-ft diameter) where heavy equipment cannot operate, the backfill material should be compacted to the greatest extent possible with the assets available (hand tampers, pneumatic tampers, plate compactors, etc.). If the crater backfill cannot be adequately compacted, the repair may provide initial operational capability, but will require frequent maintenance. The CBR may be checked using a Dynamic Cone Penetrometer following instructions given in References 8a and 8b.

4-3.3.7 Fill the crater with crushed stone material and compact, placing it in lifts approximately 152 to 177 mm (6 to 7 in.) thick. For jet aircraft operations, limit the aggregate size to a maximum of 25 mm (1 in.) in the top 152 mm (6 in.) of the crushed stone repair. Overfill the crater by approximately 76 mm (3 in.) above the original pavement surface height. Compact each lift of crushed stone using a **minimum of four passes** of a 5-ton single-drum vibratory roller or **two passes** of a 10-ton vibratory roller. One pass of the roller means traveling across and back in the same lane. If the crushed stone material is placed upon soft subgrade materials, it may be beneficial to separate the material using a geotextile fabric and place the crushed stone material in thicker lifts. In any case, the crushed stone should be compacted with a **minimum of four passes** of a single-drum vibratory roller or **two passes** of a 10-ton vibratory roller per each 152 mm (6 in.) of thickness. A 457-mm (18-in.) crushed stone layer should receive a **minimum of 12 passes** with a single-drum 5-ton vibratory roller or **six passes** with a 10-ton vibratory roller prior to cut for the final grade.

4-3.3.8 Grade the compacted crushed stone to approximately 25 mm (1 in.) above the pavement surface.

4-3.3.9 Compact the crushed stone using an additional two **passes** of a 5-ton single-drum vibratory roller or **one pass** with a 10-ton vibratory roller. The crushed stone layer should have a **minimum 25 California Bearing Ratio (CBR) to support C-17 operations or a minimum 15 CBR to support C-130 operations**. CBR values may be determined using a Dynamic Cone Penetrometer (DCP). For guidance on use of the DCP, see References 8a and 8b.

4-3.3.10 Perform profile measurements. The repaired crater must not exceed the maximum RQC of ± 19 mm (± 0.75 in.). A repair outside this tolerance may still be useable, depending on its location, but will have a much shorter life before requiring additional maintenance to bring it back within this limitation and may result in aircraft damage.

4-3.3.11 The crushed stone repair is complete at this point. Depending on the particular location on the airfield or the type of mission aircraft, it may be left uncovered

or may require a FOD cover to reduce debris damage to aircraft. Guidance for assembly and placement of FOD covers is presented in para. 4-5.

4-4 SAND-GRID REPAIR. (See Figures 4-4 and 4-5.)

4-4.1 Clear debris from around the crater at least 6 m (20 ft) in all directions to allow identification of the upheaved pavement surface. Identification and removal of all upheaval or damaged pavement is critical. It cannot be rolled down flush with the existing pavement and left. The upheaved pavement will eventually break up and create additional problems adjacent to the crater repair.

4-4.2 Perform a profile measurement and visual inspection to identify and mark the upheaval around the crater.

Figure 4-4. Sand Grid Repair

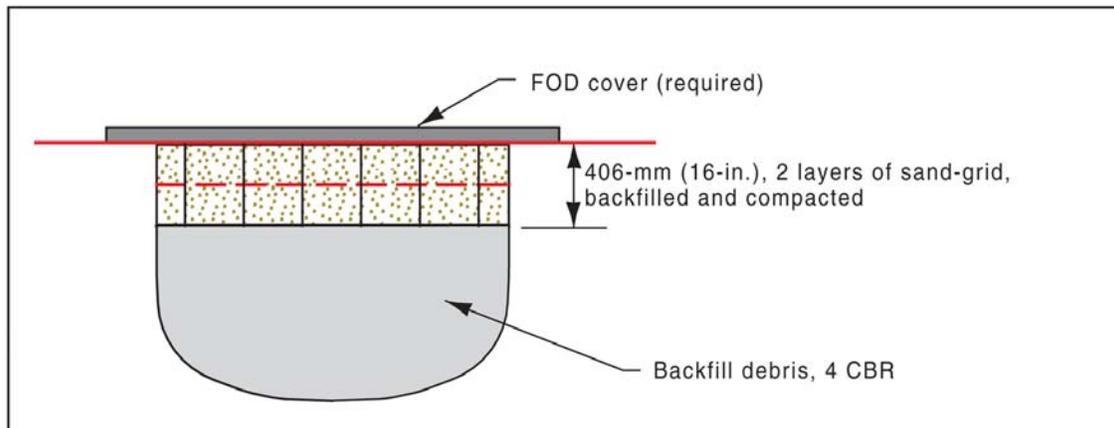
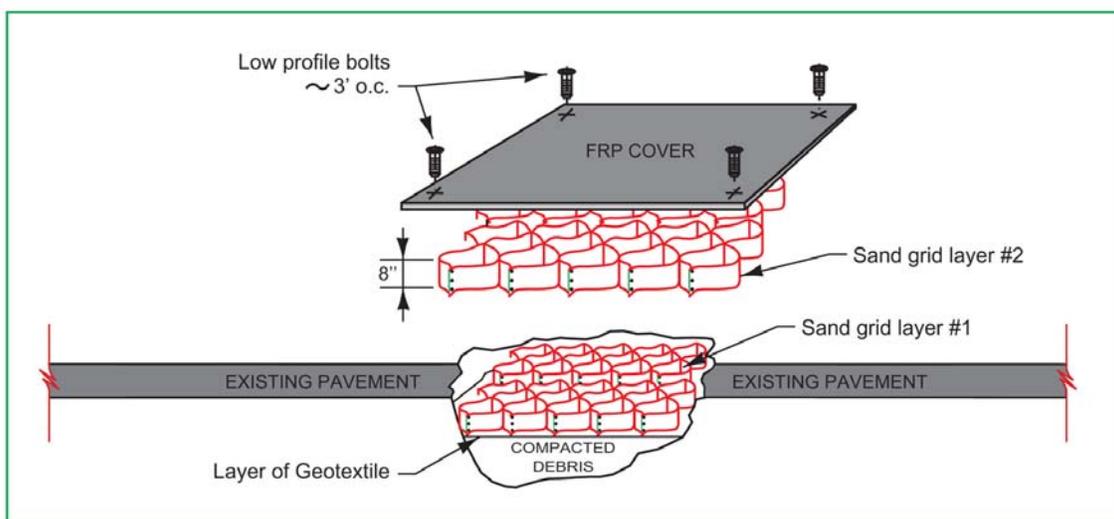


Figure 4-5. Sand Grid Repair Detail



- 4-4.3 Break out the upheaved pavement.
- 4-4.4 Square the sides of the crater to vertical from the original pavement surface down to 406 mm (16 in.).
- 4-4.5 All debris material in excess of 304 mm (12 in.) in diameter must be removed or reduced in size.
- 4-4.6 Move unusable debris at least 9 m (30 ft) off the MOS and stockpile no higher than 0.9 m (3 ft).
- 4-4.7 Standing water in the crater should be pumped or bailed out, if possible, using any means available.
- 4-4.8 Any reinforcing material protruding from the original pavement must be cut off and removed.
- 4-4.9 Clean an area 30 m (100 ft) from the crater edge for assembling the FOD cover, if possible. It is preferable that the mat assembly site be no further than 0.8 km (0.5 mile) from the repaired crater. An area approximately 15 m by 15 m (50 ft by 50 ft) square is required for assembling the mat.
- 4-4.10 Backfill the crater with useable debris or a combination of debris, crushed stone, or ballast rock (minimum 156 mm (6 in.)). Level this material to 406 mm (17 in.) below the original pavement surface. This measurement is critical to ensure a flush repair.
- 4-4.11 Compact the debris backfill to a minimum 4 CBR.
- 4-4.12 Line the backfilled crater with a geotextile to separate dissimilar materials. The use of a medium weight geotextile is recommended for separation applications in pavements and the National Stock Number for the DOD recommended products is NSN: 5675-01-471-2647. Appropriate geotextile products are not included in some ADR kits.
- 4-4.13 Place the first layer of sand-grid (NSN: 5680-01-198-7955) parallel to the centerline of the runway. Place fill material or short U-shaped pickets in the corners of the grid and along the sides to hold it in place.
- 4-4.14 Backfill the sand-grid using cohesionless material, if possible. Overfill the grid by approximately 50 mm (2 in.).
- 4-4.15 Compact this first layer of fill material. Typically, two passes with a vibratory roller are required for compaction.
- 4-4.16 After compaction, all excess material must be struck off level with the top of the sand-grid. This is critical to ensure a flush repair meeting the RQC.
- 4-4.17 Place a geotextile over the first layer of sand-grid.

4-4.18 Lay the second layer of sand-grid perpendicular to the first layer and the runway centerline.

4-4.19 Backfill and overfill the sand-grid using cohesionless material, if possible.

4-4.20 Compact this layer of backfill. If the two sand-grids were installed and compacted properly, the sand-grid should not protrude above the pavement surface.

4-4.21 Grade off excess material so the repair is flush with the original pavement surface.

4-4.22 Install and anchor the FRP mat cover. The sand-grid repair must have a FOD cover installed to be operational. Guidance for assembly and placement of FOD covers is presented in para. 4-5.

4-4.23 Verify that the repair does not exceed surface roughness criteria.

4-5 **FOREIGN OBJECT DAMAGE (FOD) COVERS.** FOD covers are generally required to prevent damage to aircraft engines. The Army, Navy/Marine Corps, and Air Force each have its version of a plastic type FOD cover. Descriptions of each type of mat and guidance for assembly of the mat over craters are presented in this section. Although AM-2 matting can be used as a FOD cover, it is more appropriately used as a structural surfacing for crater repair.

4-5.1 **Army FOD Cover Assembly Procedures**

4-5.1.1 This FOD cover is referred to as a Fiberglass Reinforced Panel (FRP) mat. The Army ADR kit contains FRP panels in three sizes. All FRP panels are 13 mm (0.5 in.) thick. There are four full-size panels (5.49 m by 2.01 m [18 ft by 6.6 ft]); two right-half panels (2.62 m by 2.01 m [8.6 ft by 6.6 ft]); and two left-half panels (2.83 m by 2.01 m [9.3 ft by 6.6 ft]). When assembled, this cover will cap one crater 7.6 m (25 ft) in diameter. See Table 4-3.

Table 4-3. Army FRP Panel Types

Type	Size, m (ft)	Number per Kit
Full Size	5.49 × 2.01 (18 × 6.6)	4
Right Half	2.62 × 2.01 (8.6 × 6.6)	2
Left Half	2.83 × 2.01 (9.3 × 6.6)	2

4-5.1.2 Assembled mat dimensions are 8.11 m by 8.11 m (26.6 ft by 26.6 ft). On one side and on one end of the mat are holes 63.5 mm (2.5 in.) in diameter for inserting anchor bushings or connector bushings.

4-5.1.3 Position the panels on a smooth level surface for assembly. Assemble in a brickwork-type pattern.

4-5.1.4 Install and tighten panel-connecting bolts as each row of panels is aligned.

4-5.1.5 Pull the assembled mat into position over the crater. The mat must overlap the crater edges by at least 304 mm (12 in.) on each side.

4-5.1.6 Secure the mat on the leading and trailing edge or perpendicular to the direction of flight. Drill pilot holes for the anchor bolts.

4-5.1.7 Anchoring the FRP mat over damaged concrete pavement uses a Wej-it® anchor bolt. There are two sizes of Wej-it® bolts in the kit: the bolt 177.8 mm long by 15.9 mm in diameter (7 in. long by 0.625 in. in diameter) is installed using rotary hammer tools; the bolt 177.8 mm long by 19.1 mm in diameter (7 in. long by 0.75 in. in diameter) is placed with the SEE (for this bolt, a pilot hole must be drilled 203 mm [8 in.] deep with a 19.1-mm [0.75-in.] bit).

4-5.1.8 Anchoring the FRP mat over damaged asphalt concrete pavement uses a screw spike style F head. This screw is 152.4 mm long by 19.1 mm in diameter (6 in. long by 0.75 in. in diameter). A pilot hole must be drilled 177 mm deep by 15.9 mm in diameter (7 in. deep by 0.625 in. in diameter).

4-5.2 **Navy-Marine Corps FOD (FRP)**

4-5.2.1 **Airfield Damage Repair (ADR) Kit Description**

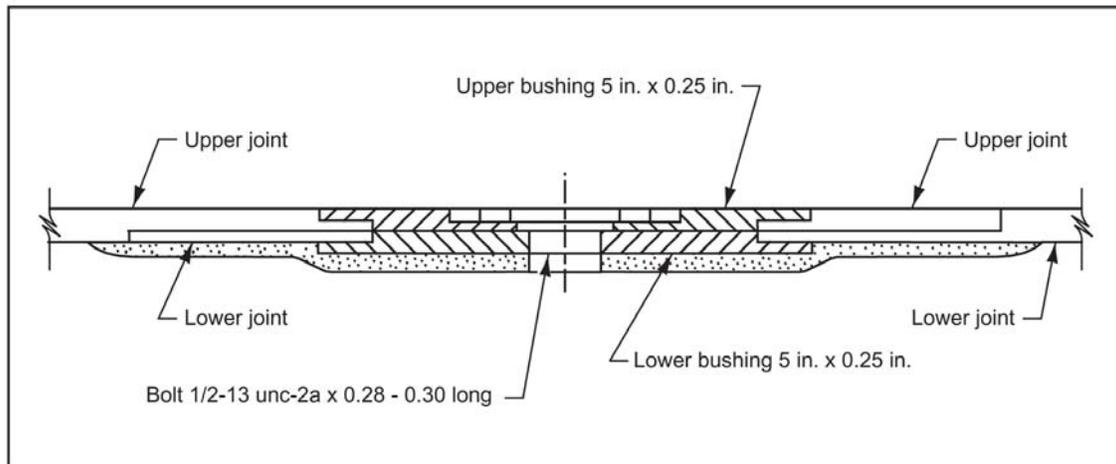
4-5.2.1.1 The Navy-Marine Corps ADR kit consists of an air-shippable International Organization for Standardization (ISO), Series 1C, 8- by 8- by 20-ft container; interior track/rail hardware; and the necessary tools, materials, and ancillary equipment to effect the assembly, installation, and maintenance of four 10.8-m-wide by 9.92-m-long (34-2/3-ft-wide by 32-ft-long) (approximate dimensions) FRP FOD cover panels; or one 21.5-m-wide by 19.2-m-long (69-1/3-ft-wide by 62-ft-long) (approximate) FRP FOD cover panel. The ADR kit has been designed to enable rapid response to a runway repair Foreign Object Damage (FOD) requirement.

4-5.2.1.2 **Panel Description.** All FRP panels are 9.5 mm (3/8-in.) thick. Five types of panels are provided, as shown in Table 4.4. Panels are assembled into mats by means of bolts fitted through bushings that are incorporated into the panels at the time of manufacture (Figure 4-6). Tapered ramp panels are used at mat edges, perpendicular to the direction of air traffic, to facilitate the passage of aircraft tail hooks. Anchor bolts secure the mats to the pavement surface along the mat edges.

Table 4-4. Navy-Marine Corps FRP Panel Types

Type	Size, m (in.)	Number per Container
Full-size	5.5 × 2 (216 × 80)	24
Left half-size	2.9 × 2 (112 × 80)	8
Right half-size	2.9 × 2 (112 × 80)	8
Ramp panel	5.3 × 0.9 (208 × 36)	16
Center panel	5.5 × 1.0 (216 × 40)	8

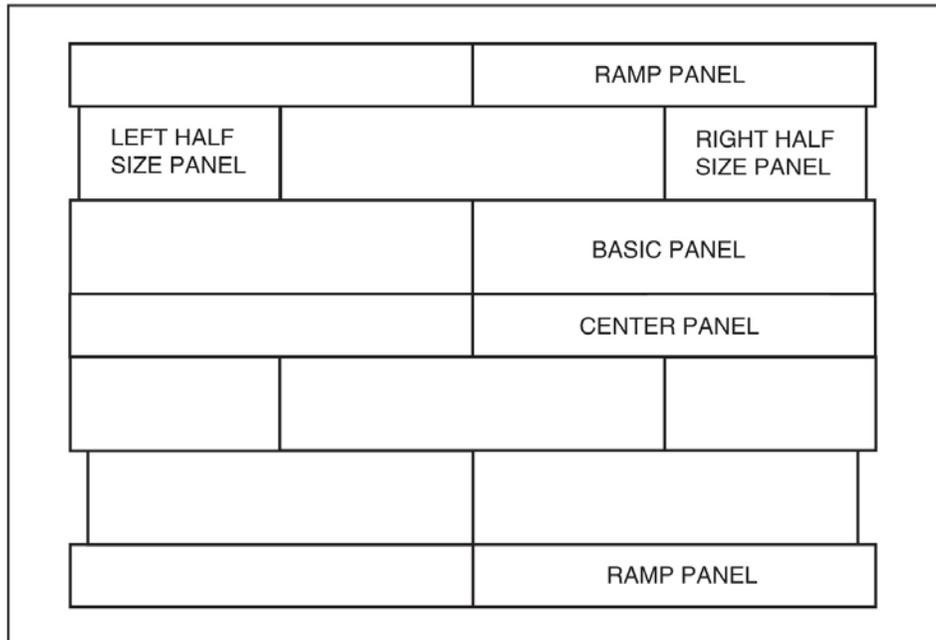
Figure 4-6. FRP Panel Bushing Detail (To convert inches to millimeters, multiply by 25.4)



4-5.2.1.3 FRP Mat Configuration. A typical FRP mat configuration (Figure 4-7) consists of the following panels required to cover a 7.6-m- (25-ft-) diam crater:

- 4 Ramp panels
- 6 Basic panels
- 2 Center panels
- 2 Left half-size panels
- 2 Right half-size panels

Figure 4-7. Typical Navy-Marine Corps FRP Mat Layout



4-5.2.1.4 **Typical Container Complement.** Based on the foregoing, a typical complement of panels in a container would be:

- 16 Ramp panels
- 24 Basic panels
- 8 Center panels
- 8 Left half-size panels
- 8 Right half-size panels

When these panels are assembled into a mat, they will cover a 15-m- (50-ft-) diam crater. Panel towing assembly is also included in this kit.

4-5.2.1.5 **Mat Assembly Sites.** Mat assembly sites should be within 400 m (0.25 mile) of the craters to be repaired, on a firm surface (not necessarily paved), so located that the mats can be towed to crater sites without traversing obstructions or interfering with other activities on the runway or taxiway. Mat assembly sites and routes from sites to craters must be clear of unexploded ordnance (UXO) and may require decontamination of chemical warfare agents. A mat can be towed over uneven terrain free from sharp obstructions such as rocks or tree stumps.

4-5.2.1.6 **Mat Assembly.** A mat for a 15-m- (50-ft-) diam crater can be assembled by a crew of 14 in 1.5 hr, including removal from the container, layout, and assembly. Generally, there is time to assemble a mat while the crater is being backfilled. Therefore, begin mat assembly as soon as the approximate size of the repair area is known. Alternatively, mats can be preassembled to a nominal size as in Figure 4-7 and expanded should larger craters be encountered.

4-5.2.1.7 **Assembly Procedure.** Assemble mats as shown in Figure 4-8. Start in the center of mat and work outward so that two crews can work at one time. Brief the panel crew to ensure that all personnel understand the order of panel assembly. Adjust panels into position with a pry bar. Carry bolts, bushings, and tools in lineman's tool bags. The finished mat will have a pattern similar to that in Figure 4-7 depending on the mat size. The following is a recommended sequence for assembling a FOD cover.

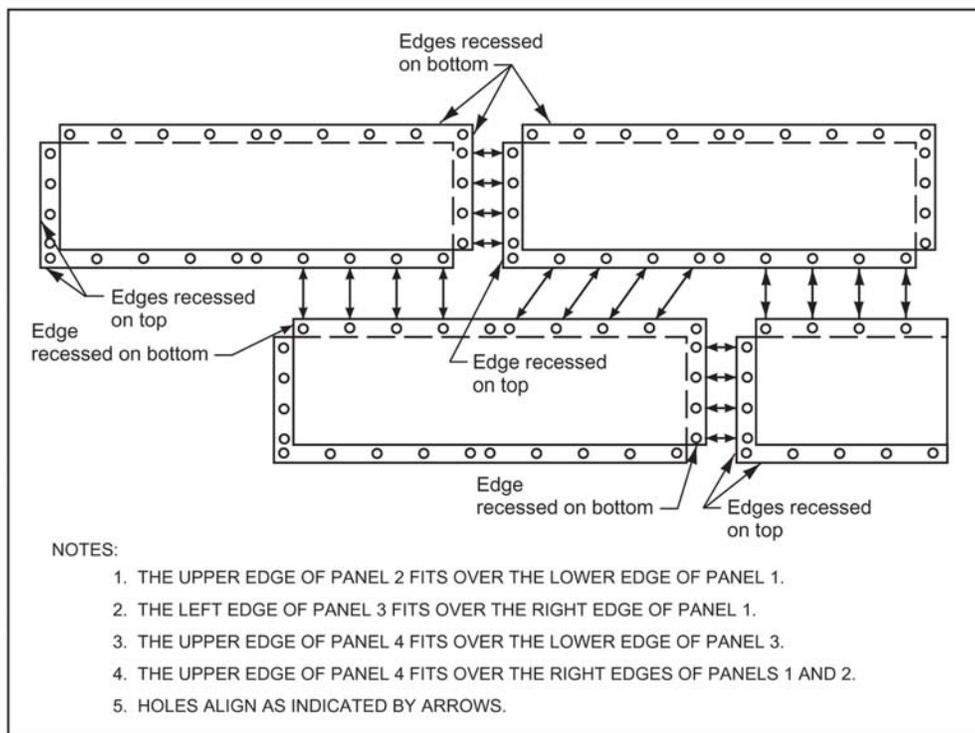
(1) Estimate the dimensions of the required crater FOD cover. This can be done as soon as the crater to be repaired is identified. After removal of upheaved material, the desired cover dimensions can be defined more accurately. **Note: Provide a minimum overlap of 0.6 m (24 in.) over the crater breakout boundary. (Refer to Figures 4-8 and 4-9 during the assembly procedure.)**

(2) Begin mat assembly from the center of the mat, working in both directions toward the ends (ramp panels) that will be aligned with Minimum Operating Strip (MOS) when the mat is installed. (The MOS is the smallest area that must be repaired in order to launch and recover aircraft after an attack.)

(3) Align bolts and bushings carefully. A screwdriver is useful for alignment. Tapping a 50-mm by 102-mm (2-in. by 4-in.) block of wood along a panel edge is another technique for alignment of the bolts and bushings.

(4) Tighten bolts with socket wrenches starting from a panel center, working toward panel edges.

Figure 4-8. Mat Assembly Sequence



4-5.2.1.8 **Crater Area Cleanup.** Crater area cleanup consists of the following steps:

(1) Sweep area around backfilled crater carefully with a rotary sweeper.

(2) Sweep pavement route over which mat is to be towed to extent that will preclude dragging debris onto the backfilled crater surface.

4.5.2.1.9 **Mat Towing.** A large assembled mat can be towed by a 2721 kg- (6,000-lb-) capacity, rough-terrain forklift; a 5-ton 6 by 6 cargo truck; or a vehicle with equivalent towing capability. Towing is accomplished by use of the FRP Cover Towing System. Two towing configurations are illustrated: (1) for towing a small mat, approximately 16.7-m by 10-m (34-2/3-ft by 32-ft) long (Figure 4-10) and (2) for towing a large mat 21.5-m by 19.2-m (69-1/3-ft by 62-ft) long (or similar size) (Figure 4-11). For either size mat position the mat so that the center of mat is lined up with centerline of crater to be covered. Pull straight ahead over the crater centerline. Ensure that map overlaps the crater by several feet on all sides.

Figure 4-9. Mat Assembly

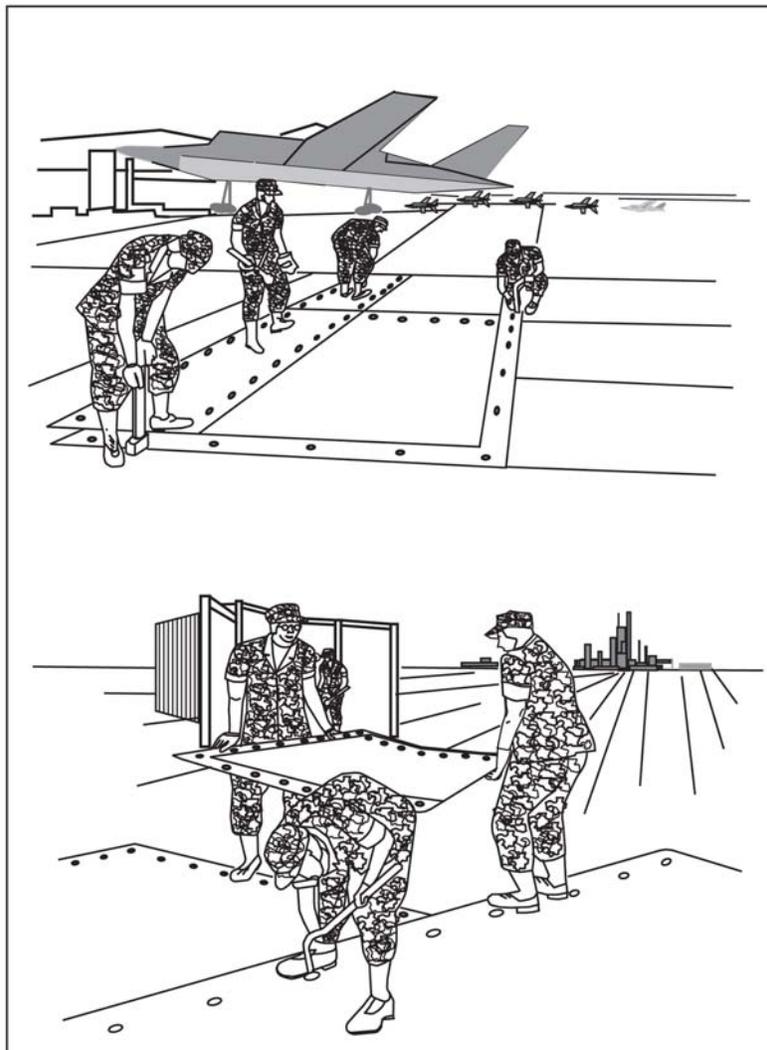


Figure 4-10. Small FRP Cover Towing System

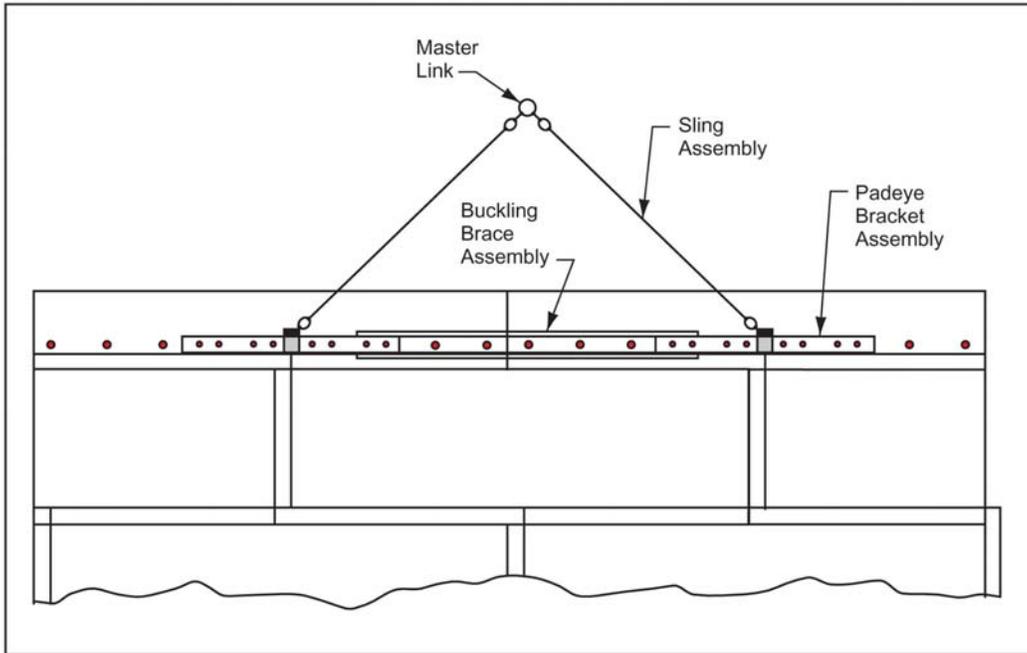
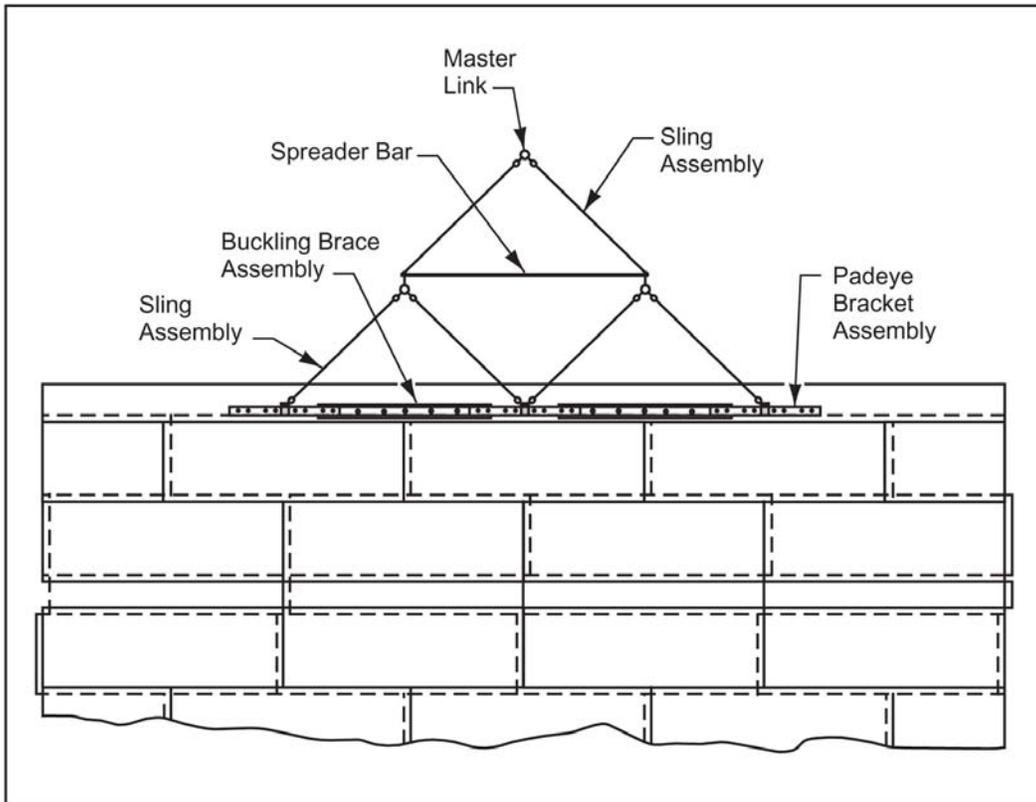


Figure 4-11. Large FRP Cover Towing System



4-5.2.1.10 **Mat Anchorage – Portland Cement Concrete Pavement.** The mat is fastened to the concrete pavement with 0.625- by 5-in. WEJ-IT bolts through the bushings in the mat edges into holes drilled in the pavement. To anchor the mat, perform the following steps:

- (1) Mark drill bit with tape to ensure drilling to a depth of 203 mm (8 in.).
- (2) Drill holes for WEJ-IT bolts using a bushing as a template. Drill holes 203 mm (8 in.) deep to ensure that the bolt can be driven into place if cuttings remain in hole.
- (3) Clear dust from hole with a compressed airjet or airbulb.
- (4) Insert WEJ-IT bolt through the top bushing, ensuring that the wedges and washer are properly set, and stamp it into place to start.
- (5) Drive the bolt into place carefully with a sledge hammer. Too hard of an initial blow may force the bolt's wedges prematurely.
- (6) Torque bolts to 81.36 joules (60 ft-lb).
- (7) If a bolt protrudes above bushing, grind off bolt head until it is flush with bushing.
- (8) Complete installation by sweeping mat and adjacent pavement.

4-5.2.1.11 **Mat Anchorage – Asphalt Concrete Pavement.** An enlarged bushing is provided (Reference 7) for fastening the mat to AC or earth. Alternatively, a WEJ-IT bolt may be used in a larger hole and grouted in.

(1) Large Bushing Method. Use the following procedures for the large bushing method:

- (a) Remove regular bushing from prefabricated panel with a hammer and chisel, being careful so as not to damage panel.
- (b) Provide a countersink for the large bushing by drilling a 63.5-mm- (2.5-in.-) diam hole in AC pavement concentric with the center of hole in the mat, to a depth of 47.6 mm (1.875 in.). Use tape on drill bit to determine the drilled depth.
- (c) Insert large bushing and drill a 38.1-mm (1.5-in.) hole into AC pavement through hole in bottom of bushing.
- (d) Remove bushing.
- (e) Insert earth anchor and seat it so that it will not project above mat surface.
- (f) Replace bushing over earth anchor, and fasten bushing to earth anchor.

(2) WEJ-IT Bolt Method. Use the following steps for the WEJ-IT bolt method:

- (a) Remove bushing from mat as described in para. 4-5.2.1.11(1)(a).
- (b) Through bushing hole in mat, drill a 38.1-mm (1.5-in.) hole in AC to a depth of 127 mm (5 in.), using bushing as a template.
- (c) Remove wedges from WEJ-IT bolt.
- (d) Mix and pour polyurethane or other rapid setting polymer material into hole in AC to a level such that when WEJ-IT bolt is inserted, grout level will be just below underside of bushing.
- (e) Insert WEJ-IT bolt into bushing so that top of nut is flush with bushing.
- (f) Insert bolt into grout material and step on it until polymer has set (approximately 1 min).
- (g) Tighten bushing down with WEJ-IT bolt nut and wrench.

4-5.3 **Air Force Folded Fiberglass Mat (FFM).**

4-5.3.1 The FFM is air-transportable, can be moved easily by vehicles, can be positioned at greater distances from airfield pavement surfaces, and can be stored indoors out of the elements.

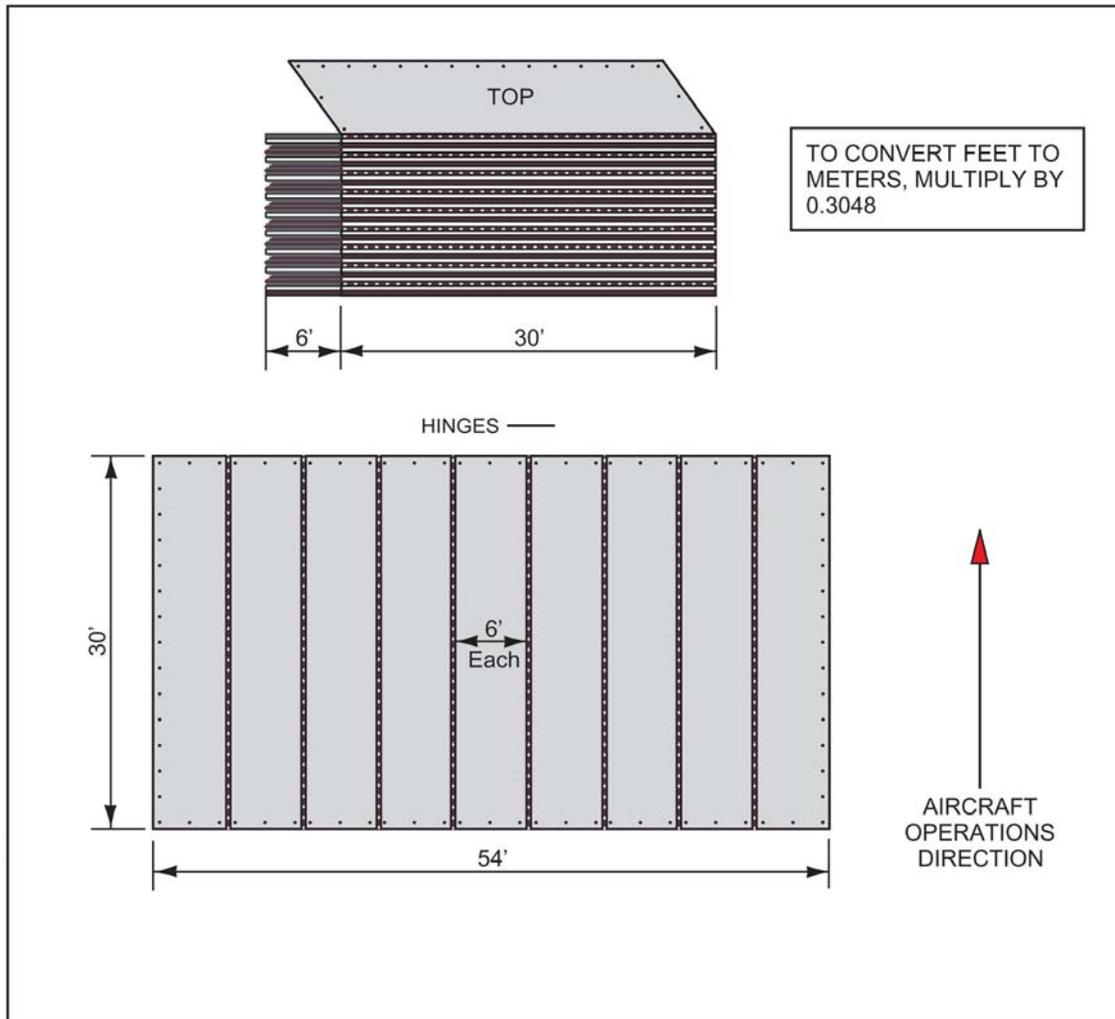
4-5.3.2 A standard FFM weighs about 1360 kg (3,000 lb) and consists of nine fiberglass panels, each 1.83 m wide by 9.14 m long by 12.7 mm thick (6 ft wide by 30 ft long by 0.5 in. thick). Elastomer hinges 76.2 mm (3 in.) wide connect the panels. When folded, these mats are 1.83 m wide by 9.14 m long and 203 to 254 mm thick (6 ft wide by 30 ft long and 8 to 10 in. thick). (See Figure 4-12)

4-5.3.3 This repair system also includes joining panels and two support mat kits. The joining panels come in 7.32-m and 9.14-m (24-ft and 30-ft) lengths. One of each size is needed to connect two 9.14-m by 16.46-m (30-ft by 54-ft) mats. The resulting 16.46-m by 18.29-m (54-ft by 60-ft) mat is the normal size suitable for most crater repairs. If larger FOD covers are required, additional mats may be spliced together.

4-5.3.4 There are two types of support mat kits for the FFM. Mat Kit A contains all the necessary tools and hardware required to assemble, install, and maintain the system. Mat Kit B contains the anchor bolts required to attach the mat to the pavement surface.

4-5.3.5 The mat assembly area can be any area near the crater repair. This area must be cleared of all debris and swept. It must be large enough to accommodate the unfolding of both mats, allow equipment operations around the mat, and not interfere with crater preparations. This area should be approximately 30.4 m by 30.4 m (100 ft by 100 ft) square, and located a minimum of 30.4 m (100 ft) from the crater and off the MAOS.

Figure 4-12. FFM Configuration



4-5.3.6 Mats are placed end-to-end about 1.2 m (4 ft) apart, with the first panel up and positioned such that both mats unfold in the same direction.

4-5.3.7 Unfold the mats in preparation for being joined together. The top panel of the mat is attached to a tow vehicle with a nylon strap (Figure 4-13). A crew of four people, or a forklift positioned on the opposite side of the mat, lifting each successive panel as the mat is being pulled open, speeds the unfolding process (Figure 4-14).

4-5.3.8 Resin flaking at the mat hinge can occur and create a FOD problem with mats that were procured from the initial manufacturing programs. To eliminate this problem, make one pass with a vibratory roller down each hinge, followed with a sweeper. This operation normally loosens and removes the flaking material from the hinges.

4-5.3.9 Join the mats together so they are aligned, the 9.14-m (30-ft) edges are even, and the 16.46-m (54-ft) edges are roughly parallel with each other.

Figure 4-13. Attaching Nylon Straps

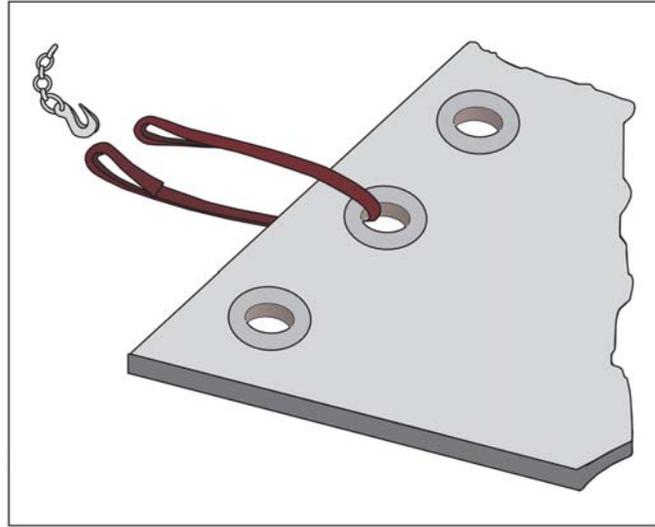
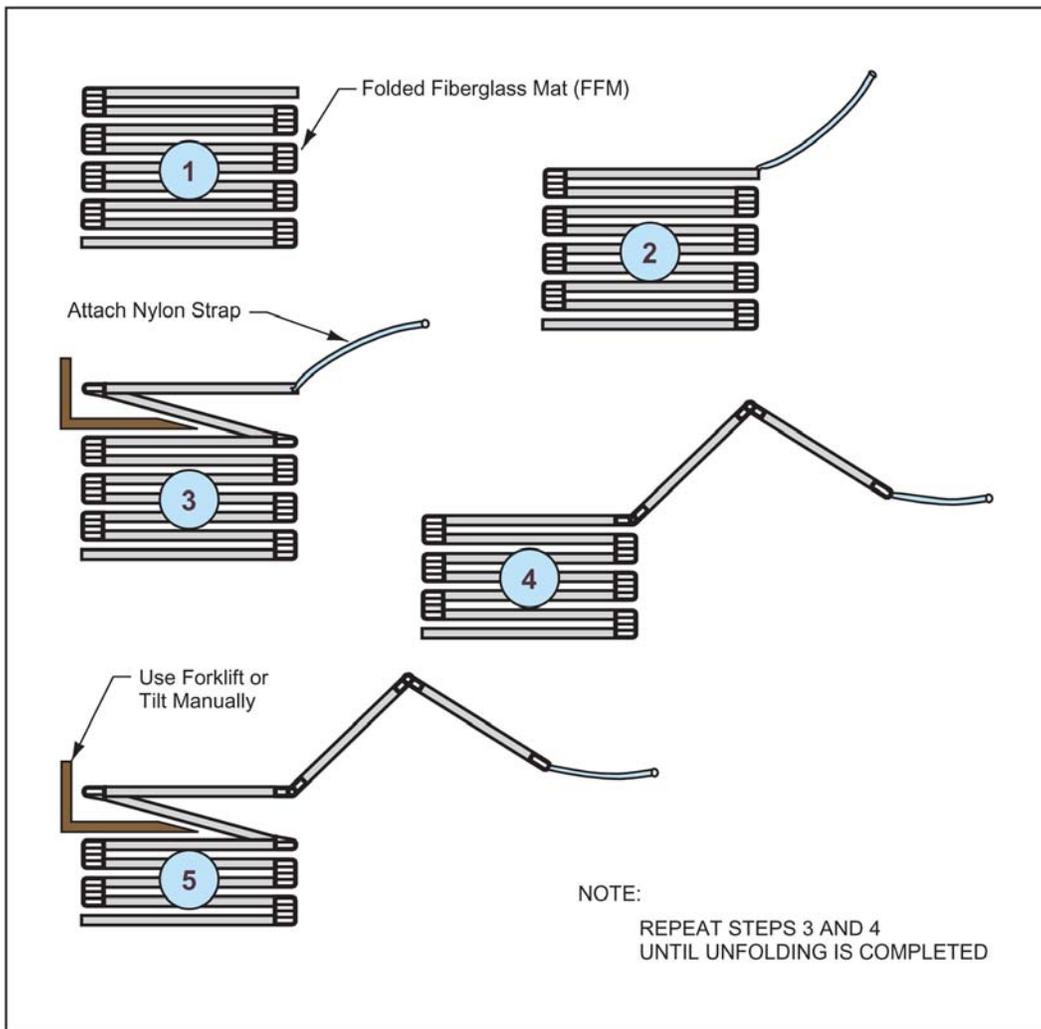
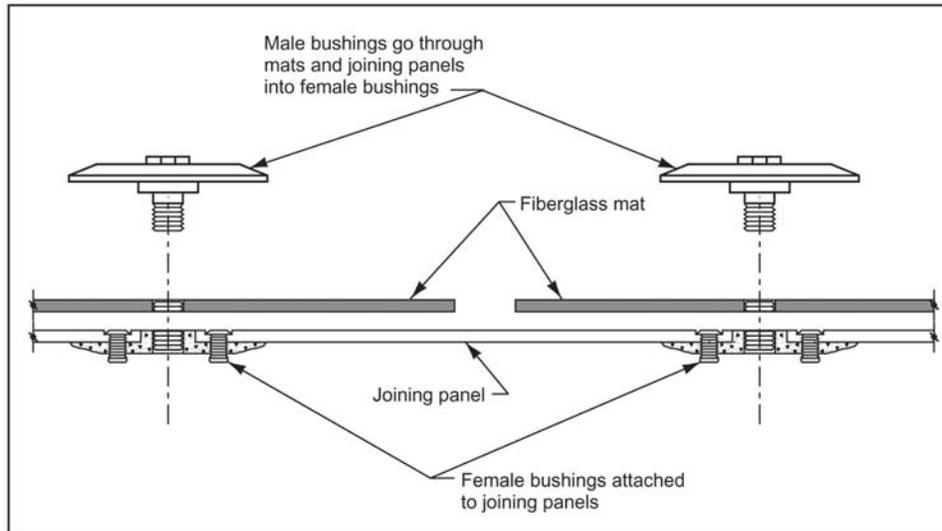


Figure 4-14. Mat Unfolding Procedure



4-5.3.10 Lift one end of the 16.46-m (54-ft) edge and slip either the 7.32-m (24-ft) or the 9.14-m (30-ft) section of joining panel underneath the raised edge. Align the holes in the mat with the joining panel bushing holes and lower the mat (Figure 4-15).

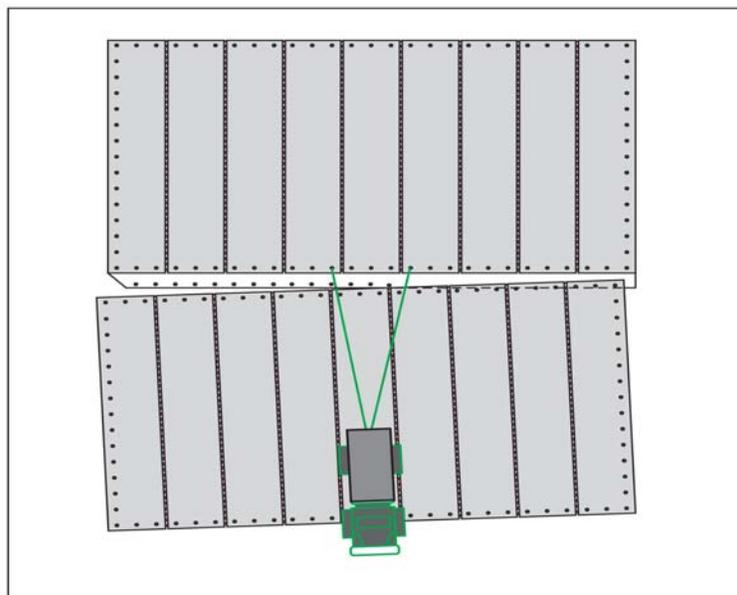
Figure 4-15. Joining Panel Attachment



4-5.3.11 Install the top joining bushings and tighten by hand. This process is repeated at the other end of the 16.46-m (54-ft) edge of the same mat using the remaining joining panel. Hand-tighten these bushings; final tightening will be accomplished later.

4-5.3.12 The second mat is then towed over to the first mat with joining panel attached. One of the holes near the end of the second mat is aligned with its counterpart on the joining panel and a top joining bushing is installed (Figure 4-16).

Figure 4-16. Joining Second Mat Using Pivot Point



4-5.3.13 This end connection acts as a pivot point when the second mat is moved into position so all the remaining holes on the joining panel are in alignment. Install the remaining top bushing and tighten the entire second mat bushing with an impact wrench.

4-5.3.14 Revert to the first top joining bushings and tighten them with the impact wrench. All joining bushings should be tightened and the joined mats are now ready to be towed over the repaired crater.

4-5.3.15 Before any towing operation can commence, the area between the mat assembly area and the repaired crater must be completely swept. Any debris that is picked up under the mat as it is being towed could damage the matting and affect the smoothness of the repair.

4-5.3.16 When the width of the MAOS permits, the mat should be towed parallel to and next to the crater. Align the joining panel with the center of the crater. Use a front-end loader or similar vehicle to tow the mat over the crater with the hinges perpendicular to the tow direction. Position the mat so the hinges are parallel to the direction of the MAOS traffic. The mat should not be more than 5 degrees off parallel.

4-5.3.17 With the mat in position over the crater, it must be anchored in place. Techniques for anchoring the FFM will depend on the type of pavement surface. The FFMs are predrilled for anchoring bolts. All three anchoring techniques use a 101.6-mm (4-in.) bushing through which the bolt passes to hold down the mat.

4-5.3.17.1 **Concrete Pavements (Figure 4-17).** The concrete anchor is normally a rock bolt that is 127 to 152.4 mm long and 15.9 to 19.1 mm in diameter (5 to 6 in. long and 0.625 to 0.75 in. in diameter). At each predrilled hole in the leading and trailing edges of the mat, drill a hole into the pavement corresponding to the diameter of the bolt being used. Position an anchor bushing in the predrilled hole as a guide for centering the drill bit. The depth of the hole must be at least 12 mm (0.5 in.) longer than the length of the bolt. Clean out the drill cutting with compressed air and insert the bolt through the bushing. Stand on the mat and bushings and tighten the bolt with an impact wrench.

4-5.3.17.2 **Asphalt-overlaid Concrete Pavements.** Asphalt-overlaid concrete usually entails using a rock bolt that is 241.3 mm long and 15.9 to 19.1 mm in diameter (9.5 in. long and 0.625 to 0.75 in. in diameter). The installation procedure is the same as those for all-concrete pavements. The key factor in this installation is to ensure the bolt has been set deep enough into the concrete layer for a firm grip.

4-5.3.17.3 **Asphalt Pavements (Figure 4-18).** Anchoring in asphalt pavement requires a 241.3-mm (9.5-in.) bolt and polymer. A hole 254 mm deep and 38 mm in diameter (10 in. deep and 1.5 in. in diameter) is drilled at the center of each predrilled

mat hole. A two-part resin polymer is mixed and poured into each hole to about 38 mm (0.5 in.) below the surface of the pavement. An anchor bushing and bolt are immediately placed into each hole and pressed firmly (standing on the bolt and bushing) against the mat. The polymer will harden in about three minutes. Drilling and setting the bolts are usually accomplished concurrently to expedite the repair process.

Figure 4-17. Concrete Pavement Anchoring

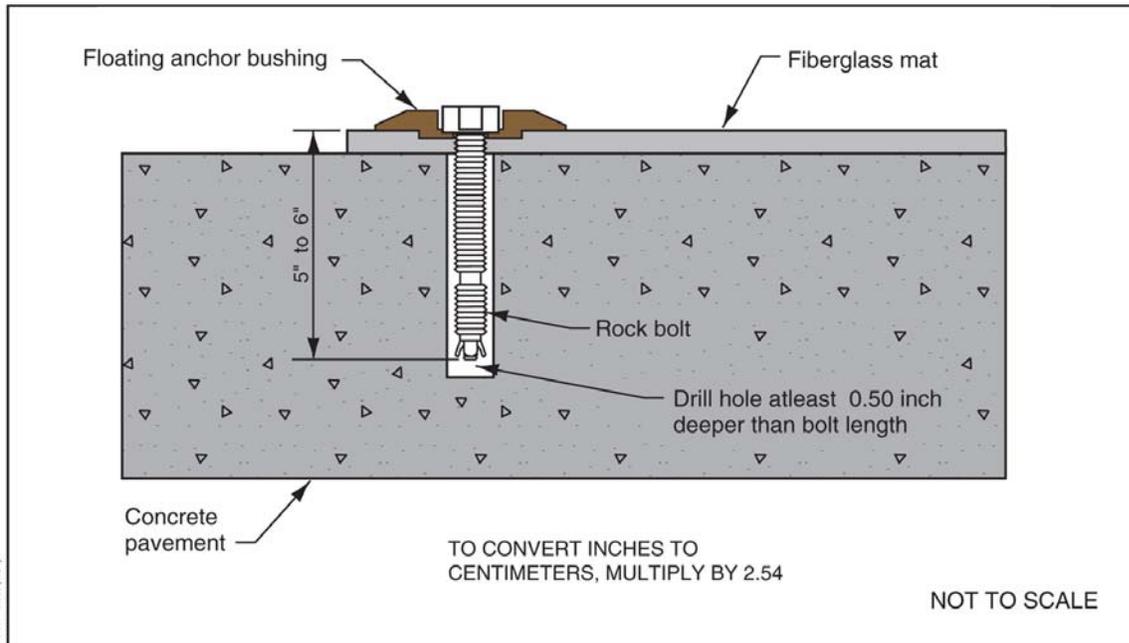
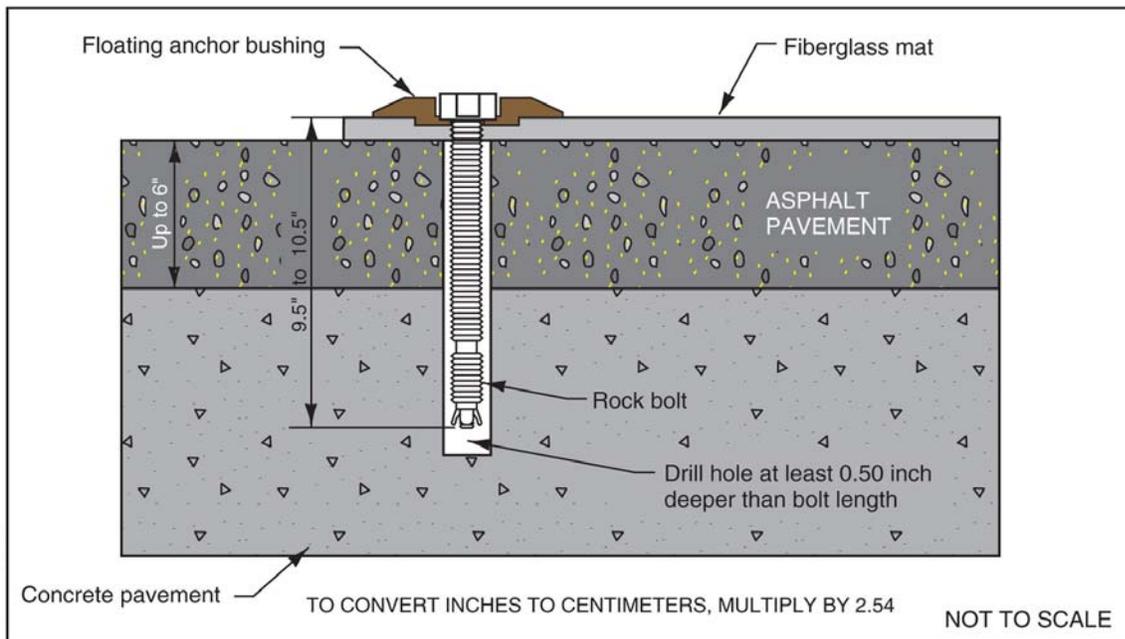


Figure 4-18. Asphalt-Overlaid Concrete Anchoring



4-6 **AM-2 MAT REPAIR.** The AM-2 mat repair method consists of placing a patch of AM-2 over the filled and compacted crater. The crater should be backfilled with debris and 406 mm (18 in.) of crushed stone following procedures for the crushed stone debris backfill repair indicated in para 4-3 and Figure 4-1. Restrictions on use of AM-2 are noted in Table 2-1. The Air Force also notes that the AM-2 patch technique has been in existence for almost 30 years (1997). Once the mainstay of ADR operations, it has been primarily relegated to secondary use. AM-2 mat repairs are generally acceptable for fighter aircraft when spacing between the patches is large. However, they are generally considered to be inadequate for use with wide body aircraft. This limitation derives from the mat's inadequate anchoring system, narrow patch width, and susceptibility to separation during hard braking and turning actions. On the other hand, AM-2 mats can be used to repair transport aircraft taxiways and aprons, provided that tight turns are not made over the mats.

Procedures for assembly and towing an AM-2 patch indicated under Army are also applicable to Navy/Marine Corps and Air Force. Specific concepts from the other services are included in this section.

4-6.1 **Army.** The AM-2 matting must be assembled while the crater is being repaired. The following steps are involved in assembling the AM-2 matting.

4-6.1.1 **Select the Assembly Area.** Early in the repair cycle, the OIC of NCOIC should identify the assembly area. The area chosen should be undamaged, preferably on the pavement. The assembly area should allow for a straight, single direction (either parallel or perpendicular to the crater) short pull of the assembled matting. Areas must be cleared of all debris before the matting is assembled. Areas should be swept to remove small ejecta. Removal of small ejecta keeps debris from accumulating in the matting grooves.

4-6.1.2 **Assemble the Keylock.** Assemble and place male-male keylock at the appropriate extended centerline of the crater, either parallel or perpendicular to the MOS centerline. The assembled keylock is 16.5 m (54 ft) long.

4-6.1.3 **Assemble the Towing Tubes.** The towing tubes on the assembled patch serve two purposes. First, by attaching the proper towing harness, the assembled patch can be pulled sideways to properly align the patch. Second, by attaching the towing tubes on both sides of the patch, the assembled matting is totally locked together and will not separate to "stair step" during positioning or continued use. Fifteen rows of matting (9.2 m (30 ft)) are placed on one side of the keylock and 20 rows of matting (12.2 m (40 ft)) are placed on the remaining side (Figure 4-19). There are various methods of attaching the towing tubes to the matting.

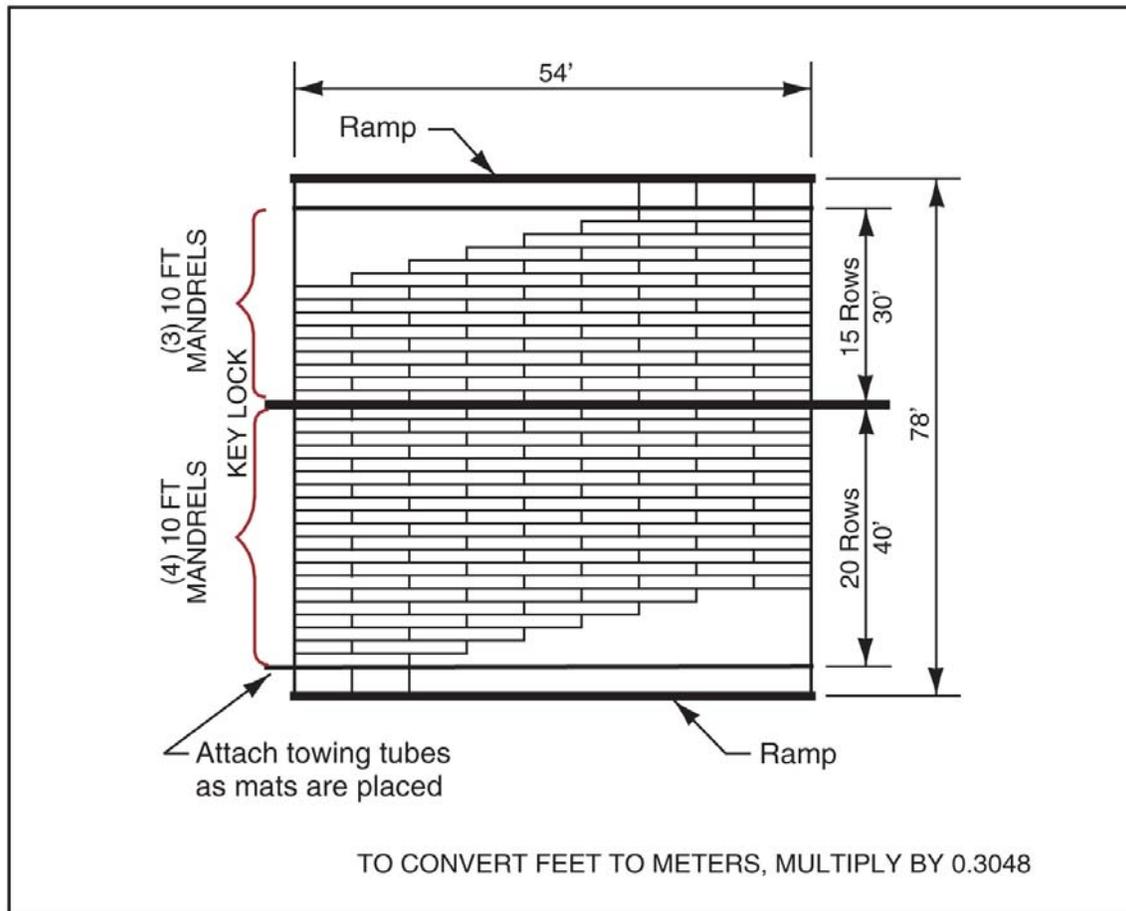
4-6.1.4 **Attaching Towing Tubes.**

4-6.1.4.1 **Method A.** Concurrent with the keylock assembly, preassemble towing tubes, mandrel, connector fittings, stops, and end caps. (Do not tighten the end caps.) Towing tubes should be assembled perpendicular to the keylock assembly (Figure 4-20) and are required on both sides of the assembled matting. The assembled

keylock and towing tubes, prior to the placement of the matting, will resemble the shape of a capital "H."

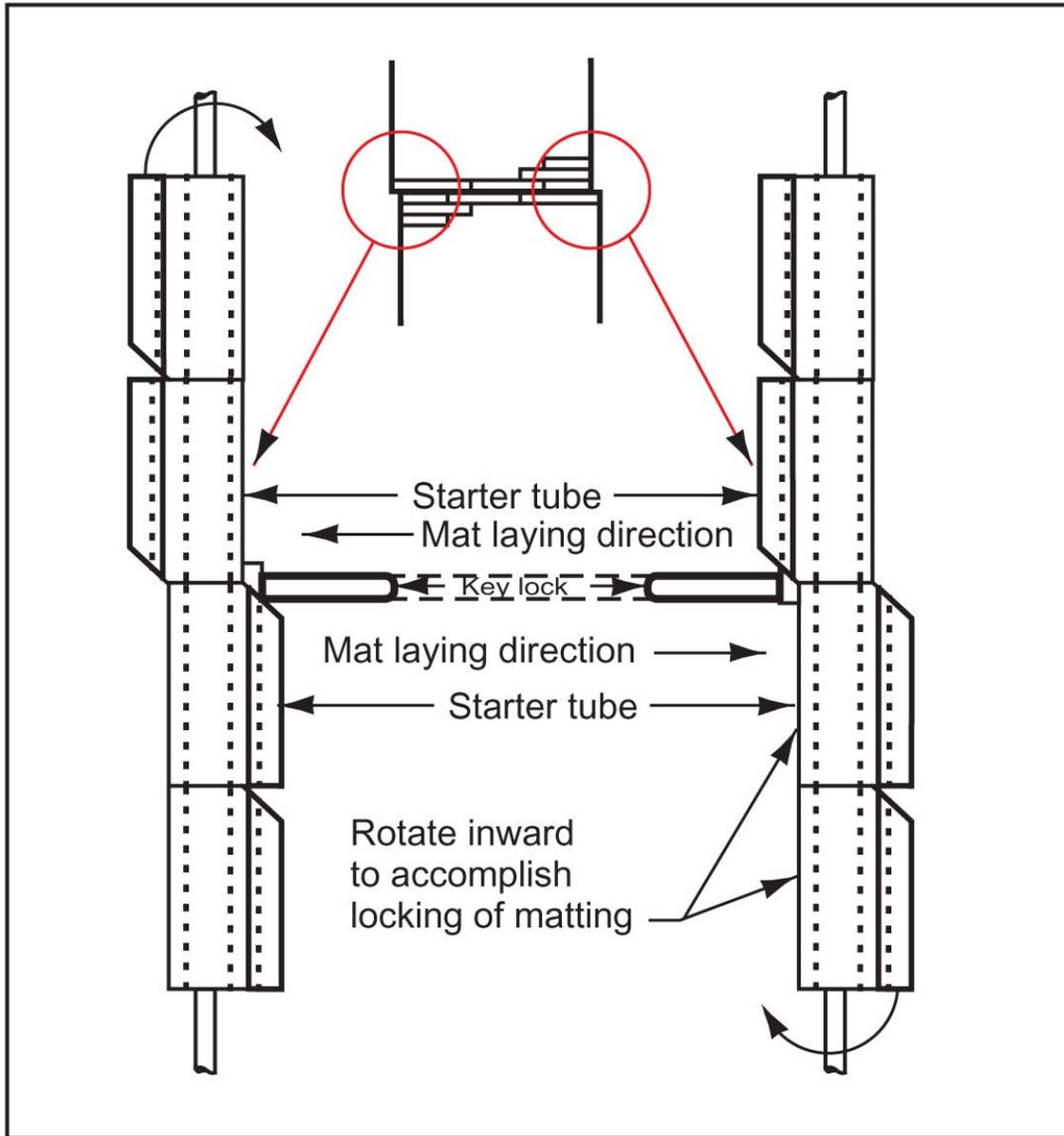
(1) Initially, two starter towing tubes are placed on a 6.1-m (20-ft) piece of assembled mandrel, centered on the special connector fitting next to both ends of the keylock. (Note: Starter towing tubes are 25.4 mm (1 in.) longer than the normal towing tubes and do not have a hole for connecting towing clamps. Recommend these tubes, four each per patch kit, be identified and painted a distinctive color to readily differentiate from normal towing tubes.)

Figure 4-19. Attachment of Towing Tubes



(2) The starter tube that receives the first piece of matting placed on the keylock must be placed on the mandrel with the prongs facing up. The starter tube that receives the last piece of matting from the first row must be placed on the mandrel with prongs up also, but will be rotated to prongs down when attached to the matting (Figure 4-20).

Figure 4-20. Towing Tube and Keylock



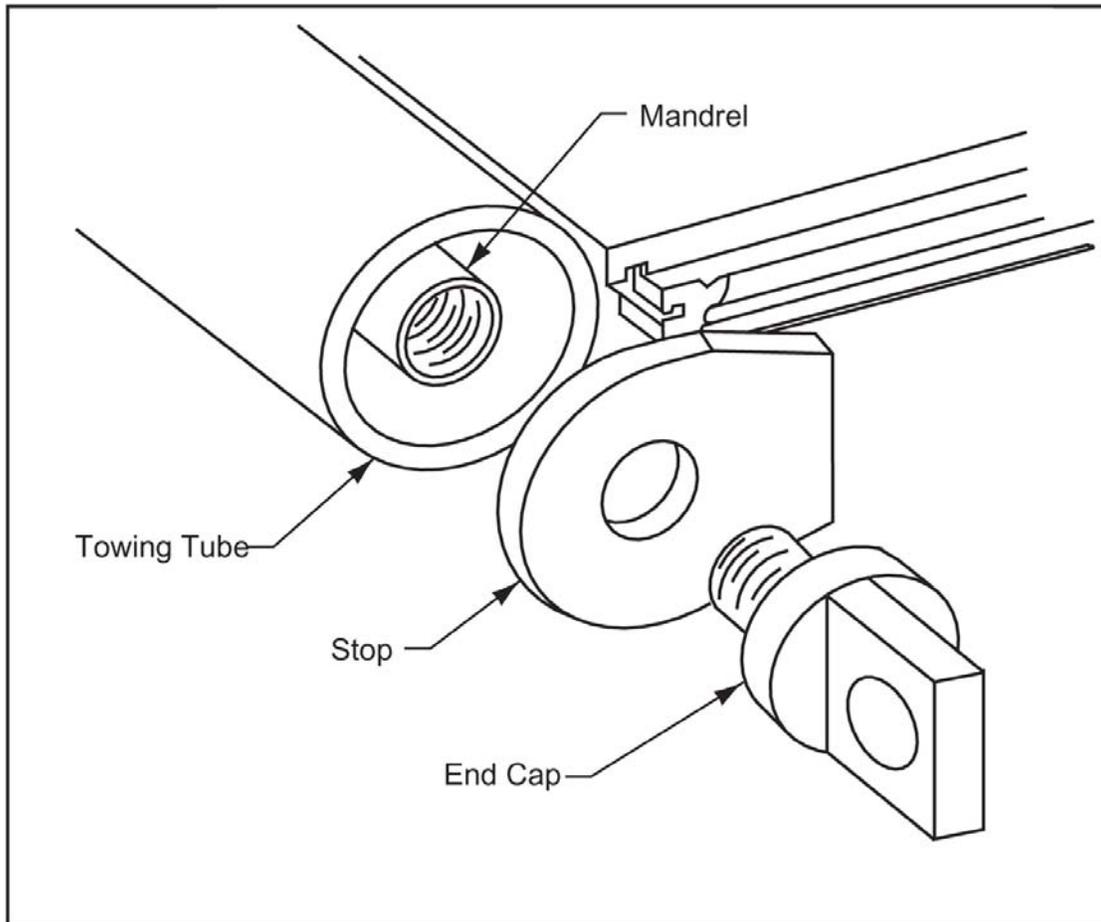
(3) Place sufficient towing tubes (15 on one side and 20 on the other) and mandrels with connector fittings to accommodate total patch. If there are fewer than five mats remaining at the end of the patch, use a short mandrel for each one. Towing tubes should be placed with prongs located identical to the starter tubes.

(4) After all tubes are placed on the mandrels (total of 2 starter tubes and 33 towing tubes on each side), place the stop and end cap on each end of the mandrel. (Do not tighten end caps until total matting patch has been assembled.)

4-6.1.4.2 **Method B.** As the first mat is placed starting a new row, connect the towing tubes to the left (looking toward the keylock) side of the matting. After each row of mats has been completed, connect the towing tube to the right side of the matting. Insert the locking bar between the mats and the tube as each connection is made. Place a starter

tube on each side of the keylock, on each side of the patch (four starter tubes required). After all tubes are placed (15 on one side and 20 on the other), insert a long mandrel with tapered bullet nose attached in the tube, from the end of the patch (Figure 4-21).

Figure 4-21. Towing Mandrel and Mandrel Fittings



(1) Using the connector fitting, connect another long mandrel to the first mandrel. Be sure that the connector is threaded all the way into the mandrel and no threads are showing. Push this assembly into the towing tube and connect another long mandrel. Repeat this procedure until the bullet nose emerges at the opposite end of the towing tube. It will be necessary to install one extra mandrel so as to provide adequate spacing to remove the bullet nose and install towing bar stop and cap.

(2) After the towing bar stop and cap have been installed on one end, pull the mandrel so that the stop is flush against towing tube. Then remove the additional mandrel from opposite end and insert a towing bar stop and cap at that end. Make sure that the long end of these stops is facing in toward the patch and they clear the mat ends.

(3) Tighten the ends equally, using the crescent wrench provided in the tool chest. If the panels expand so that the patch is longer than the assembled towing tube, add

more stops (as a shim) from the spare stops provided in the kit. Tighten the caps at each end of the tube as tight as possible. Make sure that tubes are seated correctly.

4-6.1.4.3 Method C. Attaching Towing Tubes (Preferred Method). This is a build-as-you-go method that is done concurrently with the mat assembly.

(1) Use one long connector to connect two long mandrels on each side of the end of the keylock.

(2) After mandrels are connected and laid out, slide two starter tubes, centering them on each mandrel at the center connector fitting. Remember, starter tubes are 25.4 mm (1 in.) longer than the towing tube and do not have holes drilled for the towing harness.

(3) Since the matting is always laid from left to right facing the mat laying operation, the starter tube that receives the first piece of matting placed on the keylock must be placed on the mandrel with the prongs facing up. The starter tube that receives the last piece of matting from the first row must be placed on the mandrel with the prongs up and (when connected to the end of the matting) must be rotated 180 degrees on the mandrel to the prongs down position.

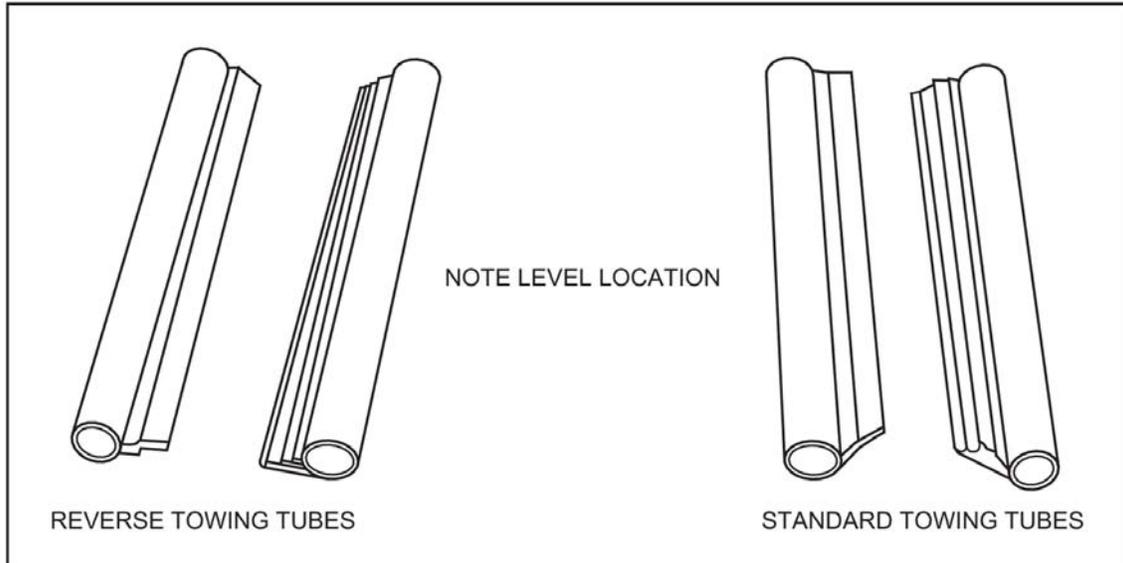
(4) Initial and final attachment of each tube on every row will be locked with a locking bar. Additional towing tubes should be placed on each mandrel as they are needed, staying ahead of the mat-laying crew at least one mandrel length until the job is done.

(5) When all towing tubes have been installed on mandrels, place stop and end cap into the ends of each mandrel. Make sure that the long end of the stops are loose and are facing toward the patch.

4-6.1.5 Assemble the Towing Tubes (Reverse Tubes). Inventories of select ADR kits indicate that some of the towing tubes supplied are reverse of the standard and cannot be assembled as recommended by Method A or Method B. These tubes are readily identifiable when compared to the standard towing tube (Figure 4-22). Following is the recommended procedure for assembling the reverse towing tubes:

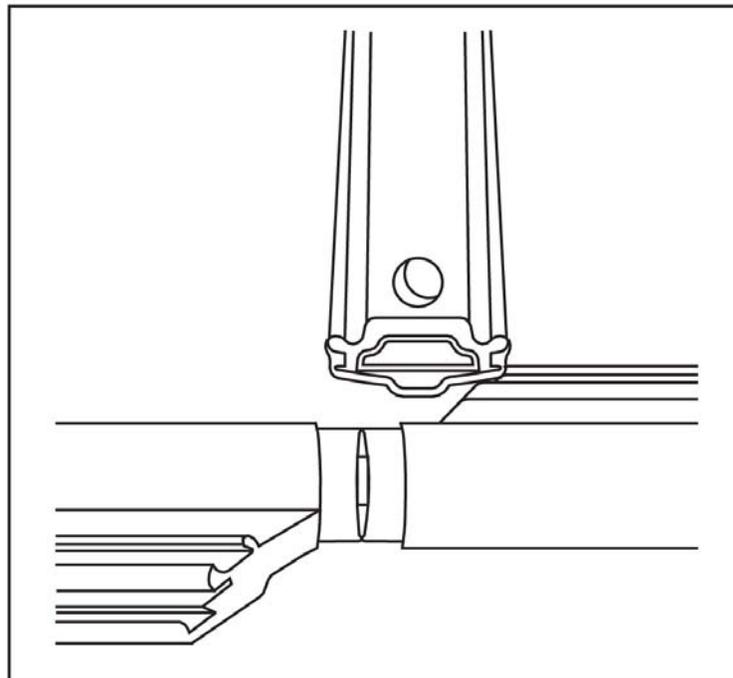
(1) Select sufficient reverse towing tubes, usually 35, to complete a towing tube assembly. (Note: Reverse and standard towing tubes cannot be intermingled in a towing tube assembly.) The reverse started towing tubes cannot be used in the assembly. (Starter tubes are 51 mm (2 in.) longer and do not have a hole in the tube to attach the towing clamp.)

Figure 4-22. Comparison of Standard and Reverse Towing Tubes

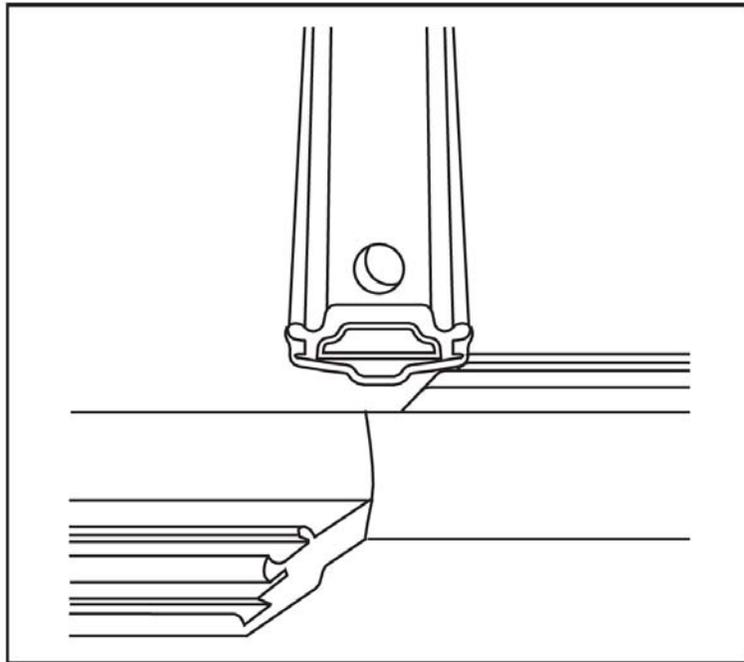


(2) The standard towing tube and keylock assembly prior to placing AM-2 matting will resemble the diagram as shown in Figure 4-23.

Figure 4-23. Standard Towing Tube and Keylock Assembly



(3) To assemble the reverse towing tubes, place a piece of 32-mm (1.25-in.) pipe, 45 mm (1.75 in.) long (threaded or unthreaded) on a 6.1-m (20-ft) piece of assembled mandrel, centered on the connector fitting. Place the reverse towing tubes with flat end toward center (Figure 4-24).

Figure 4-24. Reverse Towing Tube and Keylock Assembly

(4) Proceed with assembly as detailed in Method A, except reverse the tube.

(5) Assembly can also be completed by Method B, except tubes are reversed and when mandrel is installed, pipe spacer must be used.

(6) Assembled patch will resemble diagram as shown in Figure 4-25.

(7) Tighten towing tube assembly as previously described in standard towing tube assembly.

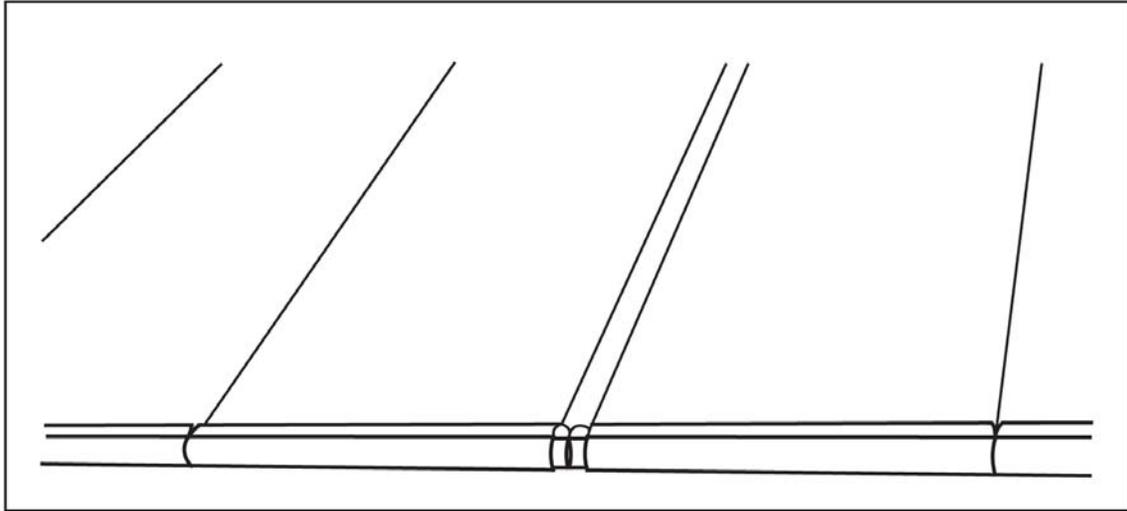
4-6.1.6 Assemble the Patch. Each patch assembly should be stored incrementally. This procedure will identify and load the patch assembly. To keep confusion to a minimum, each patch assembly should be delivered in total to the selected assembly area.

(1) Matting should be loaded on the delivery system in reverse order of use to allow efficient assembly.

(2) Transport the tools to the selected assembly area. Be careful in unpacking the materials and tools not to damage the pallets and crates, for they must be reused to store the matting patch when it is disassembled later.

(3) Proper off-loading and positioning the bundles of AM-2 matting enhance the assembly effort. Bundles of matting are off-loaded with the forklift attachment. Bundles should be positioned on wooden dunnage to ease the removal of metal and plates. Positioning bundles on dunnage should be accomplished so matting can be placed by matting teams with shortest walking distance. If properly positioned, mats can be placed directly from bundles without rotating.

Figure 4-25. Assembled Patch Towing Tube



(4) Starting with the full-size mats, connect a row of four 3.7-m (12-ft) mats and one 1.8-m (6-ft) mat to the keylock. Insert the locking bar at each end joint, as well as a locking bar at both of the towing tube connections. Now lay a second row using the same procedures. The minimum required length of the patch is 23.5 m (77 ft 6 in.) (including ramps), but may be longer, depending on the size of the crater. The 16.5-m (54-ft) width is constant. For a longer patch, get materials from another repair kit. Attach the towing tube as previously described.

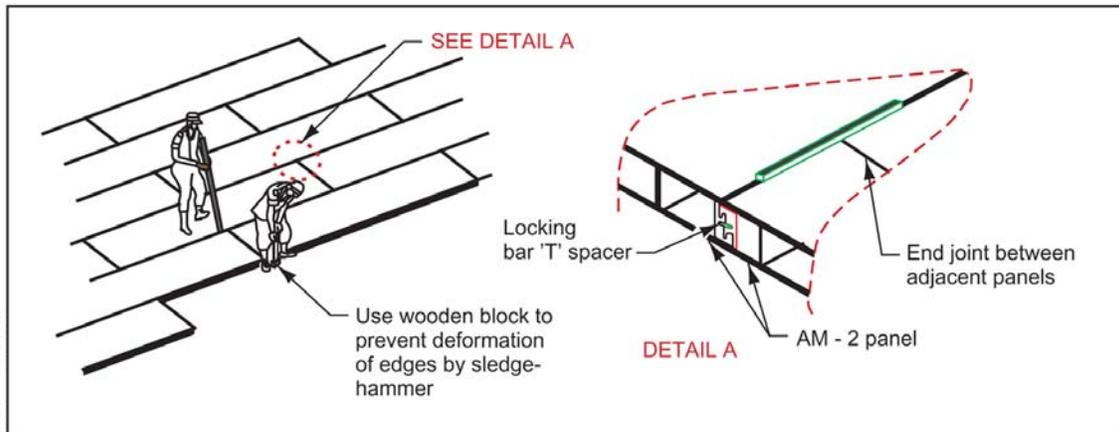
(5) Double check to make sure that the first two rows of mats and keylock are straight. Then, starting with a full-size mat, lay one row of mats on the other side of the keylock to keep the keylock from shifting. After the matting has been placed on each side of the keylock, begin laying matting on both sides at the same time.

(6) Use a 4.76-mm (0.1875-in.) locking bar as a spacer between mats in assembling the patch. (See Figure 4-26 for a graphic illustration of how these bars are placed on edge.) This locking bar (“T” spacer) is left in place for at least three rows back from the row presently being installed.

(7) After the patch has been completely assembled, the towing tube will have been assembled. Tighten the end caps as previously indicated.

4-6.2 **Navy/Marine Corps.** AM-2 matting is used for the construction of complete runways, taxiways, parking areas, and vertical takeoff and landing (VTOL) pads in accordance with References 5, 6, and 7. Assembling AM-2 to accommodate these various applications requires a number of special pieces (e.g., connectors, keylocks, spacer mats, adapters) not normally used for an AM-2 patch. Many applications require anchoring or staking to stop vertical and horizontal movement. Anchors and stakes must be installed and tested in accordance with References 5, 6, and 7.

Figure 4-26. Use of Locking Bar in Assembly Patch and Correction of Misalignment



4-6.3 Air Force.

4-6.3.1 **Purpose.** Once the mainstay of runway crater repairs, AM-2 has been mostly relegated to a secondary use for taxiway repairs and parking apron expansion. It does, however, represent an option for runway repairs if other methods cannot be used. AM-2 mat repair must meet the RQC for its location on the runway.

4-6.3.2 **Limitations.** AM-2 mat repair kits are generally acceptable for fighter aircraft and C-130s but inadequate for jet cargo aircraft landing strips. This limitation is due to the inadequate anchoring system, narrow patch width (16.5 m wide by 23.6 m long [54 ft wide by 77.5 ft long]), and susceptibility to jet blast from outboard engines. AM-2 mats can be used to repair taxiways and aprons if braking and tight turns are limited on the mat. Adequate drainage of the base and subbase layers is important. Excess moisture in these layers will cause a reduction in the load-bearing capacity of the subsurface material, and subsequently mat failure.

4-6.3.3 **Factors Affecting AM-2 Life.** AM-2 has proven over the years to be the best metal surface matting in the DoD inventory; however, it is not the panacea for all expedient and theater of operations airfield problems. Its life expectancy is directly proportional to the quality of the base, subbase, and the amount of traffic. Weather also seriously affects its service life. Where there is heavy rainfall, water collects under the matting unless there is adequate drainage. When this happens, water eventually pumps through the matting and erodes the base.

4-6.3.4 **Base Quality.** Experience has shown that AM-2 performs best on a layer of clean, well-graded, compacted crushed stone subbase. The amount of maintenance required to care for this mat varies depending on the following factors: soil condition; quality of the base/subbase; use of a geotextile; weather; and aircraft traffic.

4-6.3.5 **Geotextile.** On a base of inferior silt or clay, AM-2 matting gives much better service if a geotextile is placed beneath the AM-2 surface. Although the initial cost of

geotextile is high, it can be cost-effective for long-term operations. The use of a medium weight geotextile is recommended for separation applications in pavements and the National Stock Number for the DOD recommended products is NSN: 5675-01-471-2647. Appropriate geotextile products are not included in some ADR kits.

4-6.3.6 Traffic. The most important step in prolonging the life of AM-2 that is laid directly on a silt or clay base is to keep aircraft and vehicular traffic to an absolute minimum during and following periods of inclement weather. This will allow water under the surface to drain completely from the base; otherwise, the impact of the traffic will pump the water into the base and destroy it.

4-6.3.7 Precautions in Repairing/Laying AM-2 Panels. Remember that AM-2 can only be laid in one direction: right to left facing the direction in which the mat is placed. Experience with AM-2 has shown the following:

4-6.3.7.1 It requires 200 to 300 percent more effort to place AM-2 than to remove it.

4-6.3.7.2 The more exact the finished grade of the base course, the easier it is to lay AM-2.

4-6.3.7.3 Six hours is about the maximum time a person can sustain production when handling AM-2. In the tropics, people can handle more matting in a six-hour night shift than in a 10-hour shift in the heat of the day.

4-6.3.7.4 Use a string line along the edge for proper alignment.

4-6.3.7.5 To maintain proper alignment, always use a locking bar as a spacer behind the last joint.

4-6.3.7.6 Never crowd the bundles of stacked panels next to the panels being laid, as this may require moving the stacked bundles twice.

4-6.3.8 General AM-2 Assembly Guidelines

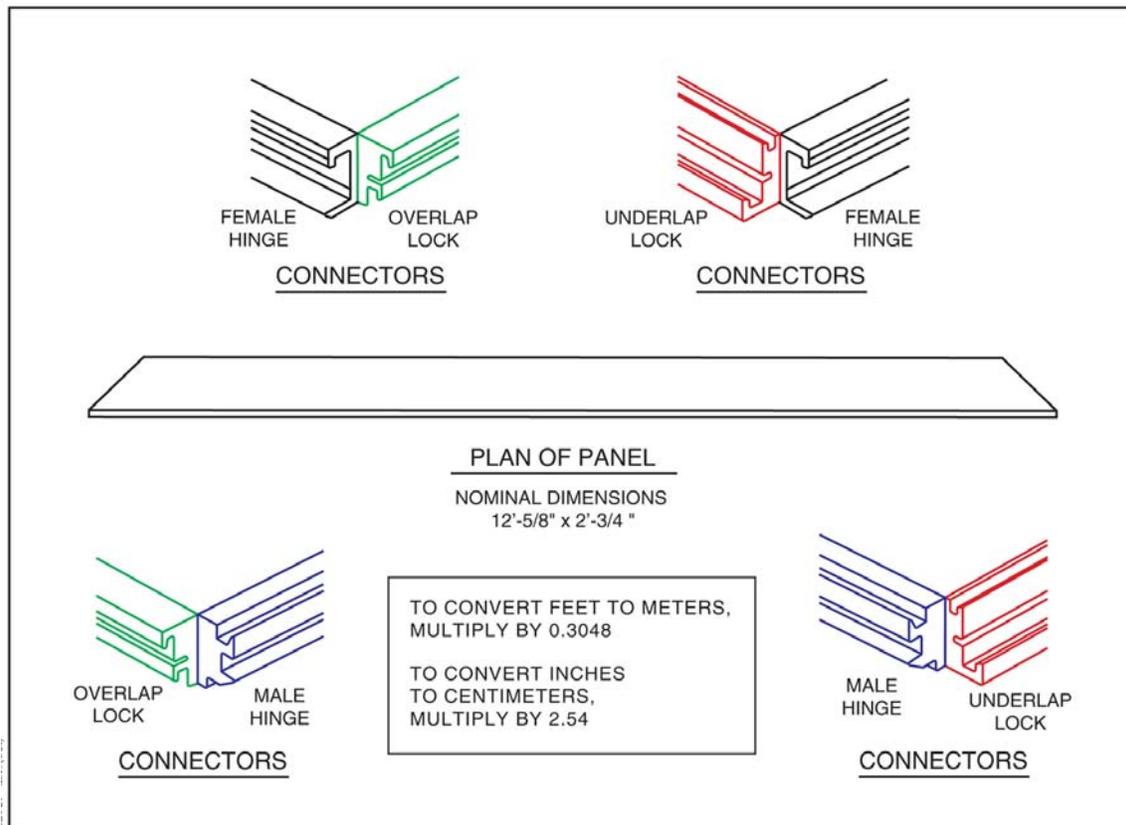
4-6.3.8.1 AM-2 matting can be assembled in place (taxiway and aprons) or away from the repair and towed into position (crater repair). Mats assembled in place usually don't require all the ancillary pieces, like starter key lock, mandrels, or towing tubes that a mat to be towed into place will require to keep it from separating during towing.

4-6.3.8.2 AM-2 can be assembled as a crater cover that is usually 16.5 m wide by 23.6 m long (54 ft wide by 77.5 ft long), or as a FOD cover, to extend a parking ramp whose dimensions are limited only by the amount of AM-2 available. The assembly procedures are similar; however, for specific instructions on how to assemble a towed patch, see para. 4-6.1.

4-6.3.8.3 Assemble the matting from left to right facing the mat laying operation. You can assemble this matting using all full mats (3.65 m [12 ft]) or a combination of full and half (1.83 m [6 ft]) mats. A standard bundle of AM-2 contains 11 full-length mats and two half-length mats; both will be described since every piece of mat will be needed.

4-6.3.8.4 Position the first piece of full mat so that the left end of the mat underlap lock has the prongs facing up. Position the second full mat so that the right end of the mat overlap lock prongs is facing down. The prongs of both mats should join together. To increase stability and lock the mats together, insert a flat locking bar into the rectangular slot formed where the end prongs are joined. Continue this process across the full width of the assembly. The only exception is the last piece of mat; use a half mat instead of a full mat. See Figure 4-27 for details of end and side of connection.

Figure 4-27. AM-2 Aluminum Mat



4-6.3.8.5 The second row is placed similar to the first, except it is started with a half mat first. Before placing each mat into position, make a quick check of the prongs for debris. Use a broom or brush to remove dirt and stone that might prevent the mat from joining together. As each mat is positioned, install the locking bars.

4-6.3.8.6 The mats are designed with a loose fit that allows for expansion; therefore, it is possible to have a row of mats installed so misaligned as to prevent the proper engagement of follow-on rows. Using locking bars as temporary spacers between the rows can normally prevent this condition. Place a locking bar on edge where the ends of two mats join and at the row ends. After three or four rows have been laid using locking bar spacers, remove the spacers further away and use them on the row that has just been laid. These locking bar spacers are commonly referred to as "T" spacers.

4-6.3.8.7 Use extreme caution in adjusting the mat; always place a wooden block against the mat edge. Strike the wooden block and not the mat. Sledgehammer blows against the edge of the mat can deform the edge enough to make it impossible to connect the next row of mats.

4-6.3.8.8 Ramps were developed to ease the transition from the pavement surface onto the mat. Start at the right corner of the assembled mat to connect the first ramp. Place the next ramp so that the holes in the overlapping plate are aligned with the threaded inserts on the ramp just installed. Fasten with flat-head screws coated with anti-seize compound. Use locking bar spacers between the mat and the ramp to keep it properly aligned.

4-6.3.8.9 After all ramps are placed and screwed together, use the ramps as a template or guide to drill holes in the pavement. Hole depth and size is dependent on the type of anchor bolt being used.

4-7 **RAPID SET MATERIAL REPAIR.** Use of proprietary rapid set cements has been limited to spall repairs. Polymer resin and magnesium phosphate are two formulations, which have been used extensively for years. The main disadvantage of the polymer resin cement is environmental and toxic hazard concerns. This material requires use of bulky protective clothing. Magnesium phosphate materials are more user friendly however they have a short working time and give off heat and noxious (non toxic) fumes. Type III Portland cement yields high strength gain however it cannot achieve the desired strength of 10.3 mPa (1500 psi) in 4 hr. Use of Type III cement is more appropriate for sustainment repairs.

4-8 **SEMI-PREPARED SURFACES.** Semi-prepared surfaces are bare soil areas with no pavement or landing mat surfacing. These are termed unsurfaced or stabilized. Semi-prepared surfaces can be utilized as runways, taxiways, and parking aprons for some aircraft, i.e., C-130 and C-17.

4-8.1 **Unsurfaced Repair.** Unsurfaced areas consist of bare soil with little or no construction preparation. These areas may be cut or fill and either be compacted to or have natural density (and thus strength) sufficient to withstand limited aircraft traffic. Unsurfaced soils must be maintained regularly if subject to heavy aircraft traffic as rutting will develop. They are subject to strength loss if exposed to excessive rainfall. Strength criteria for unsurfaced airfields are contained in References 8a, 8b, and 3.

4-8.2 **Stabilized Surface Repair.** Stabilized soils are materials that have been treated with an additive such as Portland cement or lime. The additives are mixed into the soil at a specified depth (not less than 152 mm (6 in.) depending on the aircraft type and traffic level) and compacted to a specified density. The additive reacts with the soil to form a hardened material capable of sustaining much more aircraft traffic than untreated soils. Stabilized soils are much less susceptible to strength loss if subject to rainfall. Guidance on the use of stabilized soils is contained in References 3, 8a, 8b, 10, and 11.

CHAPTER 5

SUSTAINMENT REPAIR METHODS

5-1 SUSTAINMENT REPAIR CONCEPTS

5-1.1 **Purpose.** Sustainment repairs represent higher quality repairs than expedient methods and are designed to upgrade prior expedient repairs or conduct higher quality repairs on previously unrepaired craters beyond the minimum MOS requirements. Thus, sustainment repairs provide increased operational capability as reflected in para. 2-8. It is recommended that sustainment repairs commence not later than 12 to 20 hr after expedient repairs are completed; however, mission requirements and the operational tempo will generally dictate the level, speed and direction of the repair effort.

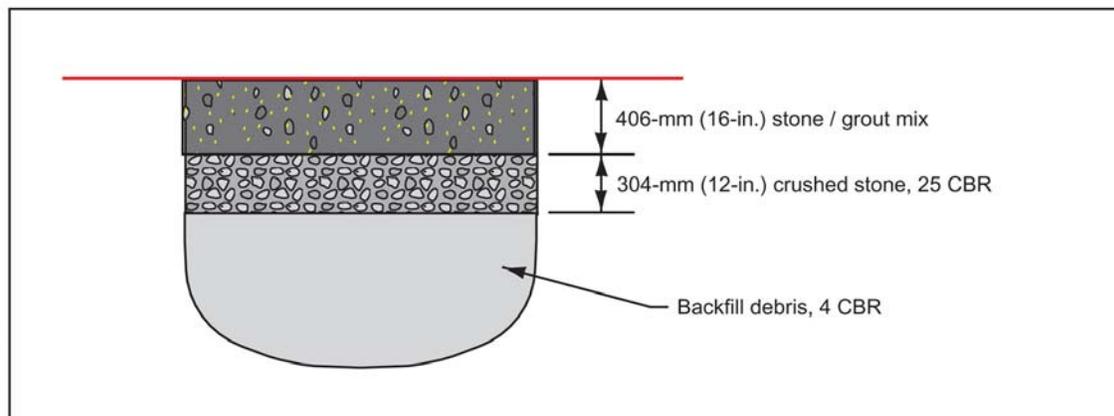
5-1.2 **Assumptions.** It is assumed that expedient repairs have been completed at this time. See para. 4-1. It is assumed that existing expedient repair materials will be removed to an appropriate depth to accommodate the successful completion of the sustainment repair alternative chosen from the alternatives in the following paragraphs.

5-2 **SELECTION OF REPAIR METHOD.** See para. 4-2.

5-3 STONE AND GROUT REPAIR

5-3.1 **Stone and Grout Repair (Above Freezing Temperatures).** See Figure 5-1.

Figure 5-1. Stone and Grout Repair



5-3.1.1 This type of repair is considered a *sustainment airfield repair*. It may be used as a replacement for both the crushed stone and sand-grid repairs when additional resources are available. Uniform compaction of backfill material is critical.

5-3.1.2 If upgrading a sand-grid or crushed stone repair, it is preferable to recycle previous repair materials.

5-3.1.3 Clear debris from around the crater at least 6 m (20 ft) in all directions to allow identification of the upheaved pavement surface. Identification and removal of all upheaved or damaged pavement is critical. **It cannot be rolled down flush with the existing pavement and left.** The upheaved pavement will eventually break up and create additional problems adjacent to the crater.

5-3.1.4 Perform a profile measurement and visual inspection to identify and mark upheaval around the crater.

5-3.1.5 Break out the upheaved pavement.

5-3.1.6 Square the sides to vertical from the original pavement surface down to a minimum depth of 406 mm (16 in.).

5-3.1.7 All debris material in excess of 304 mm (12 in.) in diameter must be removed or reduced in size.

5-3.1.8 Standing water in the crater must be pumped out, if possible.

5-3.1.9 Any reinforcing material protruding from the original pavement must be cut off and removed.

5-3.1.10 Backfill the crater with useable debris or a combination of debris and local cohesionless material and level to exactly 711 mm (28 in.) below the original pavement surface.

5-3.1.11 Backfill material must be compacted to a minimum 4 CBR.

5-3.1.12 Install a 304-mm (12-in.) layer of crushed stone (38 mm [1.5 in.] minus) over the backfill material. Place and compact the crushed stone material in lifts approximately 152 mm (6 in.) thick. Compact each lift of crushed stone using a **minimum of four passes** of a single-drum vibratory roller or **two passes** with a 10-ton vibratory roller per each 152-mm (6-in.) lift. One pass of the roller means traveling across and back in the same lane. If the crushed stone material is placed upon soft subgrade materials, it may be beneficial to separate the crushed stone from the backfill with a geotextile and to place the crushed stone material in thicker lifts. In any case, the crushed stone should be compacted with a **minimum of four passes** of a single drum vibratory roller or **two passes** of a 10-ton vibratory roller per each 152 mm (6 in.) of thickness. A 304-mm (12-in.) crushed stone layer should receive a **minimum of eight passes** with a single-drum vibratory roller, or **four passes** with a 10-ton vibratory roller. This crushed stone material must be compacted to a minimum 25 CBR. The CBR may be verified using a Dynamic Cone Penetrometer. (See References 9 and 10.)

5-3.1.13 Place a layer of sand approximately 304 mm (12 in.) wide by 25 to 50 mm (1 to 2 in.) deep around the entire inside of the crater lip to prevent seepage of the grout around the edge of the crater.

5-3.1.14 Position a layer of impervious membrane material over the entire crushed stone surface.

5-3.1.15 Place a 203-mm (8-in.) layer of grout material mixed in accordance with Table 5-1 into the crater.

Table 5-1. Stone and Grout Mix Proportions

Grout Mixture	Percentage by Weight	Weight of Additive Per Cubic Yard
Portland cement	67.8	1012 kg (2232 lb)
Calcium chloride (accelerator)	1	15 kg (33 lb)
Friction retarder	0.2	3.0 kg (6.5 lb)
Water	31	456 kg (1005 lb)

Note: This mixture will develop a compressive strength of at least 1500 lb per square in. (psi) in 24 hr.

5-3.1.16 Add 1 percent calcium chloride accelerator by weight to the grout mix.

5-3.1.17 Place a 203-mm (8-in.) layer of 76-mm (3-in.) stone into the grout mixture, producing a 406-mm (16-in.) layer of stone and grout. This stone is worked into the grout by walking a dozer or high-speed tamping foot roller across the repair.

5-3.1.18 A vibratory roller is used to percolate the grout up through the stone to the surface.

5-3.1.19 The level of the stone and grout mixture should be within 19 mm (0.75 in.) of the original pavement surface. Add equal parts of stone and grout until the repair is level with the original pavement surface.

5-3.1.20 The stone-grout mixture should be cured under a suitable curing membrane for a minimum of 24 hr. A 6 mil polyethylene sheeting (NSN: 8135-00-579-6487) can be used to seal moisture provided the pavement surface is monitored periodically to ensure that adequate moisture is maintained on the surface. One alternative is to place wet burlap or geotextile (NSN: 5675-01-471-2647) beneath the plastic sheeting to prevent maintain appropriate surface moisture.

5-3.2 Stone and Grout Repair (Below Freezing Temperatures)

5-3.2.1 Special consideration must be made when placing the stone and grout mixture in freezing temperatures. There are several methods that can be employed to help ensure successful mission accomplishment.

5-3.2.2 Add additional calcium chloride accelerator (up to as much as 3 percent by weight from the normal amount of 1 percent) to the solution of stone and grout to decrease the set time.

5-3.2.3 Heat the aggregate; this can be done in a tent surrounding aggregate stockpiles.

5-3.2.4 Heat the water. One possible method is to use immersion heaters. It is best to heat both the water and the aggregate, rather than just one. This helps ensure that the extremely cold condition of either component will not offset the heated condition of the other. Do not mix the water and aggregate until the last possible moment.

5-3.2.5 Do not uncover the subgrade until immediately before placement to allow heat to be retained. This necessitates a change in repair priorities since several craters cannot be worked on concurrently (as their subgrades would be left exposed while awaiting grout); rather, one crater is completely repaired before moving on to repair the next.

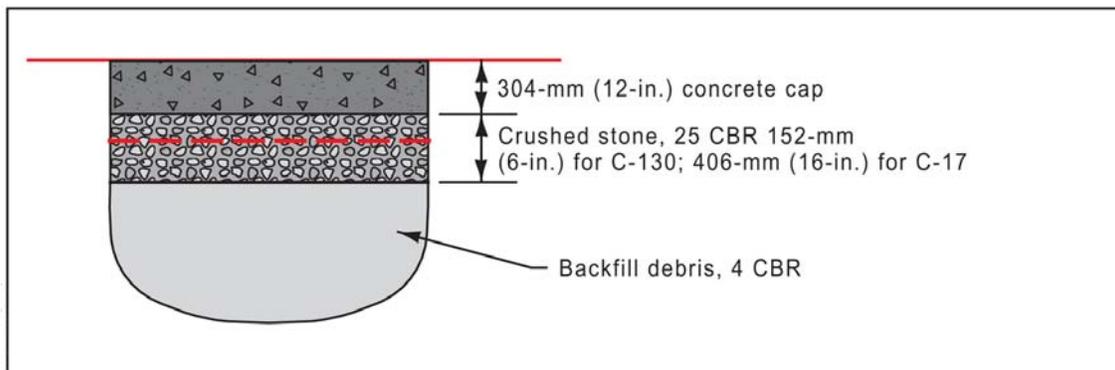
5-3.2.6 Place an insulated blanket over the finished surface. One possible composition of this blanket is a layer of impervious membrane (NSN: 8135-00-579-6487), approximately 254 mm (10 in.) of straw or hay, followed by an additional layer of impervious membrane.

5-4 **AM-2 MAT REPAIR.** See para. 4-6.

5-5 **RAPID SET MATERIAL.** See para. 4-7.

5-6 **CONCRETE CAP REPAIR.** See Figure 5-2.

Figure 5-2. Concrete Cap Repair



5-6.1 This type of repair may be used in lieu of or as a replacement for both the crushed stone and sand-grid repairs when additional resources are available. Uniform compaction of backfill material is critical.

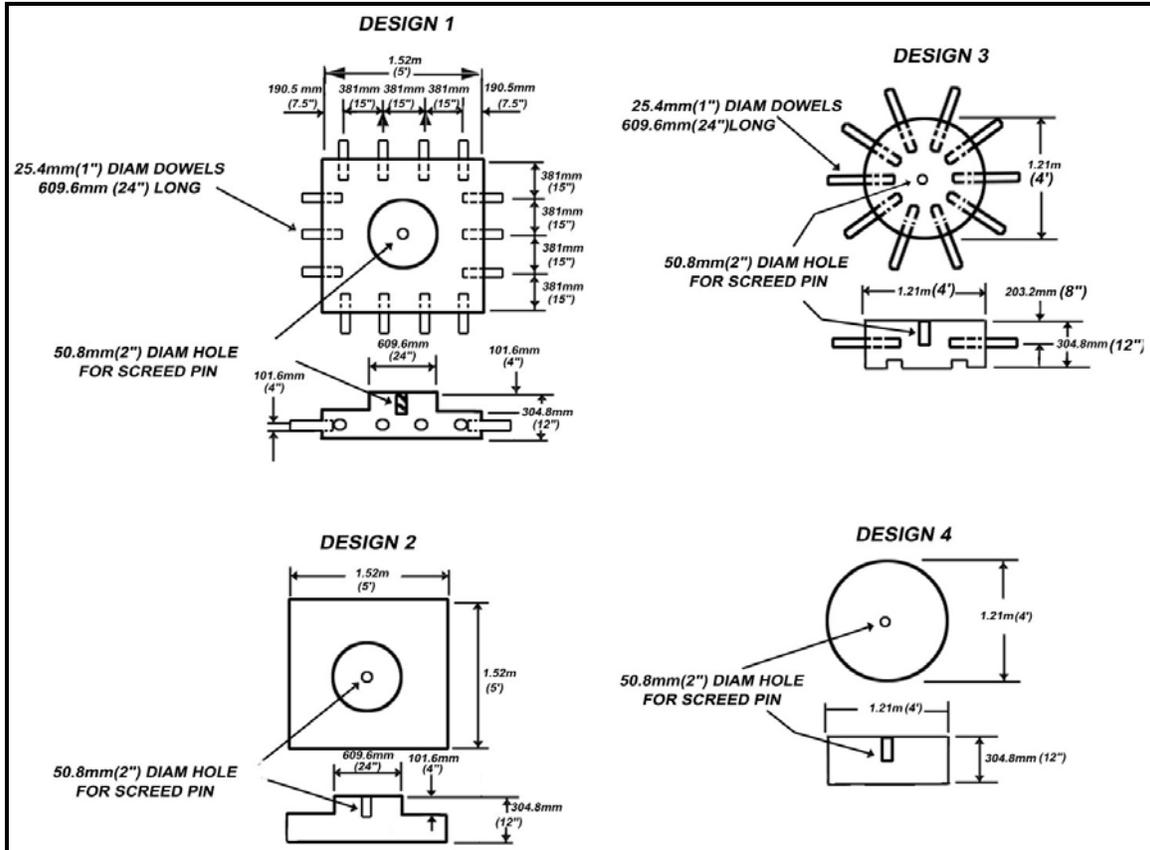
5-6.2 Clear debris from around the crater at least 6 m (20 ft) in all directions to allow identification of the upheaved pavement surface. Identification and removal of all upheaved or damaged pavement is critical. **It cannot be rolled down flush with the existing pavement surface and left.** The upheaved pavement will eventually break up and create additional problems adjacent to the crater repair.

5-6.3 Perform a profile measurement and visual inspection to identify and mark upheaval around the crater.

- 5-6.4 Square to vertical the sides from the original pavement surface down to a minimum depth of 304 mm (12 in.).
- 5-6.5 All debris material in excess of 304 mm (12 in.) must be removed or reduced in size.
- 5-6.6 Standing water in the crater must be pumped out, if possible.
- 5-6.7 Any reinforcing material protruding from the original pavement must be cut off and removed.
- 5-6.8 Backfill the crater with useable debris and level to exactly 711 mm (28 in.) below the original pavement surface to support C-17 operations, or 457 mm (18 in.) to support C-130 operations.
- 5-6.9 Backfill material must be compacted to a minimum 4 CBR.
- 5-6.10 If settling problems are anticipated, a geotextile fabric is recommended for use between dissimilar backfill and the next layer of material.
- 5-6.11 Place a layer of crushed stone (38 mm [1.5 in.] minus) over the backfill material. This layer should be 406 mm (16 in.) thick to support C-17 operations, or 152 mm (6 in.) thick to support C-130 operations. Place the material in lifts approximately 152 mm (6 in.) thick. Compact each lift of crushed stone using a **minimum of four passes** of a single-drum 5-ton vibratory roller or **two passes** with a 10-ton vibratory roller. One pass of a roller means traveling across and back in the same lane. If the crushed stone material is placed upon soft subgrade materials, it may be beneficial to separate the crushed stone from the subgrade with a geotextile and to place the crushed stone material in thicker lifts. In any case, the crushed stone should be compacted with a **minimum of four passes** of a 5-ton single-drum vibratory roller or **two passes** of a 10-ton vibratory roller per each 152 mm (6 in.) of thickness. This crushed stone must be compacted to a minimum of 25 CBR.
- 5-6.12 The final 304 mm (12 in.) is filled with concrete and leveled with the existing pavement surface. The concrete mixture design will depend on what is available in the local area. The primary requirement is that the concrete develop a minimum compressive strength of 1500 psi in 24 hr. The concrete should be moist cured as long as possible (preferably 24 hr) using an appropriate curing compound or covering.
- 5-6.13 For craters smaller than 9.1 m (30 ft) in diameter, screeding can generally be performed by hand. When single craters or overlapping craters form a damaged area greater than 9.1 m (30 ft) in diameter, a screed method using a concrete pedestal is recommended. See Figure 5-3.
- 5-6.14 Prepare the center of the crater so that the surface of the prefabricated concrete pedestal is even with the surface of the pavement. This is best accomplished with a string line.

5-6.15 Secure the screed beam to the pedestal by placing a steel pin through the beam into the slot in the pedestal.

Figure 5-3. Pedestal Designs



5-6.16 Clean the edges of the crater and place a starter form in the crater. The starter form is an artificial headboard form that allows the concrete to be rapidly leveled as it is placed into the crater. The starter form is removed from the crater as soon as the placement is completed. Experience has shown that load transfer devices (such as dowels) are not needed to permit better bonding to the existing runway.

5-6.17 It is critical to ensure a homogeneous placement of the concrete cap. At least three concrete ready-mix or concrete-mobile modules should be pre-positioned around the crater to allow an initial steady placement of concrete into the crater, if possible.

5-6.18 Finish the surface until it is level with the surrounding pavement. Every effort should be made to maintain joints across the repair for existing PCC pavement. For large crater repairs (greater than 20-ft diameter), an attempt should be made to establish joints in the repair such that equivalent sections are smaller than 20-ft by 20-ft, but not less than 10-ft by 10-ft. An accelerator must be added to quicken the curing time. The concrete must be allowed to cure at least 24 hr before trafficking with aircraft. A roughened finish, e.g., broom-finish, is desired to increase friction.

5-7 **ASPHALT CONCRETE REPAIR.** Use of cold mix asphalt and similar materials for spall repair was discussed previously. Use of hot mix asphalt as a surfacing material in crater repair has not been widely investigated and caution is advised in pursuing this approach. Design should strictly adhere to guidance for conventional flexible pavements as provided in Reference 9.

5-8 **SEMI PREPARED SURFACES.** See para. 4-8.

5-8.1 **Unsurfaced Repair.** See para. 4-8.1.

5-8.2 **Stabilized Surface Repair.** See para. 4-8.2.

CHAPTER 6

PERMANENT REPAIR

6-1 **PERMANENT REPAIRS.** Once the conflict is over, permanent repairs will return the air base to its original conditions. Permanent repairs are designed to sustain 50,000 or more C-17 passes with a gross weight of 263,008 kg (580 kips), or 50,000 C-130 passes with a gross weight of 79,380 kg (175 kips), or to support a service-defined airfield design type, depending upon mission aircraft, in accordance with References 4 and 9. Permanent repairs should be made following procedures in References 4 and 9.

CHAPTER 7

SUMMARY AND LESSONS LEARNED

7-1 **SUMMARY.** The purpose of this manual is to bring together in one document the Airfield Damage Repair (ADR) concepts of the various services (Army, Navy, Marine Corps, and Air Force). A review of this manual will reveal that in some areas the approach is the same for all services while in other areas each service (except possibly for Navy-Marine Corps) follows a different procedure. While Airfield Damage Repair in its entirety from pre-attack to post-attack and final recovery involves numerous functions and activities, the scope of this manual is limited to the area of airfield pavement repair. Covered are spall repair and expedient and sustainment crater repair procedures. Information in this manual is based on a review of manuals and other guidance documents from the various services and on informal contacts with individuals involved in ADR such as instructors in service schools and those having hands-on experience. This document represents an initial effort toward development of joint guidance in ADR.

7-2 **LESSONS LEARNED**

7-2.1 Recent operations in Afghanistan and Iraq have generated a renewed interest in ADR and a wealth of information regarding the suitability of the methods described in existing criteria and the equipment used to execute ADR by individual service units. Prior to the publication of this document, an attempt to consolidate feedback from units charged with repairing theater airfields was performed and the results are summarized in the following paragraphs. The lessons learned can generally be divided into two distinct categories, equipment lessons and methodology lessons. Each of the items presented in the following paragraphs represents the comments of multiple Army, Air Force, and Navy engineer units.

7-2.2 **Equipment Lessons.** The equipment used by units charged with executing ADR varies both by service and within service as individual units seek to customize their equipment packages to achieve additional capability. The unit feedback includes concerns and recommendations for construction equipment, tools, and Class IV materials included in ADR kits. An overarching need exists to standardize ADR equipment across units and services as much as possible for economic as well as functional reasons.

7-2.2.1 A universal comment regarding ADR equipment was praise for the utility of small skid steer equipment for ADR. Skid steers have a reduced logistical footprint compared to traditional construction equipment while maintaining adequate construction efficiency. This is critical when conducting expedient repairs where the airfield may not be operational and the equipment must either be air-dropped or sling-loaded for delivery. The ability of the skid steers to quickly remove debris, change attachments, and begin new tasks was unparalleled. Recommended attachments for ADR in order of importance to the mission include: a combination bucket, pavement breaker, vibratory roller, sweeper, concrete mixer, rotary tiller (for soil stabilization),

- forklift, bulldozer blade, auger, and excavator (mixed reviews of excavator by individual units).
- 7-2.2.2 The Army's Small Emplacement Excavator (SEE) was invaluable in the theater of operations due to its ability to excavate the debris from the crater and serve as a power supply for hydraulic tools. However, the pavement breaker attachment of the skid steers was preferred over the SEE for removing upheaval.
- 7-2.2.3 The DEUCE should be omitted from the Army's LARPs. Units prefer the skid steer's versatility and the capability of the JD-450 bulldozer over the DEUCE. The consensus is that the DEUCE has minimum utility in ADR other than initial debris clearance and serving as a power supply for hydraulic tools.
- 7-2.2.4 Due to the initial reliance upon soil and stabilized soil for repairs, the complete lack of water assets became a major concern. Units recommended adding a skid-mounted water tank to the equipment package that could be placed in the bed of a 5-ton dump truck or replacing the DEUCE in the inventory. Water assets will continue to be critical for construction operations in arid environments and transportation of water resources in other climates.
- 7-2.2.5 Repairs executed by traditional heavy engineer units (SEABEEs, RED HORSE, and Army Combat Heavy) relied heavily upon the ability to mix and place concrete. Army units, particularly light engineers, do not have an organic concrete capability. Army units recommended the addition of an organic concrete repair capability to execute more permanent repairs in order to reduce the sustainment requirements of expedient pavement repair techniques. Units recommended the addition of portable concrete mixers (1 cubic ft, ½ cubic yard, or ¾ cubic yard) or a concrete mixer attachment for the skid steers. The units recommended the addition of a larger concrete saw, particularly as a skid steer attachment, for upheaval removal and slab harvesting. Other equipment identified included concrete vibrators, adjustable screeds, and plastic sheeting for curing.
- 7-2.2.6 Hand tampers or walk-behind vibratory compactors were required for in-crater compaction, which was critical for supporting heavy cargo aircraft.
- 7-2.2.7 Equipment redundancy was emphasized, especially Army units where the equipment is often air-dropped in order to open the landing zone.
- 7-2.2.8 The order of equipment delivery and prioritization of equipment during pre-deployment is very important. Equipment was prioritized according to the following order: skid steers, SEE/excavator, vibratory roller, grader, bucket loader, dump trucks, DEUCEs, and remaining equipment.
- 7-2.2.9 Both Army and Air Force units indicated the need for a new and improved FOD cover. Current FOD covers are very difficult to ship and require excessive volumes. Units recommended that new designs be optimized for

standardized shipping platforms including the 18-ft by 88-in. pallets commonly used. A man-portable system is desired to remove the requirement for using limited equipment assets to deploy the matting and tow it over the repaired crater. Other comments indicated that the average crater diameter was approximately 20-ft, and some craters would require multiple FRP kits due to its 25-ft-diameter configuration.

7-2.2.10 All of the rapid set cements now in use for spall repairs demonstrate one or more undesirable characteristic, e.g., toxic or noxious fumes, high heat of reaction, short workability window, short shelf life, high cost, etc. A rapid-set cement with improved properties is needed. Rapid setting cements and epoxies that result in a high strength and/or a brittle repair should only be used for portland cement concrete pavements.

7-2.2.11 Cold mix asphalt, including proprietary cold mix patch materials, are not satisfactory for spall repair on rigid pavements. Experience has shown that these materials tend to deform severely under aircraft traffic when used for spall repair on rigid pavements. Cold mix asphalt repair products should only be used to repair asphalt concrete pavements.

7-2.2.12 ADR activities are not limited to daylight operations, and a method for identifying upheaval at night should be developed.

7-2.2.13 Lighter, structurally improved matting should be developed to replace AM-2. New advances in composite materials technology should be explored.

7-2.3 **ADR Methodology Lessons.** Individual units charged with airfield damage repair also provided feedback concerning the procedures and techniques used to execute repairs in the theater of operations. The restriction on the use of FOD covers for C-17 landings resulted in the adaptation of repair techniques. The following paragraphs consolidate the comments.

7-2.3.1 Most of the spall and crater repairs failed due to failures of the surrounding pavement surface. This could result from improper identification and removal of damaged or upheaved pavement or simply represent the poor overall condition of the pavement systems at a particular airfield.

7-2.3.2 The principle means of crater repair used by Army units and some SEABEE units was cement stabilized soil. Cement stabilized soil repairs were used effectively until sustainment repairs could be made. Cement stabilized soil repairs consisted of spreading the soil in thin 3-4 in. lifts, adding the appropriate amount of cement, mixing the soil and cement with hand tools, and compacting the material in place.

7-2.3.3 One method used included backfilling the crater with debris to within 20 in. of the surface, placing two layers of sand grid according to the procedures for an expedient sand grid repair and capping the sand grid with a 4-in. layer of cement stabilized soil. However the cement stabilized soil repair without sand

grid was preferred due to the perceived improvement of stabilized material rather than sand grid reinforced material.

- 7-2.3.4 Slab harvesting consists of removing portland cement concrete slabs from an unused area of the airfield and placing them in an excavated repair. A similar concept of using pre-cast concrete slabs was also used where slabs of a given size were mixed and placed offsite and then placed during lulls in the operations tempo. This technique requires a large concrete saw, forklift, and repair materials for sealing the edges. The difficulty in achieving smooth surfaces and the lack of load transfer between the existing pavement and independent slab resulted in mixed performance.
- 7-2.3.5 A common sustainment repair consisted of backfilling the crater with debris to within 16 in. of the surface. The crater was then divided into slabs and formed according to typical slab sizes and concrete placement capability. Portland cement concrete was then placed and finished with or without reinforcement. Pickets were often used as substitute tensile reinforcement due to the lack of rebar. Procurement of significant quantities of cement and suitable aggregate early in the repair cycle was very difficult.
- 7-2.3.6 The sand grid repairs surfaced with soil and stabilized soil did not withstand a significant number of heavy cargo aircraft operations without maintenance. Units eventually abandoned the technique as they procured concrete placement equipment and materials for performing sustainment repairs.
- 7-2.3.7 The sustained maintenance and repair of an airfield requires more manpower and equipment than that included in the Army's LARP. The LARP was intended as the minimum resources required to perform a minimum of repairs to open a damaged airfield. However, due to air flow limitations, the LARP was tasked with continual sustainment of a rapidly deteriorating airfield. Planners must recognize that additional manpower, equipment, and materials beyond the LARP will be required for sustained operations.

GLOSSARY

Acronyms and Abbreviations

720 STG/DOO — 720th Special Tactics Group, Operations and Training

ABFC — Advanced Base Functional Component

ADR — airfield damage repair

AFJPAM — Air Force Joint Pamphlet

AFM — Air Force Manual

AFMAN — Air Force Manual

AFPAM — Air Force Pamphlet

AFPD — Air Force Policy Directive

AMOG — Air Mobility Operations Group

CBR — California Bearing Ratio

COTS — commercial-off-the-shelf

DCP — dynamic cone penetrometer

DEUCE — Deployable Universal Combat Earthmover

DoD — Department of Defense

ETL — Engineering Technical Letter

FAS — Forward Aerial Supply

FFM — folded fiberglass mat

FLIP — Flight Information Publication

FM — Field Manual

FOD — foreign object damage

FRP — fiberglass reinforced plastic

HQ AFCESA/CES — Headquarters Air Force Civil Engineer Support Agency, Technical Support Directorate

HQ AFCESA/CESC — Headquarters Air Force Civil Engineer Support Agency, Civil Engineering Division

HQ AFSOC/DOO — Headquarters Air Force Special Operations Command, Operations and Training

HQ AMC TACC/XOPM — Headquarters Air Mobility Command, Tanker Airlift Control Center, Mission Support Cell

HQ AMC/DOK — Headquarters Air Mobility Command, Directorate of Operations

HQ AMC/DOVS — Headquarters Air Mobility Command, Airfield Analysis

in— inch

kg — kilogram

LARP — Light Airfield Repair Package

lb — pound

MAOS — minimum airfield operating surface

mm— millimeter

MOS — minimum operating strip

MWSG — Marine Wing Support Group

MWSS — Marine Wing Support Squadron

NAVAIRINST — Naval Air Systems Command Instruction

NAVAIRMAN — Naval Air Systems Command Manual

NAVFAC — Naval Facilities Engineering Command

NAWCADLKE — Naval Air Warfare Center Aircraft Division Lakehurst

NCF — Naval Construction Force

NMCB — Navy Mobile Construction Battalions

NOTAM — Notice to Airman

PLL — Prescribed Load List

POL — petroleum, oil, lubricants

Prime BEEF — Priority Improved Management Effort - Base Engineer Emergency Force

psi — pound per square inch

RED HORSE — Rapid Engineers Deployable - Heavy Operations Repair Squadron Engineers

RQC— Repair Quality Criteria

RRR— rapid runway repair

SEE — Small Emplacement Excavator

STT — Special Tactics Team

T.O. — Technical Order

TALCE — Tanker Airlift Control Element

TC — Training Circular

UFC — Unified Facilities Criteria

USACE — US Army Corps of Engineers

VTOL — vertical takeoff and landing

Terms

Actual crater diameter: Opening in the airfield surface after all the debris and upheaved surface have been removed. Also measured from lip-to-lip, and in most cases is significantly larger than the apparent diameter.

Airfield: An airfield may be captured, constructed, or provided by the host nation, and may consist of any suitable aircraft operating surface.

Apparent crater diameter: Opening in the airfield surface that can be seen before any work is accomplished on the crater; measured from upheaval lip-to-lip.

Camouflet: Craters with relatively small apparent diameters but deep penetration and subsurface voids. Penetration-type projectiles with time-delay fuses normally cause camouflets.

Expedient airfield repair: Provides an accessible and functional MAOS that will sustain 100 C-17 passes with a gross weight of 227,707 kg (502 kips), or 100 C-130 passes with a gross weight of 79,380 kg (175 kips), or 100 passes of a particular aircraft at its projected mission weight if other than the C-17 or C-130, or the number of passes required to support the initial surge mission aircraft.

Large crater: Damage that penetrates into the base course from the airfield surface. Large craters have an apparent diameter that exceeds 6 m (15 ft).

Minimum airfield operating surface (MAOS): The minimum surface on an airfield that is essential for the movement of aircraft. It includes the aircraft dispersal areas or parking aprons, the runways, and the taxiways between them.

Minimum operating strip (MOS): The smallest amount of area that must be repaired to launch and recover aircraft. Selection of the MOS will depend upon mission requirements, taxi access, resources available, and estimated time to repair. The length of the MOS will depend on the take-off or landing distance of the mission aircraft, whichever is greater. For fighter aircraft, the typically accepted dimensions are 1524 m long by 15.2 m wide (5,000 ft long by 50 ft wide). For the C-130 Hercules, the dimensions are 1067 m long by 18.3 m wide (3,500 ft long by 60 ft wide). For the C-17 Globemaster III, the dimensions are at least 18.3 m long (but may be longer depending upon altitude, surface type, and runway condition rating of the airfield; see ETL 98-5, *C-130 and C-17 Contingency and Training Airfield Dimensional Criteria*) and 27.4 m (90 ft) wide. These dimensions do not include the requirement for a 93-m (300-ft) overrun.

Note to Airman (NOTAM): A NOTAM is issued for inclusion in DoD Flight Information Publications (FLIP) to alert aircrews of the establishment and condition of, or changes to, airfield facilities. This would include any restrictions or limitations placed upon airfield operations due to airfield damage.

Permanent airfield repair: This repair increases the MAOS to sustain 50,000 or more C-17 passes with a gross weight of 263,008 kg (580 kips), or 50,000 C-130 passes with a gross weight of 79,380 kg (175 kips), or to support a service-defined airfield design type, depending upon mission aircraft, in accordance with UFC 3-260-02, *Pavement Design for Airfields*.

Small crater: Damage that penetrates into the base course from the airfield surface. Small craters have an apparent diameter of 6 m (15 ft) or less.

Spall field: Cluster of spalls within an area requiring repair. May include from 10 to several hundred spalls, depending on the munitions used.

Spall: Pavement damage that does not penetrate through the pavement surface to the underlying soil layers. A spall damage area could be up to 1.5 m (5 ft) in diameter.

Sustainment airfield repair: Maintains or increases the MAOS to support the operation of 5,000 C-17 passes with a gross weight of 227,707 kg (502 kips), or 5,000 C-130 passes with a gross weight of 79,380 kg (175 kips), or the number of passes required to support mission aircraft at the projected mission weights throughout the anticipated operation, if other than the C-17 or C-130.

APPENDIX A

CRATER PROFILE MEASUREMENT WITH STANCHIONS

A-1 **Description.** This section describes the assembly and use of stanchions for Line-of-Sight (LOS) measurement of the extent of upheaval around the crater perimeter and the verification of crater repair quality. These procedures are based upon T.O. 35E2-5-1, Crushed Stone Crater Repair and Line-of-Sight Profile Measurement for Rapid Runway Repair. The goal of the crater repair process is to achieve a flush quality repair (+/- 3/4"). If this goal is not met the SRC provides allowable RQC for each crater repair on the MOS.

A-1.1 **Applications.** The stanchion LOS technique is used to determine where upheaval begins around the perimeter of the crater. Crater repair measurements are made before and after FOD cover installation. Stanchion LOS techniques can be used to determine when crater repair maintenance is required.

A-1.2 **Manpower.** The stanchion LOS technique requires a minimum of 3 trained personnel to efficiently perform the required measurements. One NCO acts as the Crater Profile Measurement (CPM) team chief. The CPM is supported by two properly trained augmentees. When not performing actual profile measurements, the profile team will work other tasks assigned by the crater repair team chief. This may include spotting for dump trucks reversing, shoveling, or driving of dump trucks or machinery if licensed.

A-1.3 **Equipment.** The stanchion LOS technique requires two LOS stanchions, one LOS rod, and marking material (paint, keel, or chalk). Detailed descriptions of the LOS stanchions are provided in Figures A1 and A2. The LOS target rod is shown in Figures A3 and A4.

A-2 **Procedures.** The stanchion LOS technique is used initially to identify the extent of crater upheaval around the perimeter of the crater. Verification measurements should be made after the upheaval has been removed to verify all upheaval has been removed. A third set of measurements should be conducted to verify that the repaired crater is within flush repair tolerance. Measurements should also be conducted after several sorties have flown across the repair patch to ensure the patch is within the allowable RQC tolerances, and periodically during traffic to identify when maintenance is needed on the repairs.

A-2.1 **Initial Upheaval Identification.** The following procedures describe the process for identification of the upheaval around the perimeter of the crater. See Figure A5.

- (1) Locate assigned crater repair and have equipment operators clear debris from one entire half of the crater so you may begin identifying upheaval while they clear debris from the other half of the crater. Identify upheaval around the crater in halves. Work from the center of the crater outward in one direction.
- (2) Place LOS stanchions on a line through the middle of the repair, parallel to the MOS centerline. Place LOS stanchions approximately 10 paces from the crater lip on both sides of the crater. Ensure stanchions are placed on sound (no upheaved) pavement, and remove any debris from under the feet of the stanchions.
- (3) Level the sighting plates using the bubble level attached to the sighting planes. If

windy conditions exist, ensure security of the stanchions by either using a sandbag, or holding them upright with your foot.

- (4) The NCO stands approximately 2 meters behind one stanchion and sights along the top edge of the stanchion level plates.
- (5) The rodman, using the single target end of the rod, holds the rod plumb and clearly on crater upheaval. Following the directions of the engineering technician, the rodman moves outward from the edge of the crater towards the stanchions. The rodman moves in 1-meter increments towards the stanchions until the single target drops below the line-of-sight. At this point, the rodman takes the heel of his foot, places at the base of the rod cleans and marks the pavement using paint, keel, or chalk at the toe of his foot (approximately $\frac{1}{2}$ meter). If rainy, have the excavator jackhammer operator mark the pavement surface with his bit and proceed. See Figure A6.
- (6) The rodman then proceeds to the opposite side of the crater to accomplish the same task.
- (7) Once the center profile line of the crater has been marked, move the LOS stanchion 2 meters outward towards either the right or left crater edge. Continue marking until $\frac{1}{2}$ of the crater is encompassed with marks on the pavement identifying the point of maximum pavement upheaval.
- (8) Repeat procedures on the other half of the crater, as the excavator moves to the marked side of the crater to begin jackhammering/removing the upheaved lip.
- (9) Once the crater cavity is encircled with upheaval marks, use a push broom to clear dirt/small debris to paint/mark a line connecting all the upheaval marks.
- (10) Secure stanchions and marking materials away from equipment operations area for later use. Assist with the repair a directed by the crater repair team chief.

A-2.2 Intermediate Line-of-Sight checks. Verification measurements should be made after the upheaval has been removed to verify all upheaval has been removed. See Figure A7.

- (1) Verification measurements should be made when upheaval has been removed back to upheaval identification marks on the first half of the crater.
- (2) Place LOS stanchions back in position, and level the plates as before.
- (3) Place the single target end of the rod at the crater lip.
- (4) Ensure target is below the LOS on both sides of the repair.
- (5) Perform measurements on at least 5 profile lines across the crater. If additional upheaval is identified, mark with paint, keel, or chalk, and advise the crater repair team chief of the additional upheaval for needing removal.

A-2.3 Repair Quality Criteria (RQC) Check. A third set of measurements should be conducted to verify that the repaired crater is within flush repair tolerance. Measurements should also be conducted after several sorties have flown across the repair patch to ensure the patch is within the allowable RQC tolerances, and periodically during traffic to identify when maintenance is needed on the repairs. See Figures A8 through A11.

- (1) Conduct RQC checks to ensure that repairs are within flush repair tolerances ($\pm \frac{3}{4}$ ").
- (2) Use the adjustable target end of the LOS rod. Allow $\frac{1}{4}$ " for the thickness of the fiberglass mat FOD cover if used.

- (3) Set the bottom (bump) target to ½” below the zero mark.
- (4) Set the top (sag) target to 1” above the zero mark.
- (5) Set LOS stanchions in place again, starting along the centerline of the crater.
- (6) Have the rodman start at the far edge of the repair and proceed in 1-meter increments across the repair.
- (7) Have the rodman mark the repair with paint if the repair is above (+) or below (-) at any location on the profile line.
- (8) The repair is considered to be out of tolerance if the LOS rod target gap falls slightly outside (more than ¼”) the line-of-sight at three consecutive points on a profile line or grossly out of tolerance at any one point. Mark the locations of out of tolerance with paint and notify the crater repair team chief. The team chief will either direct the repair team to correct the deficiency or contact the DCC and SRC to see if the out of tolerance is within the required RQC tolerance.
- (9) RQC numbers for each repair are given to the DCC by the SRC once calculations have been accomplished.
- (10) To check the finished repair prior to aircraft operations or to check the repair after trafficking, set the movable targets on the LOS rod to the numbers furnished by the SRC. For example, if the SRC tells you a 3” RQC is acceptable for the repair, set the bottom (bump) target to 3”.
- (11) Set the top (sag) target to 2”. Remember the rule a 2” sag is allowed for any numbered (0” to 6”) RQC repair.
- (12) For the crater to be considered within RQC tolerance, set and level the LOS stanchions along the crater centerline, and have the rodman proceed across a profile line from the far edge walking towards your position behind one of the stanchions.
- (13) The repair is considered within tolerance if all spots fall within the gap between the bump and sag targets on the rod. The repair is considered to be out of tolerance if three consecutive spots on one profile line are slightly out of tolerance (more than ¼”), or any one spot on the profile line is grossly out of tolerance.
- (14) If the repair surface is out of tolerance, mark the repair surface with paint, and notify the crater repair team chief.

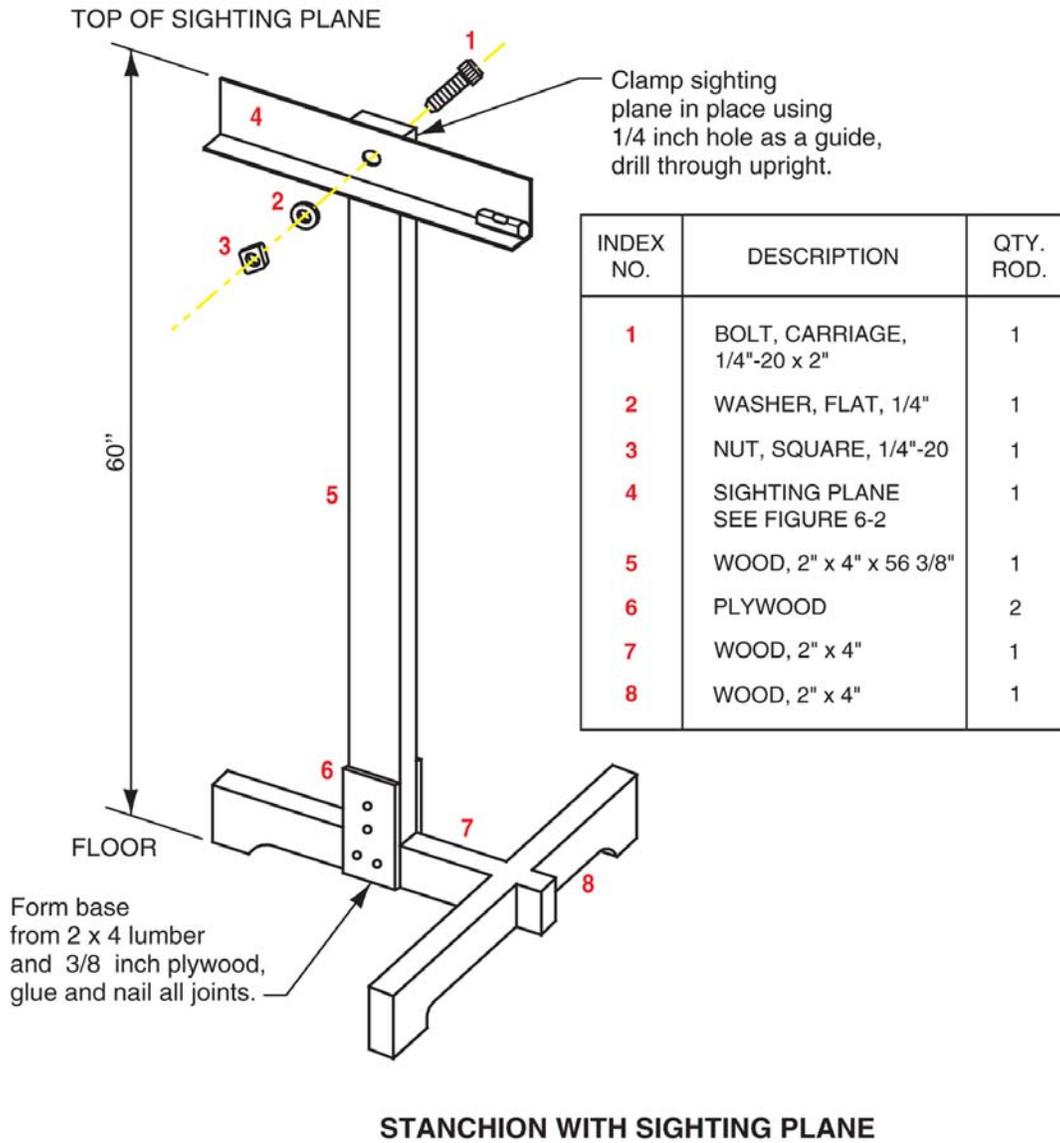
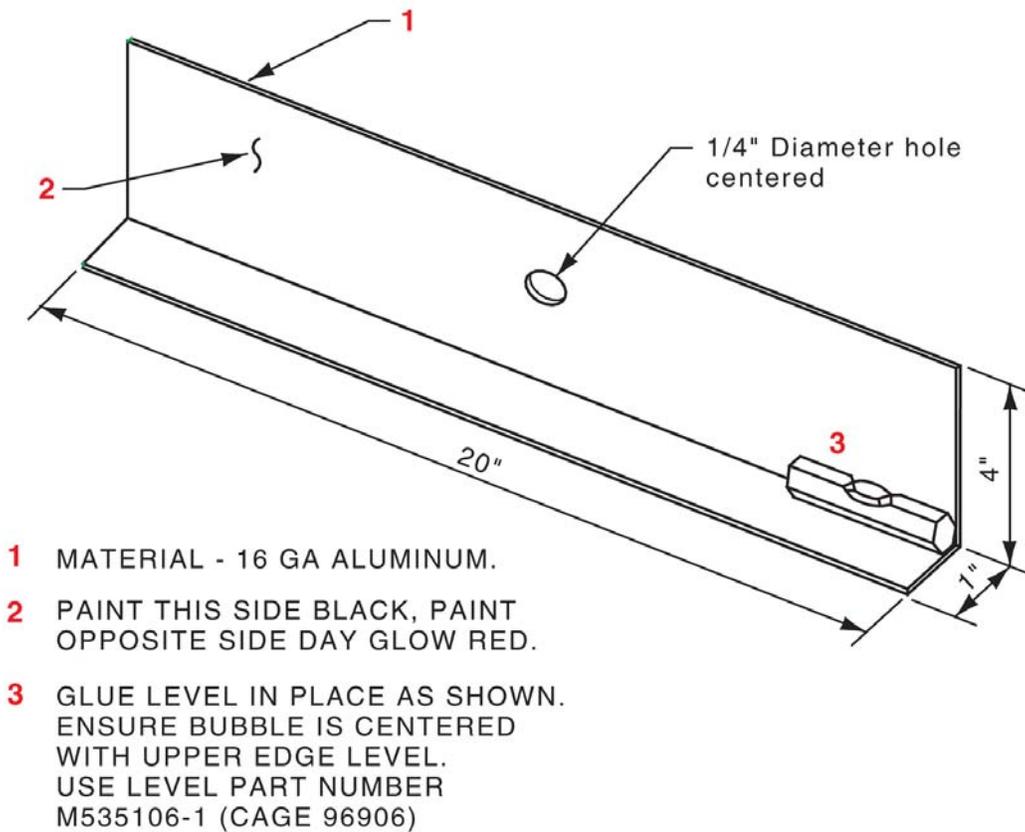
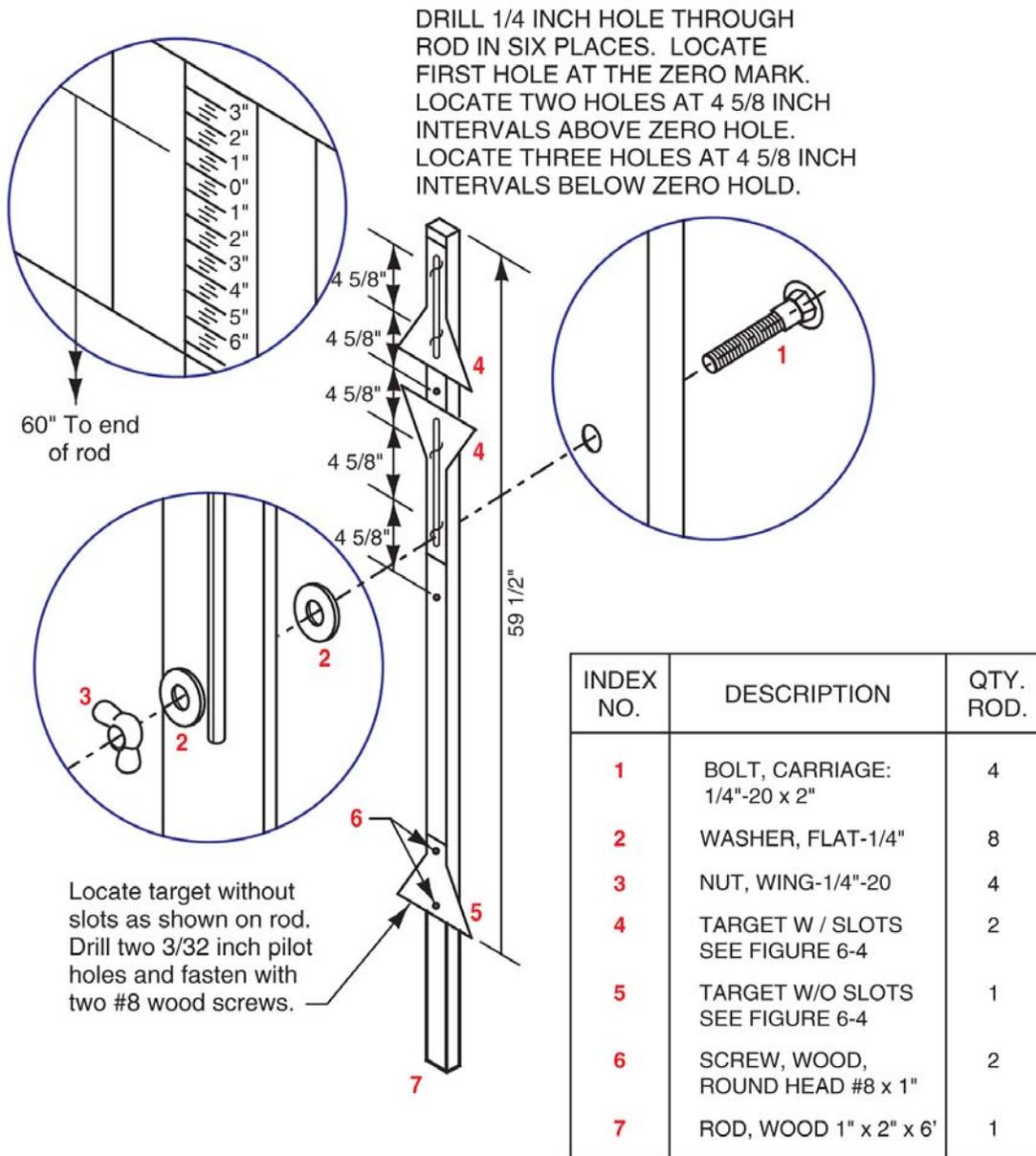


Figure A1. Components and assembly of stanchion with sighting plane



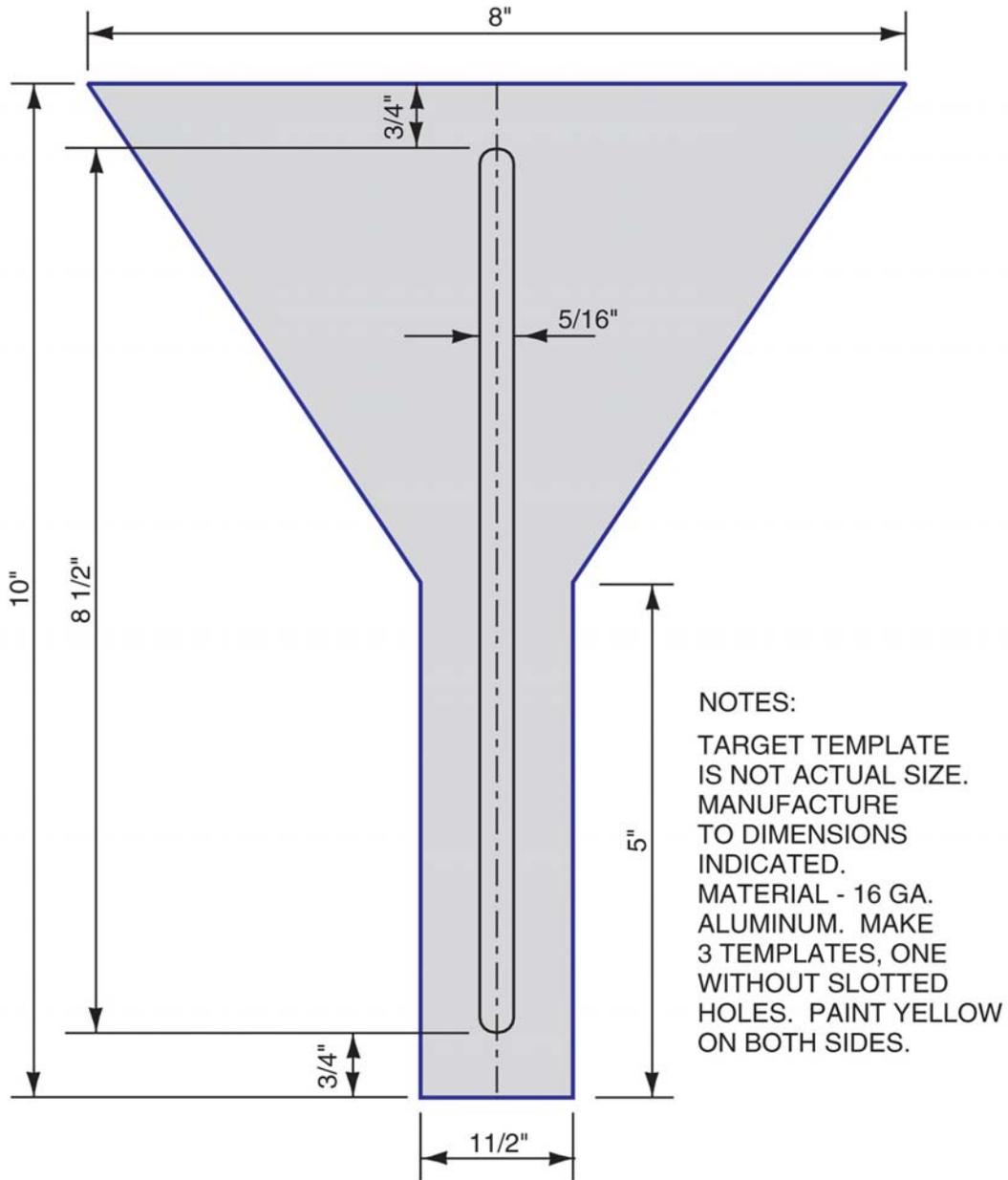
SIGHTING PLANE

Figure A2. Dimensions of sighting plane for use with stanchions



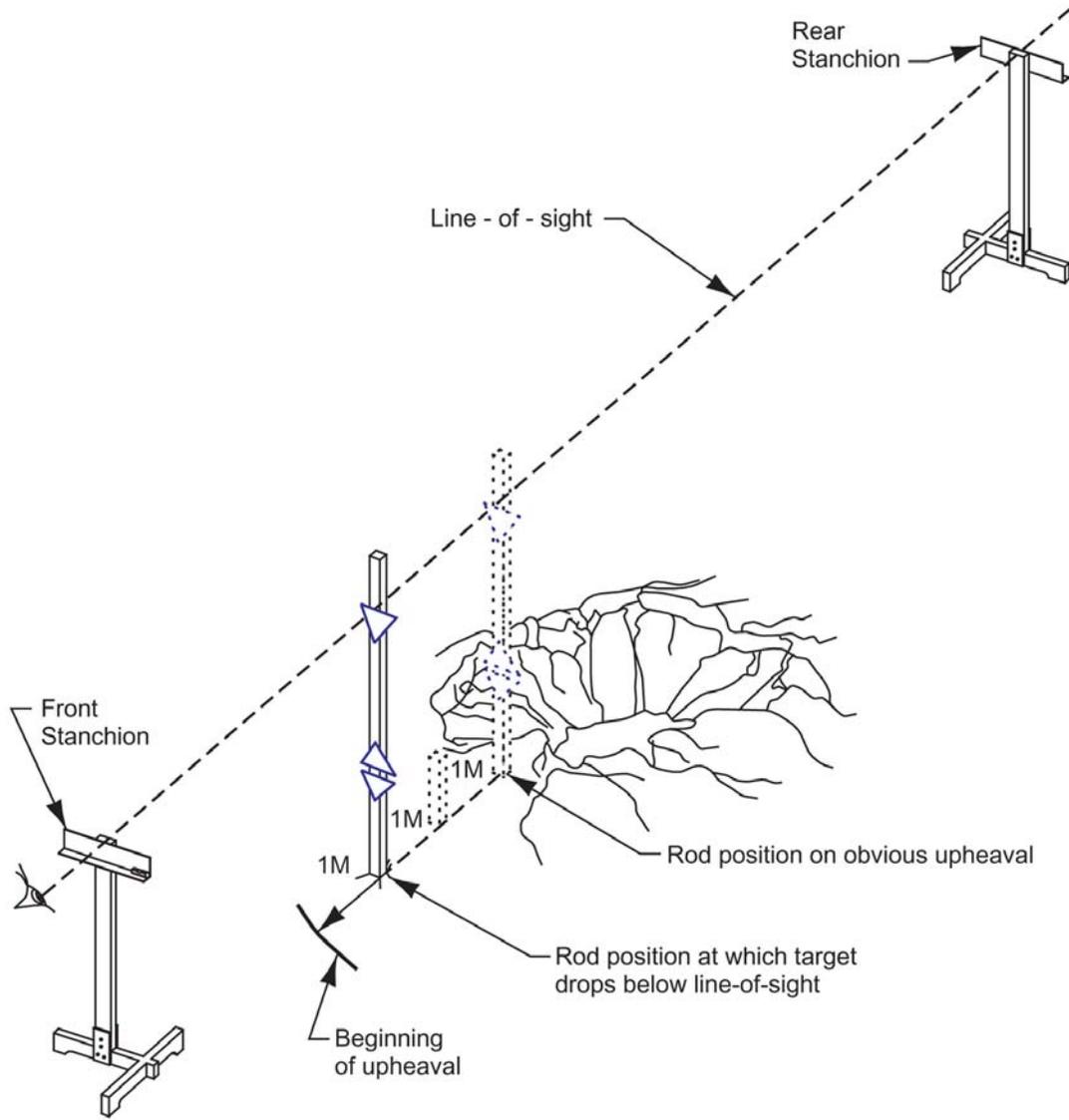
ROD WITH TARGETS

Figure A3. Components and assembly of target rod



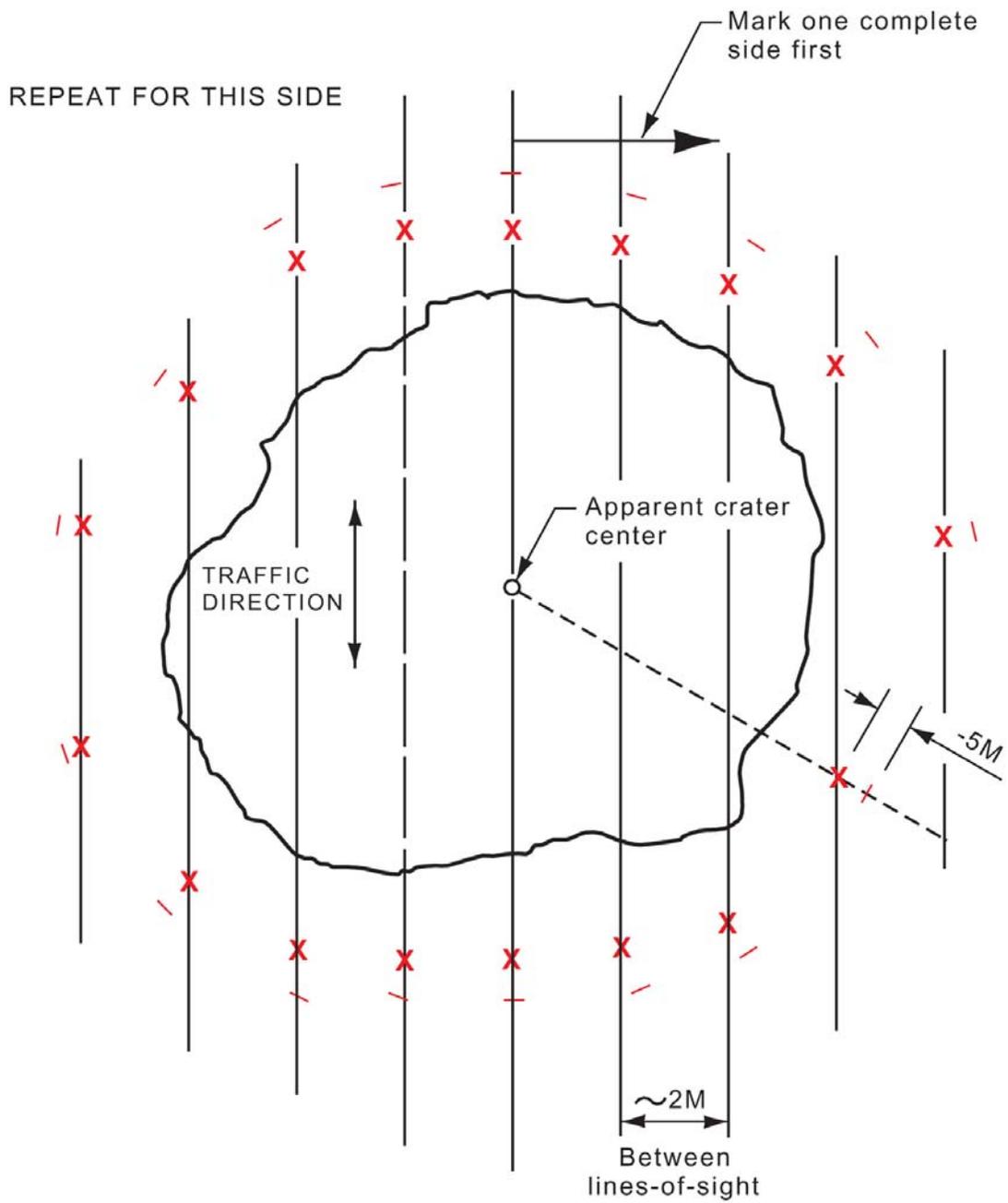
CRATER PROFILE MEASUREMENT TARGET TEMPLATE

Figure A4. Dimensions of target template for use with line-of-sight stanchions



UPHEAVAL IDENTIFICATION

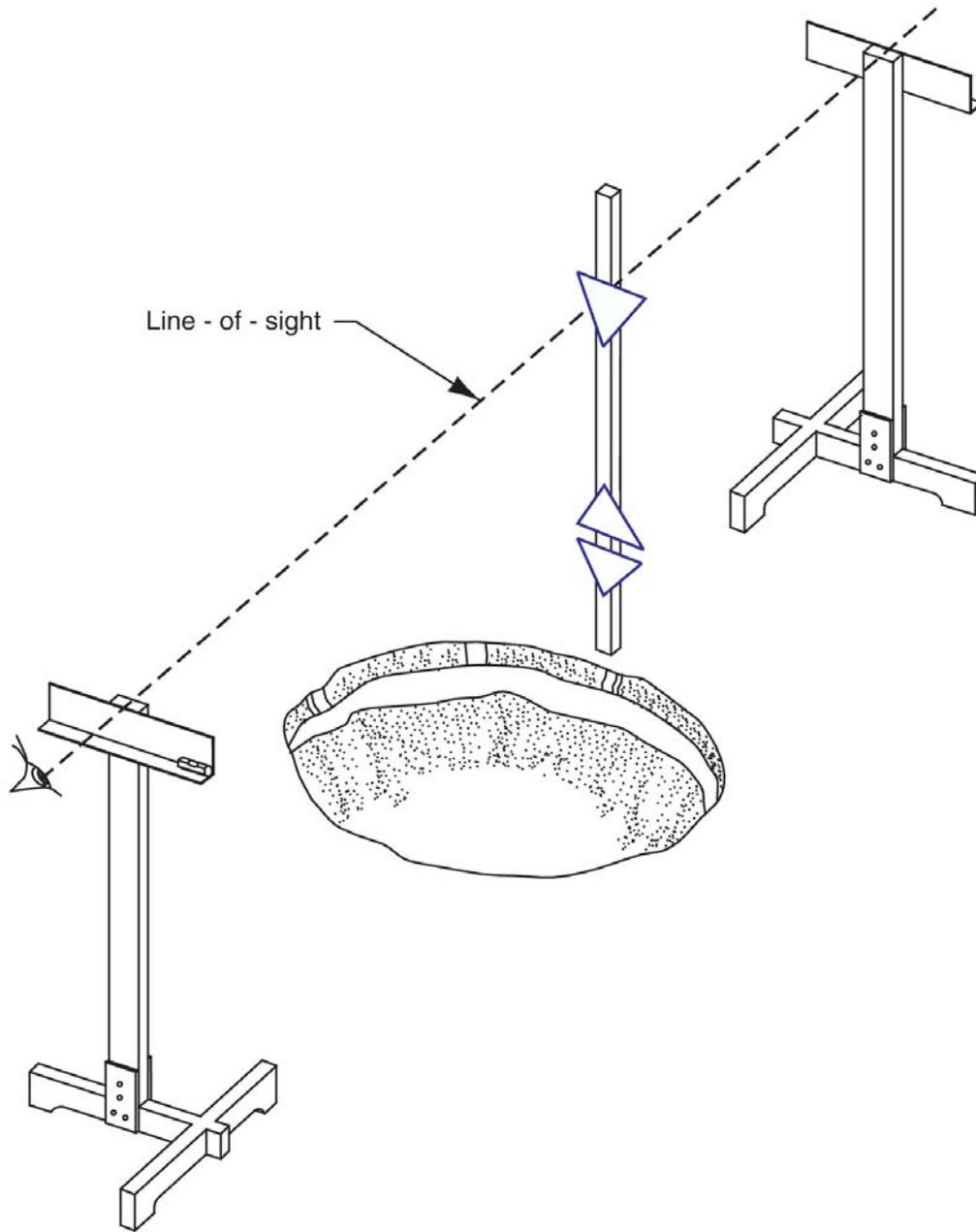
Figure A5. Upheaval identification using line-of-sight stanchions



- X** POINT AT WHICH TARGET DROPS BELOW LINE OF SIGHT
- PAINT MARKING BEGINNING OF UPHEAVAL

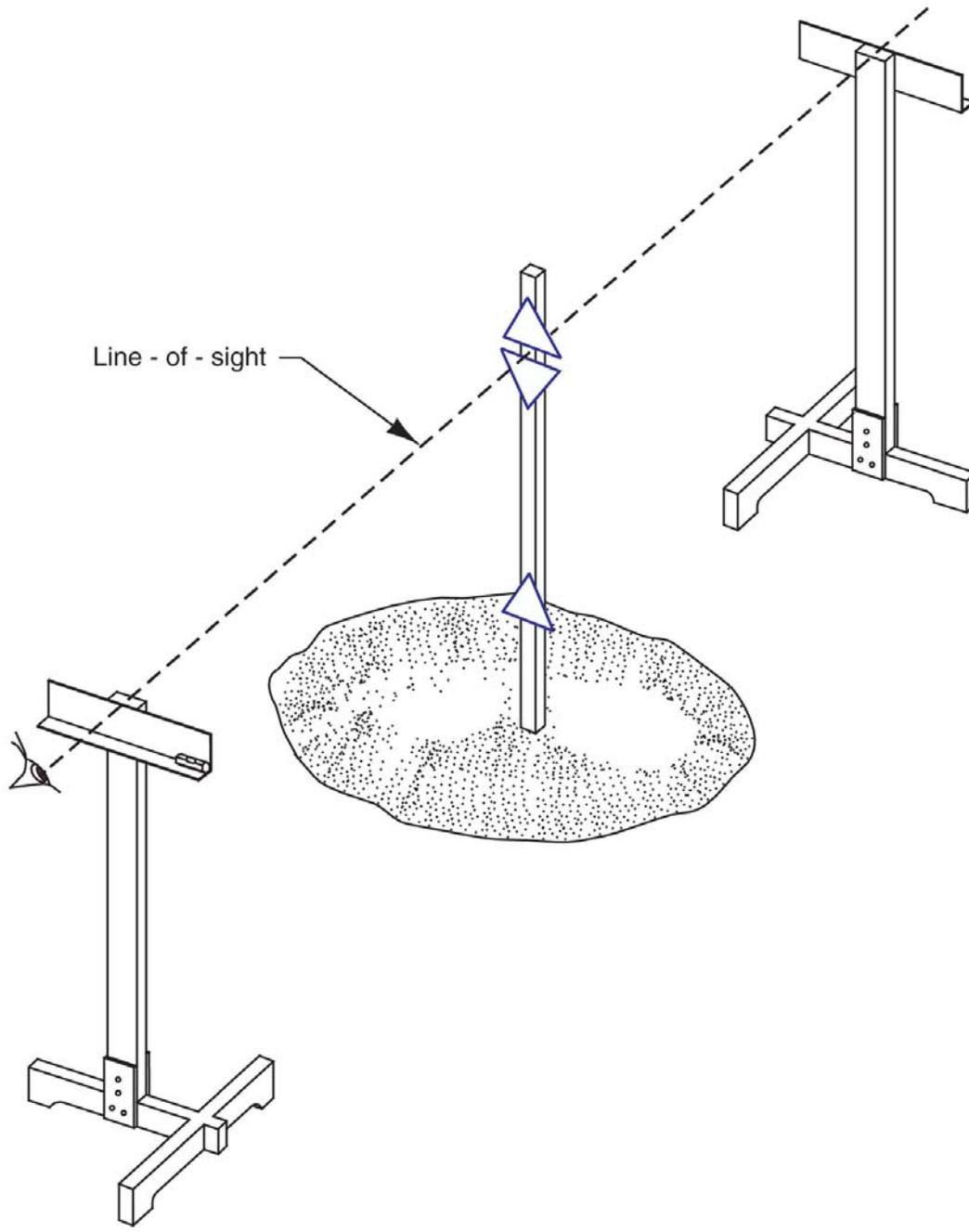
MARKING UPHEAVAL

Figure A6. Illustration of marking extent of upheaval around a crater



INTERMEDIATE CRATER PROFILE CHECK

Figure A7. Intermediate line-of-sight checks

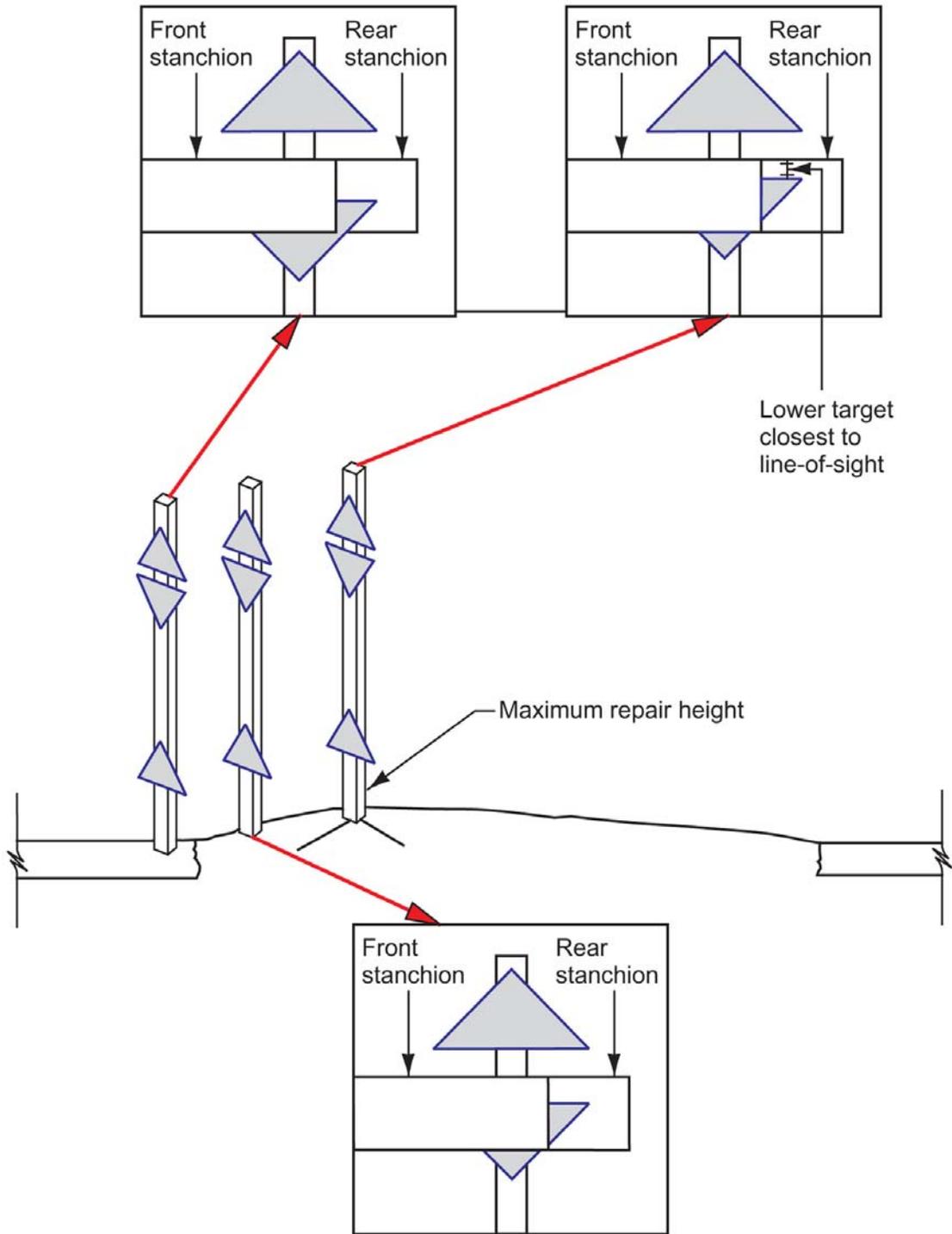


QUALITY CONTROL CHECK

Figure A8. Repair quality check using line-of-sight stanchions

DRAFT

**UFC 3-270-07
30 JUNE 2003**



LOCATING MAXIMUM REPAIR HEIGHT

Figure A9. Locating maximum repair location and height

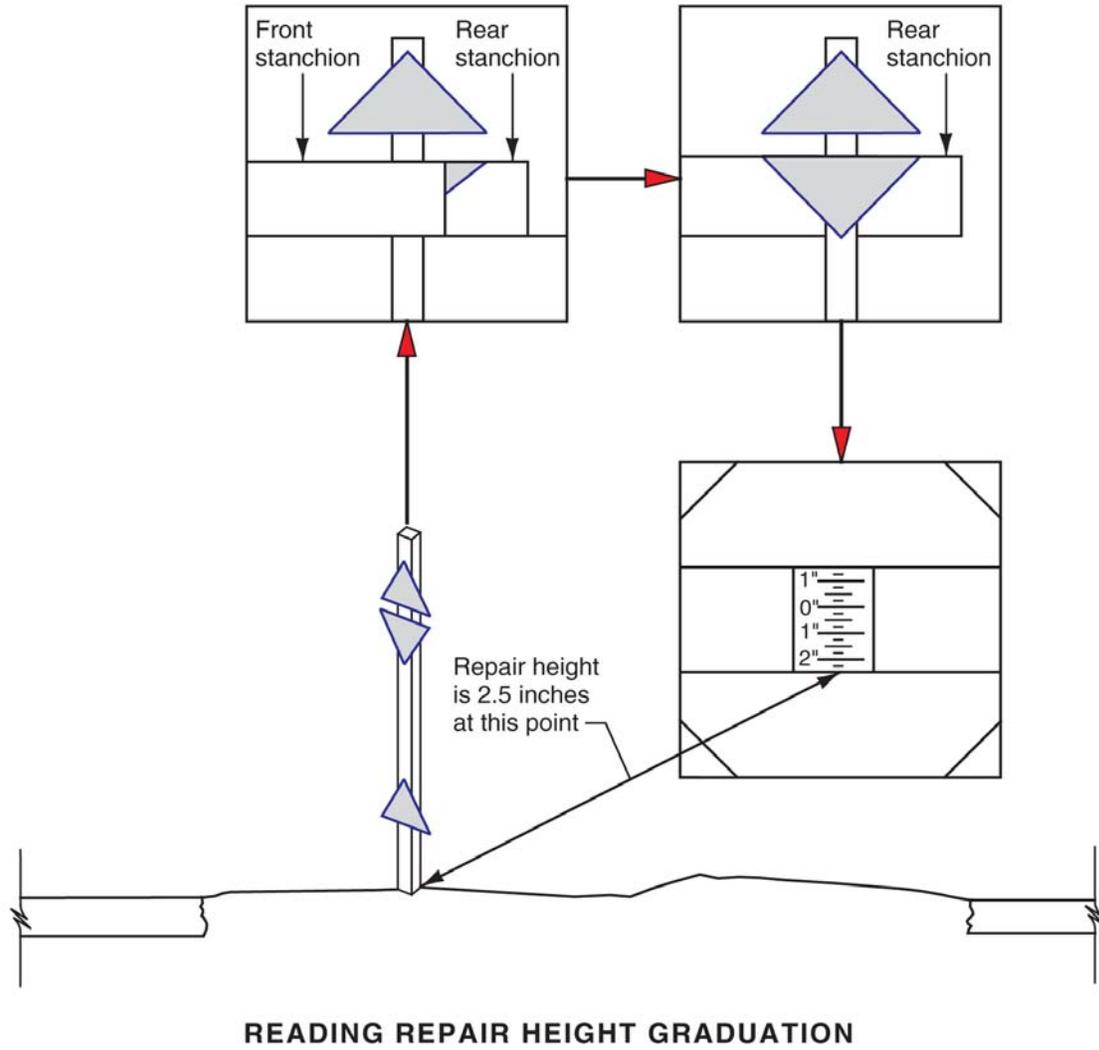
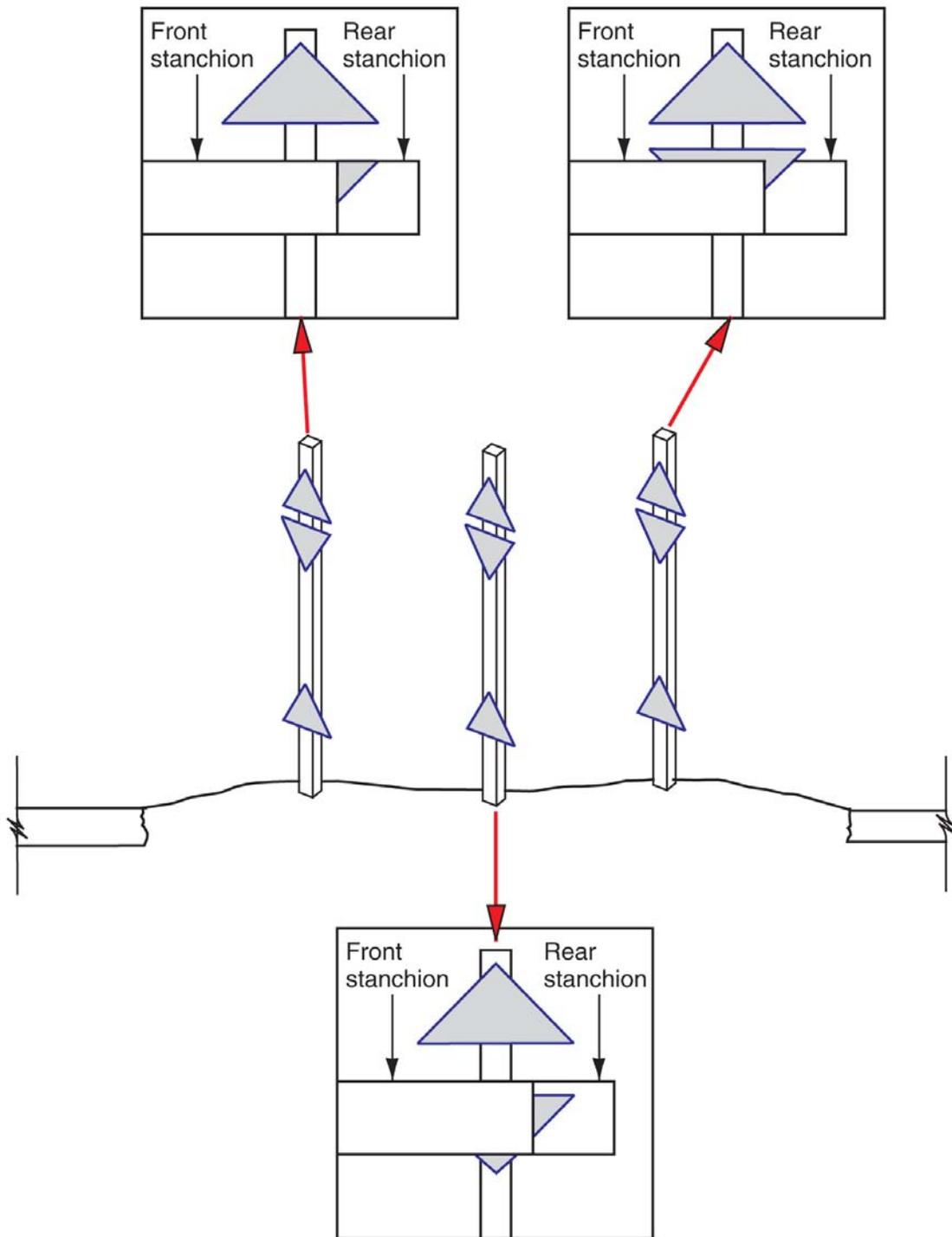


Figure A10. Example of reading graduated stanchions to determine repair height



MOVING TARGET ROD THROUGH A SAG SECTION

Figure A11. Identification of sag sections using the target rod

APPENDIX B

EQUIPMENT AND MANPOWER REQUIREMENTS

Note: Equipment and manpower requirements vary by branch of service, type of unit, and the number of repair team members assigned. The following listing identifies the types of equipment and manpower assets typically used in ADR.

B-1 **ARMY.** Airborne and Air Assault engineer units have the bravado capability of repairing airfields to obtain a required MOS during forcible entry operations. They accomplish this mission through the installation of an air-transportable ADR kit. This expedient pavement repair kit was developed to provide all the materials and non-organic unit equipment required to repair one 7.6-m- (25-ft-) diam crater on either a concrete- or asphalt-surfaced runway. To install this kit, Army units have developed a Light Airfield Repair Package (LARP) that is comprised of organic construction equipment and the ADR kit. **Note:** All equipment in these packages is inserted either by Airborne (heavy drop) or Air Assault (external cargo helicopter loads) techniques.

B-1.1 **CAPABILITIES:**

- (1) Airfield Assessment
- (2) Spall and Crater Repair
- (3) Limited Concrete Capability
- (4) Limited Night Capabilities

B-1.2 **COMPOSITION:** Equipment included in the Army's Airborne and Air Assault LARPs is shown in Tables B-1 and B-2, respectively.

Table B1. Army Airborne LARP
(Requires seven platforms via C-17 or C-130)

- 2.5 cubic yard front-end loader – one each
- SEE (Small Emplacement Excavator) – one each
- Dozer (Deployable Universal Combat Earthmover [DEUCE]) – one each
- Single-drum vibratory compactor – one each
- Dump truck – one each
- ADR kit (FRP matting, sand-grids, miscellaneous tools) – two each
- FAS (Forward Aerial Supply) Box - Includes additional sand-grid; water for compaction; 50 repair parts from the Prescribed Load List (PLL) for LARP equipment; petroleum, oil, lubricants (POL) products; gas-powered hand tampers; generator; and assorted miscellaneous hand tools

Table B2. Army Air Assault LARP
(Requires five lifts via CH-47D Chinook)

- 836G Bobcat with bucket – one each
- 836G Bobcat with sweeper – one each
- JD 450 dozer – one each
- SEE – one each
- ADR kit (FRP matting, sand grids, miscellaneous tools) – one each

B-1.3 Manpower requirements for a task organized engineer section are as follows:

- 1 OIC
- 14 NCOs/Equipment Operators
- 2 Mechanics

B-2 NAVY/MARINE CORPS

B-2.1 **Civil Engineer Support Equipment (CESE).** For Navy crater repair units, most of the construction equipment is contained in Advanced Base Functional Component (ABFC) P-36. Typically, ABFC P-36 is provided to an advanced naval air base located in friendly territory for airfield damage repair (ADR). ABFC P-36 is also included with the ABFCs to be deployed with the Naval Construction Force (NCF) participating in the seizure, construction, and occupation of an advanced naval air base in enemy territory. The ABFC P-36 ADR component contains the material and equipment required for repairing bomb craters using specified types of equipment for crater cleanout, backfilling, grading, and compaction. FOD cover panels, emplaced over the repaired craters, are fabricated from the following:

- Prefabricated panels of AM-2 matting.
- On-site-assembled FOD cover panels (FRP) prepared from prefabricated bolt-together panels.

B-2.1.1 Basic earthmoving and compaction equipment is available in Marine Wing Support Squadrons (MWSS) and Force Engineer Support Battalions. Crater repair FOD cover material is configured in an ADR kit that contains FRP panels and all the necessary ancillary hardware to field two large or four small mats.

B-2.1.2 If the ADR site is located at an existing friendly airfield having ABFC P-36 component the assignment and distribution of CESE for ADR operations will be dependent on the amount of available equipment, the structure of the ADR organization, and the number of people in the ADR organization. In fact, it is highly likely that the Battalion will find that CESE availability is the major constraining factor in developing its ADR organization. Recommended CESE assignments are listed in Tables B3 and B4 for main body/large DET and Air DET/small DET, respectively.

**Table B3
Navy Recommended ADR CESE Distribution: NMCB Main Body/Large Detail**

ADR CREW	CESE ASSIGNMENT	QUANTITY
ADR OIC/AOIC	3/4T Utility Truck	1 each
DAT	Armored/Hardened Vehicle	1 each
Hauling Crew Chief	3/4T Utility Truck	1 each
Hauling Crew	Tractor w/35T Tilt Top TRLR 15T Dump Truck Loader 4/1 Bucket 6K LB RT Forklift or larger	5 each 3 per crater crew 2 per stock pile crew 2 per every other crew
Crater Crew Chief	3/4T Utility Truck	1 each
Runway Clearing Crew	Grader Tractor w/Sweeper Magnetic Sweeper 15T Dump Truck Loader 4/1 Bucket	5 per crew 6 each 2 each Share with hauling crew 3 each
Crater Repair Crew	Loader 4/1 Bucket Dozer (w/oracle blade) Grader Compactor, Vibratory Light Plant Trailer Compressor, 250 CFM Concrete Saw Centrifugal Pump	2 per crew 1 per crew 1 per crew 1 per crew 2 per crew 1 per crew 1 per crew 2 per crew
FOD Cover Crew	Uses Loaders from Crater Repair Crew 6K LB RT Forklift or larger	1 per crew
Crater Support Crew Chief	3/4T Utility Truck	Share with crater crew
Spall Repair Crew	1T Pick-up Truck 11S or Larger Mixer Water Truck Compressor 150 CFM	2 per crew 1 per crew 1 per crew 1 per crew
Cretemobile Crew	Cretemobile w/15T Tractor Loader 4/1 Bucket 6K LB RT Forklift Water Distribution Truck Tractor w/High Boy TRLR	1 per crew 1 per crew 1 per crew 1 per crew 1 per crew
MOS Lighting Crew	1-1/4T Truck Light Plant TRLR	1 per crew 1 per crew
MOS Marking Crew	1-1/4T Truck Light Plant TRLR	1 per crew 1 per crew
MAAS Installation	15T Tractor	1 per crew
NOTE: Actual number of pieces of CESE used should be tailored to the site.		

Table B4
Navy Recommended ADR CESE Distribution: NMCB Air Det/Small Det

ADR CREW	CESE ASSIGNMENT	QUANTITY
ADR OIC/AOIC	3/4T Utility Truck	1 each
DAT	Armored Vehicle	1 each
Hauling Crew	Tractor w/35T Tilt Top TRLR Dump Trucks Forklift (6K or larger) Loader	1 each 2 per crater crew 2 each 1 each
Runway Clearing Crew	Grader Tractor w/Sweeper Magnetic Sweeper	1 each 1 each 1 each
Crater Crew Chief	3/4T Utility Truck	1 each
Crater Repair Crew	Loader Dozer Compactor, Vibratory Light Plant Trailer Compressor, 250 CFM Concrete Saw	1 per crew 1 per every other crew 1 per crew 1 per crew 1 per crew 1 per crew
FOD Cover Crew	Uses the CESE of Crater Repair Crew	
Spall Repair Crew	2-1/2T Cargo Truck or Pick-up Truck	1 per crew
Cretemobile Crew	Uses the CESE of Crater Repair Crew plus: Cretemobile w/Tractor Loader Forklift Water Distribution Truck	1 per crew 1 per crew 1 per crew 1 per crew
MOS Lighting Crew	1-1/4T Truck	1 per crew
MOS Marking Crew	1-1/4T Truck	1 per crew
MAAS Installation	Tractor	1 per crew
NOTE: The actual number of pieces of CESE used should be tailored to the site.		

Given these CESE distribution recommendations, the Battalion should develop its ADR organization based on both CESE and personnel availability.

B-2.2 Manning Levels. Manpower requirements for large (main body) and small (air) detachments are shown in Tables B5 and B6, respectively.

Table B5
Navy Recommended Main Body or Large DET ADR Manning

TITLE	MANNING LEVEL
BTN Liaison Officer (Assigned to Station Command Center)	1
MOS Selection Team (2 Teams) Team Chief Selection Plotter Communicator	8
Damage Assessment Teams Main Body – 4 Teams/Large DET – 3 teams Team Leader Team Members (2 ea)	MB 12 LG DET 9
ADR OIC	1
ADR AOIC	1
Crater Crew Chief	1
Crater Crew (5 Teams) Team Leader Equipment OP (4 ea) Laborer (3 ea)	40
FOD Cover Crew 1 – Concrete Slab Team Leader Equipment OP (4 ea) Laborer (3 ea)	8
FOD Cover Crew 2 – Bolted FRP Team Leader Laborer (14 ea)	15
FOD Cover Crew 3 – Folded FRP Team Leader Equipment OP (2 ea) Laborer (6 ea)	9
FOD Cover Crew 4 – AM-2 Matting Team Leader Laborer (14 ea)	15
FOD Cover Crew 5 – Cretemobile RSPC Placement Team Ldr Equipment OP (10 ea) Laborer (15 ea) Cretemobile Team Ldr Equipment OP (1 ea) Additional FOD Cover Crew (As Required)	28

Table B5 (Continued)
Navy Recommended Main Body or Large DET ADR Manning

TITLE	MANNING LEVEL
Hauling Crew Chief	1
Hauling Crew Equipment OP (5 ea) Dump Truck OP (3 ea per Crater Crew)	30
Stock Pile Crew – 2 Front End Loaders per Stock Pile	2
Crater Support Crew Chief	1
Debris Clearing Crew Team Leader Equipment OP (13 ea)	14
Crater Support Crew Team Leader CM's (2 ea)	3
Spall Repair Crew (as required) Team Leader Equipment OP (1 ea) Laborer (2 ea)	20
MOS Marking Crew Team Leader Equipment OP (1 ea) Laborer (1 ea)	3
MOS Lighting Crew Team Leader Laborer (5 ea)	6
MAAS Installation Crew Team Leader Laborer	2

Total manning level: Main Body 221, Large Det 218

Note: These manning levels are approximate.
COMSECONDNCB/COMTHIRDNCBINST 3300.1 of 31 JAN 1994 states: The Battalion's ADR organization shall be developed in conjunction with and as part of the overall Station BDR/ADR organization... In general, the ADR organization should field the hauling and runway clearing crews and as many crater repair crews as the on-site Civil Engineer Support Equipment (CESE) and personnel will support.

**Table B6
Navy Recommended Air DET or Small DET ADR Manning**

TITLE	MANNING LEVEL
BTN Liaison Officer	1
ADR OIC	1
ADR AOIC	1
MOS Selection Team Team Chief Selection Plotter Communicator	4
Damage Assessment Team (2 Teams) Team Leader Team Members (2 ea)	6
Crater Crew Chief	
Crater Crew (2 Teams) Team Leader Equipment OP (4 ea) Laborer (3 ea)	16
FOD Cover Crew 1 – Concrete Slab Team Leader Equipment OP (4 ea) Laborer (3 ea)	8
FOD Cover Crew 2 – Bolted FRP Team Leader Laborer (10 ea)	11
FOD Cover Crew 3 – Folded FRP Team Leader Equipment OP (2 ea) Laborer (6 ea)	9
FOD Cover Crew 4 – AM-2 Matting Team Leader Equipment OP (1 ea) Laborer (10 ea)	12
FOD Cover Crew 5 – Cretemobile RSPC Placement Team Ldr Laborer (13 ea) Cretemobile Team Ldr Equipment OP (3 ea)	18
Hauling Crew Equipment OP (1 ea) Dump Truck OP (2 ea per crater)	(Assume 10 craters) 30

**Table B6 (Cont'd)
Navy Recommended Air DET or Small DET ADR Manning**

TITLE	MANNING LEVEL
Stock Pile Crew – 2 Front End Loaders per Stock Pile	2
Debris Clearing Crew Team Leader Equipment OP (5 ea)	2
Spall Repair Crew (2 Teams) Team Leader Equipment OP (1 ea) Laborer (2 ea)	8
MOS Marking Team Leader Laborer	2
MOS Lighting Crew Team Leader Laborer (5 ea)	6
MAAS Installation Crew Team Leader Laborer	1

TOTAL MANNING LEVEL: 136

Note: These manning levels are approximate.

COMSECONDCB/COMTHIRDCBINST 3300.1 of 31 JAN 1994 states: The Battalion's ADR organization shall be developed in conjunction with and as part of the overall Station BDR/ADR organization. In general, the ADR organization should field the hauling and runway clearing crews and as many crater repair crews as the on-site Civil Engineer Support Equipment (CESE) and personnel will support.

B-3 Air Force. An ADR equipment set is a standardized set of equipment and vehicles that enables Air Force civil engineers to conduct ADR. There are three fielded ADR sets. The sets are graduated in a building-block manner to provide a designated crater repair capability.

B-3.1 Traditional Airfield Damage Repair Equipment

B-3.1.1 Basic (R-1) Set. The R-1 Set listed in Table B7 supports the repair of three bomb craters (15 m [50 ft] in diameter) with AM-2 matting and/or FFM in four hours. Basic sets are currently in place at most theater locations and contain 59 items of vehicles/construction equipment (e.g., front-end loaders, dump trucks, excavators) and additional supplemental items (flood lights, spall repair material, AM-2, FFM mats).

B-3.1.2 Supplemental (R-2) Set. The R-2 Set listed in Table B8 contains 26 items of additional vehicles and equipment which are additive to the R-1 set and gives the capability to repair six craters in four hours.

B-3.1.3 Supplemental (R-3) Set. The R-3 Set listed in Table B9 contains 18 pieces of additional vehicles and equipment that, when combined with the R-1 and R-2 sets, enables six repair teams to accomplish 12 crater repairs in four hours. Only a few main operating bases have the R-3 package in-place.

B-3.2 Personnel. Figure B1 illustrates a typical ADR organization predicated on the use of the combined R-1 and R-2 equipment and vehicle packages. In a situation that dictates the use of the full R-1 through R-3 equipment and vehicle packages, present Prime BEEF planning and force employment concepts envision that two 55-person lead team (UTC 4F9EA) and two 42-person follow teams (UTC 4F9EB) be used. While the full 194-person engineer complement will not be employed solely in the ADR role, a majority of the personnel will be dedicated to this tasking.

**Table B7
U.S. Air Force R-1 Vehicle and Equipment Set**

Vehicles	Quantity
Excavator	3
Grader	3
Dozer (T-7)	3
Front-End Loader (4-cy)	6
Front-End Loader (2.5-cy)	3
Vibratory Roller	3
Dump Truck (8-cy)	8
Dump Truck (5-ton)	4
Tractor (7.5-ton)	3
Tractor (10-ton)	3
Trailer (22-ton)	3
Trailer (60-ton)	3
Vacuum Sweeper	2
Tractor Mounted Sweeper (ADR)	2
Paint Machine (Part of MOSMS)	2
HMMWV	2
ADR Trailer	3
1,500-Gallon Water Truck	3
Dolly Converter (8-ton)	3
Basic ADR Equipment Support Kit	1
Basic ADR Airfield Lighting Kit	1
AM-2 ADR FOD Cover Kit	3/6/9
AM-2 Support Kit	1/2
Folded Fiberglass Mat FOD Cover Kit (Kit-A)	1
Folded Fiberglass Mat FOD Cover Kit (Kit-B)—Anchoring Systems	2
Spall Repair Kit	4
Minimum Operating Strip Marking System (MOSMS)	1

Table B8
U.S. Air Force R-2 Vehicle and Equipment Set Additives

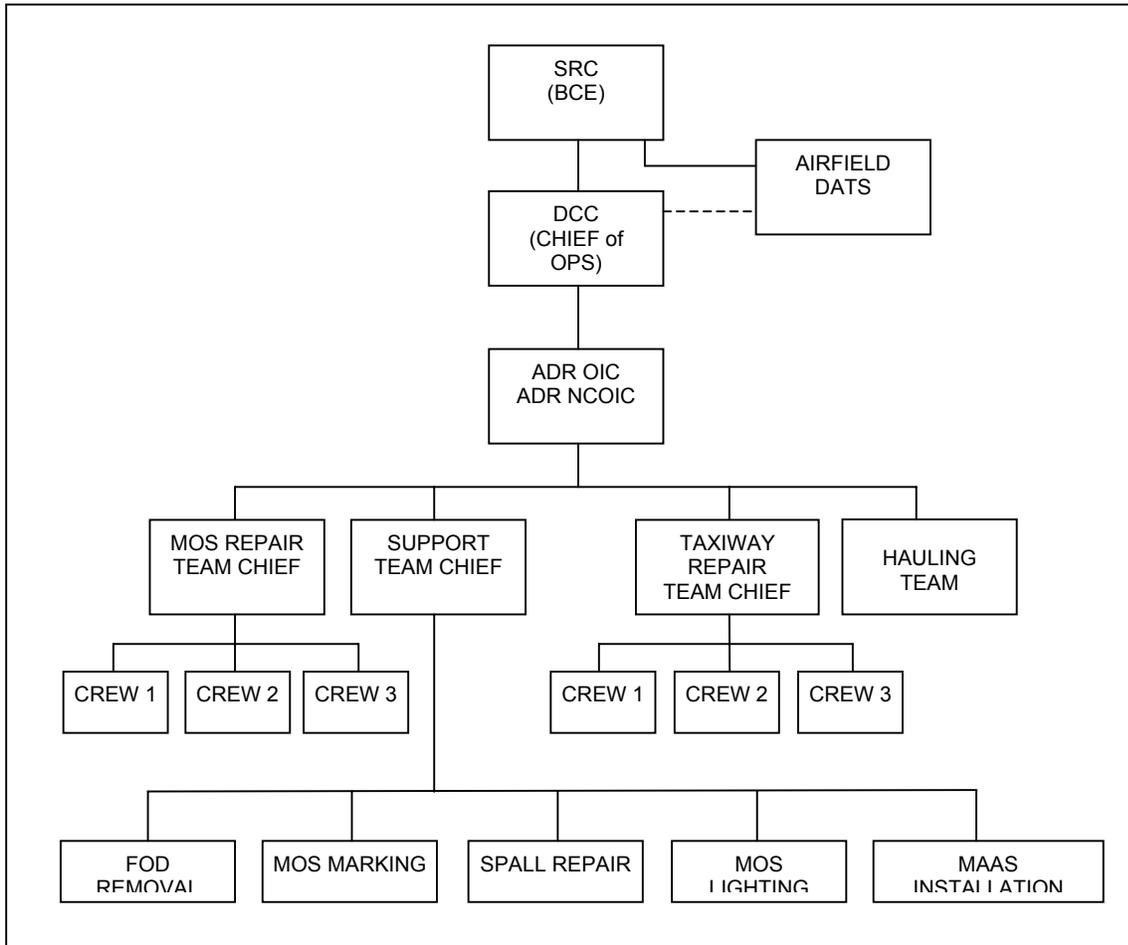
Vehicles	Quantity
Excavator	3
Front-End Loader (4-cy)	3
Front-End Loader (2.5-cy)	3
Vibratory Roller	3
Dump Truck (8-cy)	7
HMMWV	4
ADR Trailer	3
Total Vehicle Requirement	26
Equipment Items	Quantities
Floodlight/Generator Set	6
Generator Set (Diesel)	1

Table B9
U.S. Air Force R-3 Vehicle Set Additives

Vehicles	Quantities
Front-End Loader (4-cy)	4
Dump Truck (8-cy)	7
Vacuum Sweeper	2
Dirt Sweeper (RRR)	5
Total Vehicle Requirement	18
Additional Equipment Item	Quantity
Floodlight/Generator Set	6

B-3.3 **Air Force Airborne Red Horse Capability.** The U.S. Air Force is currently developing Airborne engineer units that will have the capability of repairing airfields to obtain a required MOS. These units will provide an engineering asset for theater airfield repair missions, while Army, Marine Corps, or Special Operations Forces will continue to be tasked with forcible entry operations. The Air Force has developed an air-transportable ADR kit, similar to the Army's light engineer assets. To install this kit, the Air Force units have developed a Mobile Airfield Repair Equipment Set (MARES) that is comprised of organic construction equipment and the ADR kit. **Note:** All equipment in these packages is inserted either by Airborne (heavy drop) or Air Assault (external cargo helicopter loads) techniques.

Figure B1. Typical ADR (R-2 or R-3 Set) Organization



B-3.3.1 CAPABILITIES:

- (1) Airfield Assessment
- (2) UXO Clearance
- (3) Obstruction Demolition
- (4) Force Protection Construction
- (5) Installation of Expedient Airfield Lighting
- (6) Spall and Crater Repair
- (7) Limited Concrete Capability
- (8) Limited Night Capabilities

B-3.3.2 **COMPOSITION:** Equipment included in the Air Force's Airborne MARES is shown in Table B-1 and personnel in Table B-2.

Table B10. Air Force Airborne MARES
(Requires seven platforms via C-17 or C-130)

- CAT 277 Multi-Terrain Loaders – two each
- CAT 420D IT Backhoe Loader – one each
- IHI IC-45 Tracked Crawler Carrier – one each
- IC-45 Tracked Combat Support Trailer – one each
- Lightweight EOD Equipment - as needed
- Lightweight Crash Rescue Equipment – as needed
- FAS (Forward Aerial Supply) Box - Includes sand-grid; water for compaction; repair parts from the Prescribed Load List (PLL) for MARES equipment; petroleum, oil, lubricants (POL) products; gas-powered hand tampers; generator; and assorted miscellaneous hand tools

Table B11. Air Force Airborne Minimum Personnel Flight for ADR
(Requires five lifts via CH-47D Chinook)

- Readiness – 2 Personnel
- Red Horse – 21 Personnel
- EOD – 6 Personnel
- Fire/Crash Rescue – 6 Personnel
- Total Flight – 35 Personnel

APPENDIX C

REFERENCES

GOVERNMENT PUBLICATIONS:

1. Joint Publications

Ref. 4: Unified Facilities Criteria (UFC) 3-260-02, *Pavement Design for Airfields*

Ref. 8a: Army Field Manual (FM) 5-430-00-1, Air Force Joint Pamphlet (AFJPAM) 32-8013, Volume I, *Planning and Design of Roads, Airfields, and Heliports in the Theater of Operations – Road Design*

Ref. 8b: FM 5-430-00-2, AFJPAM 32-8013, Volume II, *Planning and Design of Roads, Airfields, and Heliports in the Theater of Operations – Airfield and Heliport Design*

Ref. 11: TM 5-822-14, AFJMAN 32-1019, *Soil Stabilization for Pavements*

Ref. 13: FM 5-530, NAVFAC MO-330, AFJMAN 32-1034, *Materials Testing*

2. Air Force

Ref. 1: Engineering Technical Letter (ETL) 98-5: *C-130 and C-17 Contingency and Training Airfield Dimensional Criteria*

Ref. 3: Technical Order (T.O.) 35E2-4-1: *Repair Quality Criteria System for Rapid Runway Repair*

Ref. 4: Engineering Technical Letter (ETL) 97-9: *Criteria and Guidance for C-17 Contingency and Training Operations on Semi-Prepared Airfields*

Ref. 12: Engineering Technical Letter (ETL) 02-19: *Airfield Pavement Evaluation Standards and Procedures*

3. Army

Ref. 9: Unified Facilities Criteria (UFC) 3-250-03, *Design Standard Practice Manual for Flexible Pavements*

Ref. 10: Engineering Research and Development Center, Geotechnical and Structures Laboratory, Airfields and Pavements Branch:
<http://pavement.wes.army.mil/>

4. Navy/Marine Corps

- Ref. 5: Naval Air Systems Command Instruction (NAVAIRINST) 13800.12B, *Certification of Expeditionary Airfield AM-2 Mat Installations, Aircraft Recovery Equipment, Visual/Optical Landing Aids, and Marking/Lighting Systems*
- Ref. 6: Naval Air Systems Command (NAVAIR) 51-60A-1, Technical Manual, Handbook, *AM-2 Airfield landing Mats and Accessories; Installation, Maintenance, Repackaging, & Illustrated Parts Breakdown*
- Ref. 7: Naval Air Warfare Center Aircraft Division Lakehurst (NAWCADLKE)-MISC-48J200-0011, *Expeditionary Airfield AM-2 Mat Certification Requirements*

APPENDIX D

BIBLIOGRAPHY

GOVERNMENT PUBLICATIONS:

1. Joint Publications

UFC 3-250-03, *Standard Practice Manual for Flexible Pavements*

TM 5-822-7, AFM 88-6 Chapter 8, *Standard Practice for Concrete Pavements*

TM 5-822-9, *Repair of Rigid Pavements Using Epoxy Resin Grouts, Mortars, and Concretes*

<http://airfielddamagerepair.com/> (This joint service Web site is currently under development.)

2. Air Force

T.O. 35E2-5-1, *Crushed-Stone Crater Repair and Line-Of-Sight Profile Measurement for Rapid Runway Repair*

T.O. 35E2-3-1, *Folded Fiberglass Mats for Rapid Runway Repair*

ETL 97-9, *Criteria and Guidance for C-17 Contingency and Training Operations on Semi-Prepared Airfields*

Air Force publications are available online at <http://www.e-publishing.af.mil/>

Air Force ETLs are available online at <http://www.afcesa.af.mil/Publications/ETLs/default.html> and (for CCB subscribers) <http://www.ccb.org/html/home.html>

Air Force T.O.'s are available online at (<https://toindex-s.robins.af.mil/toindex/>)

Headquarters Air Force Civil Engineer Support Agency, Civil Engineering Division (HQ AFCESA/CESC), Pavements Program:
<http://www.afcesa.af.mil/Directorate/CES/Civil/Pavements/Pavements.htm>

3. Army

Army Technical Manual (TM) 5-822-7, Air Force Manual (AFM) 88-6, Chapter 8, *Standard Practice for Concrete Pavements*

Army Training Circular (TC) 5-340, *Air Base Damage Repair (Pavement Repair)*

Army CE Manuals: <http://www.usace.army.mil/inet/usace-docs/armytm/>

TM 5-822-14 Soil Stabilization for Pavements

4. Navy/Marine Corps

Naval Facilities Command (NAVFAC) P-80, *Facility Planning Criteria for Navy and Marine Corps Shore Installations*

NAVFAC P80.3, *Facility Planning Factor Criteria for Navy and Marine Corps Shore Installations, Appendix E, Airfield Safety Clearances*

Naval Air Systems Command Manual (NAVAIRMAN) 48J200-00-21, *Subgrade Requirements for Expeditionary Airfields*

NAVAIR 00-80T-115, *Expeditionary Airfield NATOPS Manual*

Navy/Marine Corps Runway Crater Repair Handbook

NAWCADLKE MISC-48J200-0021, *Subgrade Requirements for Expeditionary Airfields*

NAWCADLKE-DDR-48J200-0038, *In-Plane Bow Repair Method*

Navy/Marine Corps Web site – Under development

AM-2 Mat Repair Procedure # 1, Removal Rubber Buildup from AM-2 Utilizing the Sodium Bicarbonate Blasting Process.

APPENDIX E

Airfield Damage Repair Log		
Airfield Name/Location:	Repair Location(s):	
Date of Repairs:	Repair Team:	
Repair Method: <ul style="list-style-type: none"> <input type="checkbox"/> Crushed Stone <input type="checkbox"/> Sand Grid <input type="checkbox"/> Stone and Grout <input type="checkbox"/> AM-2 <input type="checkbox"/> Rapid Set Material, _____ <input type="checkbox"/> Concrete Cap <input type="checkbox"/> Asphalt <input type="checkbox"/> Stabilized Surface, Type: _____ <input type="checkbox"/> Other (<i>describe in Comments</i>) 	FOD Cover: <ul style="list-style-type: none"> <input type="checkbox"/> FRP (Army) <input type="checkbox"/> FRP (Navy) <input type="checkbox"/> FFM (Air Force) <input type="checkbox"/> None <input type="checkbox"/> Other (<i>describe in Comments</i>) 	Amount: _____
Repair Criteria: <ul style="list-style-type: none"> <input type="checkbox"/> Expedient <input type="checkbox"/> Sustainment <input type="checkbox"/> Permanent 	Mission Aircraft: <ul style="list-style-type: none"> <input type="checkbox"/> C-17 <input type="checkbox"/> C-130 <input type="checkbox"/> Other, _____ 	
Comments (<i>type and quality of repair materials, CBR of compacted materials, deviations from approved repair procedures, problems encountered, repair performance to-date, etc</i>):		
Aircraft Traffic (<i>if available</i>):		
Subsequent Maintenance:		
Certification: Engineer on Site:	Organization:	Date: