INTERIM RDR TACTICS, TECHNIQUES, AND PROCEDURES

Revision 17.0

1 August 2023

RAPID DAMAGE REPAIR (RDR)

AIR FORCE CIVIL ENGINEER CENTER

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INTERIM PROCESS FOR RAPID DAMAGE REPAIR (RDR)

Supersedes: *Interim RADR TTP Revision 16.1*, 3 February 2023

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PURPOSE: To provide **interim** tactics, techniques, and procedures (TTP) for expeditious airfield recovery after attack or natural disaster. These TTPs are unofficial guidance until officially codified in official Departmental Publications, e.g., Air Force Tactics, Techniques, and Procedures (AFTTP), and posted on USAF e-Pubs. It supports Air Force Instruction (AFI) 10-210, *Prime Base Engineer Emergency Force (BEEF) Program*, Air Force Pamphlet (AFPAM) 10-219, Volume 4, *Airfield Damage Repair Operations*, and Air Force Doctrine Annex 3-34, *Engineer Operations*. This publication applies to the Regular Air Force, the Air Force Reserve, and the Air National Guard. Refer recommended changes and questions about this publication to the Air Force Civil Engineer Center (AFCEC) via the AFCEC Reachback Center at 1-888-232-3721 (toll free), 1-850-283-6995 (commercial), Defense Switched Network 312-523-6995, or email at **AFCEC.RBC@us.af.mil**. Ensure all records generated as a result of processes prescribed in this publication adhere to AFI 33-322, *Records Management and Information Governance Program* and are disposed in accordance with the Air Force Records Disposition Schedule, which is located in the Air Force Records Information Management System. 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 DAF.

SUMMARY OF REVISION 17.0 CHANGES: This document has been substantially revised and should be completely reviewed. This revision changes the title, updates terminology and references, and includes or expands information related to Rapid Damage Repair (RDR) in support of Rapid Airfield Damage Recovery (RADR) operations.

APPLICATION: This TTP applies to Civil Engineer personnel performing airfield recovery after a major attack or natural disaster. This document is authoritative but not directive and does not replace mandatory compliance instructions found in directive publications. For conflict with other nondirective publications, contact the AFCEC Reachback Center or CE Dash (with contact info) for resolution. Applicable AFIs take precedence when this publication and AFIs conflict.

SCOPE: This publication describes expeditious airfield recovery TTPs after an attack or natural disaster. It describes required resources, planning factors, and expeditious airfield repairs supporting emergency launch and/or recovery of mission aircraft.

Chapter 1

INTRODUCTION

1.1. Background. Rapid Damage Repair (RDR) is an essential element of enabling air base resiliency and continuation of airfield operations to ensure the rapid projection and application of US military power around the globe. RDR encompasses actions required to rapidly repair aircraft operating surfaces to recover operations at an airfield after attack or natural disaster, whether the airfield is offered for use by a host nation (HN) or established as a United States (US) operating location.

1.1.1. RDR is only one phase of recovery after an attack, which is only one function within Rapid Airfield Damage Recovery (RADR) falling under the larger umbrella of Airfield Damage Repair (ADR). RADR rapidly establishes a minimum airfield operating surface (MAOS) utilizing in addition to RDR: MAOS Marking and Striping, Emergency Airfield Lighting (EALS), Aircraft Arresting System (AAS), Water and Fuel Expedient Repair Systems (WaFERS), and FOD Removal. While other phases within RADR include: MAOS sustainment, MAOS expansion, and reconstitution of the airfield, the TTP focuses only on RDR operations. For a complete overview of the ADR Program, refer to AFPAM 10-219V4, *Airfield Damage Repair Operations*. In addition, contact the Air Force Civil Engineer Center Reach-Back Center when looking for information not found herein or the references in **Attachment 1**. Contact the Reach-Back Center at 1-888-232-3721 (toll free), 1-850-283-6995 (commercial), Defense Switched Network 312-523-6995, or email at **AFCEC.RBC@us.af.mil**.

1.1.2. Integration of Overlapping Phases. After an attack on the airfield, hundreds of craters, camouflets, spalls, and thousands of unexploded explosive ordnance (UXO) could be expected. RDR capability requires multiple critical tasks be accomplished with seamless integration. These are often accomplished within overlapping and simultaneous timeframes; otherwise, there is risk of failing to meet time goals while keeping attrition of recovery equipment, personnel, and vehicles within Combatant Commander's (CCDR's) acceptable levels.

1.1.3. The RDR process repairs selected pavement damage to establish the MAOS. MAOS includes a minimum operating surface (MOS) up to 150-ft. x 10,000 ft., and associated taxiways, ramps, access routes, and critical infrastructure. The resulting durable repairs provide an acceptable number of passes for any combination of US aircraft before requiring sustainment maintenance.

1.2. Repair Times. The process times discussed in this TTP were derived from years of field experiments, documented vehicle performance specifications, and industry standard efficiency rates; thus, times presented have been normalized. Users of this TTP should concentrate on the processes and not the times.

Chapter 2

SAFETY

2.1 Background. As in construction practices, there are multiple known risk factors in performing RDR tasks. It is vital to protect workers from hazards such as high-pressure subsystems and components, harmful solvents and adhesives, and silica dust. The risks and safety factors involved with materials and operations should be identified prior to commencing RDR operations and briefed to all personnel that could be involved. A key responsibility of supervisors is to ensure personnel have and wear the necessary personal protective equipment (PPE) and individual protective equipment (IPE) for the working environment. Unsafe field operations while conducting RDR could cause short- and long-term injuries, health issues, and negatively affect the mission.

2.2. General Safety Guidelines. It is important to review applicable safety standards and technical manuals for additional safety requirements before performing RDR operations. Compliance with technical order (T.O.) warnings and cautions is mandated. Below are several important safety publications:

2.2.1. DAFMAN 91-203, *Air Force Occupational Safety, Fire, and Health Standards*, lists PPE for selected CE activities. Although T.O. and other job-related publications address proper wear and use of PPE and IPE, workers ultimately have the responsibility to properly use, inspect, and care for protective equipment assigned.

2.2.2. AFI 48-137, *Respiratory Protection Program*, provides training documentation procedures, and inhalation guidance. 29 CFR 1926.1153 *Respirable Crystalline Silica Standard for Construction,* provides additional guidance and information. End users consult 29 CFR 1910.134, *Respiratory Protection.*

2.2.3. Safety Data Sheets. Handlers and users of any polymeric repair material should get with their HAZMAT manager to ensure the manufacturer product

Safety Data Sheet (SDS) always accompanies the material. The SDS provides critical use and handling information. Before use, review and follow all product SDS guidance for PPE and other safety precautions.

2.2.4. AFMRA/SG3PB Memorandum, *Joint Service General Purpose Mask (JSGPM) M50 Use During Rapid Airfield Damage Recovery Training Events*, dated 30 Sept. 2020. Provides commanders the option to direct the use of M50 series protective masks or a NIOSH certified respirator as PPE during RDR training and encourages consultation with the local Bioenvironmental Engineering (BE) Flight when exercising these options.

2.2.5. 29 CFR 1910.133., *Eye and Face Protection, Occupational Safety and Health Administration (OSHA)* discusses the types of eye protection to include side protection needed for possible eye injury risk from flying objects. It details information on how the eye protection should be marked to wear with prescription eyewear.

2.2.6. AFI 48-127, *Occupational Noise and Hearing Conservation Program* discusses the types of hearing protection, coordination, and approval through Bioenvironmental and Public Health offices.

2.3. Personal Protective Equipment (PPE). Supervisors should coordinate with the Bioenvironmental (BE) Flight and the Wing Safety office on the PPE needed to perform RDR operations. Brief safety procedures and appropriate PPE before operations and verify all PPE has been approved for the work to be performed. **Table 2.1** is a listing of typical PPE by operation. **Note:** Breathing crystalline silica dust is a serious health hazard. Those performing duties where they may be exposed to silica dust should wear appropriate PPE (including respiratory and eye protection).

Table 2.1. Listing of Typical PPE by Operation.

Operation or Equipment	Typical PPE Requirements
Asphalt Recycler, Compact Track Loader, Dozer, Dump Truck, Forklift 6k, Front End Loader, Grader, Industrial Tractor with Broom, Pneumatic Roller, Telehandler, Tractor/Trailer, Trailer Flatbed (Attachment & Material), Trailer (Lowboy), Vacuum Sweeper, Excavator, Vibratory Roller, Volumetric Mixer, Water Truck, and Water Trailer	Coverall (if needed) Eye protection (dust and bright sun) Gloves Hearing protection Respiratory protection (if dusty)* Safety-toe boots
Light Cart, MAOS Paint Striper, Water Skid, Walk Behind Saw	Coverall (if needed) Eye protection (dust and bright sun) Gloves Hearing protection Respiratory protection (if dusty)* Safety-toe boots
Portable power tools (e.g. dual paddle mixer, electric jack hammer, portable generator, rotary hammer drill)	Eye protection (dust and bright sun) Gloves Hearing protection Respiratory protection (if dusty)* Safety-toe boots
Laborers and spotters	Coveralls (if needed) Eye Protection Gloves Hearing Protection Respiratory protection * Steel toe boots Rubber Concrete boots (over the steel toe boots)
*-N-95, P-95, or R-95 respirator or M50 JSGPM, as directed by Commander.	

2.4 Repair Material Hazards. Flowable-fill and rapid-setting concrete materials contain concentrated amounts of crystalline silica. Over exposure to crystalline silica may cause chronic silicosis, a serious and incurable respiratory disease. The following is a rule-of-thumb in regard to silica: if dust containing silica is visible in the air, it is almost always over the permissible limit.

2.4.1. In accordance with the Occupational Safety and Health Administration (OSHA)[1], individuals in RDR positions (e.g., pavement cutting spotters, excavation spotters, volumetric mixer tendering laborers, laborers slashing flowable-fill super sacks, Spall Repair Crew) exposed to respirable crystalline silica (i.e. airborne dust from the repair material) should wear a suitable National Institute of Occupation Safety and Health (NIOSH)-certified respirator in accordance with the manufacture's guidance and the AFMRA/SG3PB Policy Memo dated 30 Sept. 2020.

2.4.2. NIOSH recommends using N, R, or P95 respirator to minimize inhalation of silica dust. NIOSH-certified N95 filtering face-piece respirators (GM 8210) are in Drawer #1 of the RDR Tool Trailer. In addition, suitable dust goggles should also be worn in accordance with directive guidance referenced within this publication.

2.4.3. In accordance with AFMRA/SG3PB Policy Memo dated 30 Sept. 2020, "Commanders have the option to direct the use of the JSGPM M50 Series protective mask or NIOSH certified respirators as suitable PPE against respirable silica dust exposure during RDR training events.

2.4.4. In highly dense silica dust environments, members can wear the N-95 instead of the M50 JSGPM protective mask during training exercises.

Warning: All crew members work in close proximity and should exercise extreme caution or serious injury or death to personnel could result.

Chapter 3

FOREIGN OBJECT DEBRIS (FOD) REMOVAL

3.1. Overview. This team provides the capability to remove large and small debris from the convoy routes, repair areas, perform initial and simultaneous sweeping operations on the airfield and around the repair areas, and perform final sweeping operations before aircraft trafficking begins. One FOD Removal Team supports all RADR capabilities (i.e., small, medium, large, and very large), see AFTTP 3-32.10, *Introduction to Rapid Airfield Damage Recovery*, for information on RADR capabilities. For example, if the installation has a Medium RADR Capability, only one FOD Removal Team is postured to support the three repair teams. It may be augmented with debris removal equipment from the repair teams (front end loader (FEL) and compact track loaders (CTLs) with buckets and/or brooms). See **Figure 3.1** for recommended order of operations after clearing the convoy routes and material delivery routes. **Note:** The following debris removal data may be useful for planning purposes:

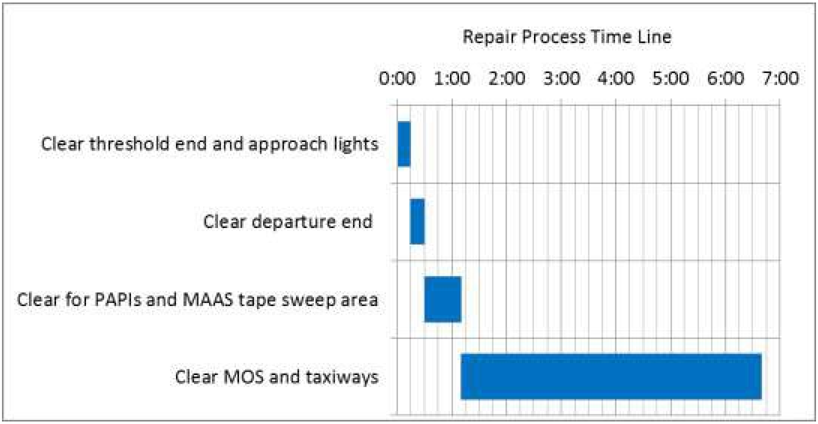
- Time to remove and sweep a 3-ft x 10-ft x 100-ft debris berm from side of runway: 55-min
- Time to remove 1-in minus debris, no higher than 3-ft, from a 75-ft x 300-ft area: 1.5-hr
- Time to sweep and vacuum 75-ft x 300-ft: 1.75-hr

3.2. Runway Cleanliness Standards. The peacetime standard of cleanliness for runways and taxiways requires they be kept free of any debris that could cause damage to aircraft. In wartime, the runway surfaces could be extensively covered with debris after an attack; the Senior Airfield Authority (SAA) defines the airfield surfaces cleanliness standards prior to aircraft operations. Although the standard for fighter aircraft would likely not change it is possible C-130 or C-17 operations may not require as pristine operating surfaces.

3.2.1. Different effectiveness of cleaning is achieved by using various combinations of equipment in the RADR Unit Type Codes (UTCs). Tests have shown very little benefit is achieved by making more equipment coverages than the following recommendations:

3.2.1.1. The cleanest surface is achieved with one fast (4- to 5-mph) sweep of the area with a grader, followed by two coverages with a vacuum sweeper traveling at 3.5- to 4-mph.

Figure 3.1. Recommended Order of Operations.



3.2.1.2. A clean surface is achieved by conducting one fast (4- to 5-mph) grader coverage followed by one coverage of the industrial tractor with a front-mounted broom traveling at approximately 5.5-mph. These speeds are effective only if debris is mostly dry. If debris is wet and sticky, a broom cannot produce a good clean surface.

3.2.1.3. A slow (2- to 3-mph) grader coverage followed by a second, faster (3- to 5-mph) coverage is going to leave a "dirty" surface, because more large stones are left.

3.2.1.4. The "dirtiest" surface, but fastest operation, is conducting one fast (4- to 5-mph) coverage with a grader only.

3.3. Resources. Table 3.1 identifies the resources for the FOD removal process.

3.3.1. Vehicles. Vehicles for the FOD Removal Team are provided by UTC 4FWFD. See **Table 3.1** for a complete list of the FOD Removal Vehicle Set.

3.3.2. Personnel. Personnel on the FOD Removal Team are sourced from permanently assigned personnel at a main operating base and/or beddown forces at a contingency location.

Table 3.1. FOD Removal Resources.

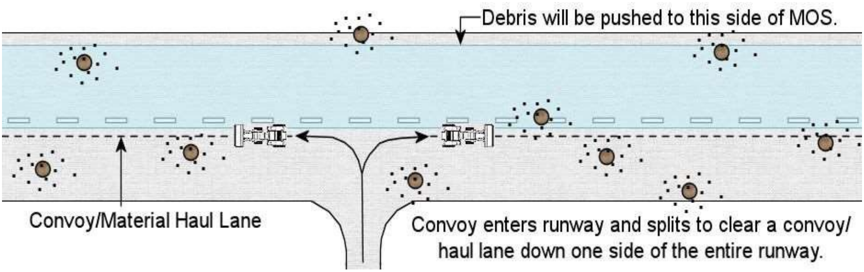
Position	Suitable AFSCs	Vehicle/Equipment/Tools	Equipment Subs
Team Lead	3E2X1	Grader, tractor/trailer with lowboy, dozer	See Notes 1 and 2
Operator	3E2X1	Grader	See Note 2
Operator	3E0X1, 3E0X2, 3E1X1, 3E2X1, 3E3X1, 3E4X3, 3E6X1	FEL	See Note 2
Operator	3E2X1, 3E4X3	Industrial tractor w/ broom	CTL w/broom attachment
Operator	3E2X1, 3E4X3	Industrial tractor w/ broom	CTL w/broom attachment
Operator	3E0X1, 3E2X1	Vacuum sweeper	None
Operator	3E0X1, 3E2X1	Vacuum sweeper	None

Operator	3E0X1, 3E2X1	Vacuum sweeper	None
Note 1: The FOD Removal Team Lead's primary vehicle is the grader; however, if the dozer is required to remove damaged aircraft from the MAOS, he/she should haul the dozer to the airfield on the tractor-trailer first and then return to retrieve the grader. **Note 2:** Any piece of equipment with a bucket or blade can be used to clear debris.			

3.4. Process. Clean all airfield operating surfaces trafficked by aircraft even if debris appears minimal. It is essential to remove as much shrapnel as possible since even small pieces of sharp metal can damage tires. The following steps are an example of convoying from staging areas to the MAOS. See **Attachment 5** for a RADR Pre-Convoy briefing template.

3.4.1. Step 1: The FOD Team leads the convoy to the runway. Upon arrival, the FOD Removal Team splits into two crews (augmented by one FEL from each Repair Team). Each crew clears a 25-ft wide convoy/material haul lane down the entire MOS (**Figure 3.2**). The RADR Officer In Charge (OIC)/Repair Chief directs which side of the MOS is the haul lane to be cleared; debris is moved to the opposite side. If repair zones are located on a taxiway, haul lanes need to be cleared there as well.

Figure 3.2. FOD Team Clearing Haul/Material Lane.



3.4.2. Step 2: After clearing the haul lane, the FOD Removal Team clears the threshold and departure ends. After the ends of the runway have been cleared, the repair team FELs return to their respective teams.

3.4.3. Step 3: Make a single coverage about 15-ft wide with a grader 1,400-ft down the centerline of the MOS overruns to provide access for approach lighting placement.

3.4.4. Step 4: Clear a path about 15-ft wide from the MOS to the Precision Approach Path Indicator (PAPI) installation location.

3.4.5. Step 5: Clear a path about 25-ft wide from the MOS to the Aircraft Arresting System (AAS) installation locations.

3.4.6. Step 6: Clear parking aprons and taxiways. A better standard of sweeping is required on parking aprons and uphill sections of the taxiway where the aircraft needs to use more power and is therefore likely to suck up more debris. Use an industrial tractor with broom or a second coverage of a grader at these locations.

3.4.7. Step 7: Clear the MAOS as follows:

3.4.7.1. Clear the first 300-ft of the MOS (the most critical area) with a vacuum sweeper.

3.4.7.2. Clear the next 800-ft of the MOS with a vacuum sweeper, if possible.

3.4.7.3. Clear remainder of MAOS with industrial tractors with broom or two coverages with grader passes.

3.4.8. The above recommendations should be considered just that—recommendations. They are not the minimum requirements. As time and vehicles permit, remove as much FOD as possible from all airfield operating surfaces to be used for launch and/or recovery purposes. Plan on making frequent trips to the

MAOS for FOD clean up—aircraft activity and winds will continually blow additional debris onto the airfield operating surfaces. **Note:** The FOD Removal Team is most likely to operate as a distributed team to adequately support all recovery teams. As such, it is critical for the command and control (C2) element to be kept informed of clearing operations and upcoming requirements.

Chapter 4

RAPID DAMAGE REPAIR

4.1. Overview. In its most basic interpretation, the RDR mission is to provide an accessible and functional MAOS within 6.5-hrs once repairs commence. Although simplistic in outward appearance, RDR is a highly complex undertaking that may require accomplishment at night, in any weather condition, with threat of recurring attacks, and possibly in a chemically contaminated environment. RDR is a subset of RADR which is a subset ADR. See AFPAM 10-219V4 and AFTTP 3-32.10 for a complete overview of the ADR Program.

4.1.1. The scope of RDR varies proportionally to the intensity of the attack. It could range from minor pavement disruption to major airfield damage with hundreds of craters, spalls, camouflets, and thousands of UXO. It is this latter scenario AF engineers should be prepared to handle swiftly, efficiently, and competently.

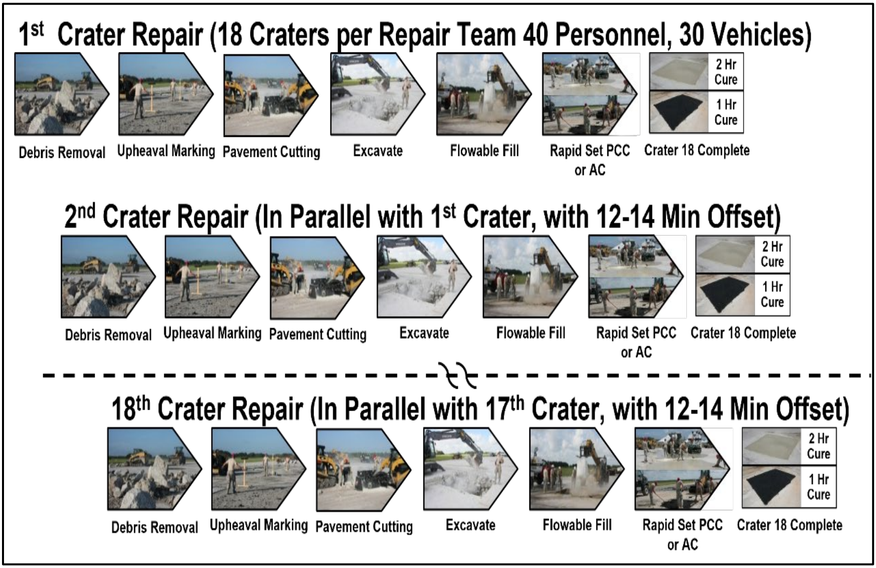
4.1.2. RDR is a modular and scalable team-based process. The size and number of repairs ultimately determine duration to complete repairs. Preferred repair materials support a mix of rotary-wing, fighter, bomber, tanker, and airlift missions from the same operating surfaces. The resulting repairs are durable and sustainable and minimize airfield downtime for follow-on maintenance actions.

4.2. Description. The crater repair process is based on an assembly line concept where the assembly line (repair crews) moves from repair to repair (**Figure 4.1**). Each step in the repair process has a dedicated crew that performs the same step at each repair, one repair after another until the step is completed on all repairs in the identified repair zone. The seven steps of the crater repair processes are:

- Step 1. Debris Removal
- Step 2. Upheaval Marking
- Step 3. Pavement Cutting

- Step 4. Pavement Breaking
- Step 5. Excavation
- Step 6. Backfilling
- Step 7. Capping

Figure 4.1. Repair Process.



4.2.1. The predominant expected crater size results in an 8.5-ft x 8.5-ft x 24-in deep repair. Repairs are based on 18-in thick concrete runway surfaces with no reinforcing steel, or asphalt surfaces of any thickness. A repair team can compete 18 small repairs (8.5-ft x 8.5-ft x 24-in) or two large repairs (30-ft x 30-ft x 24-in) in 6.5-hrs under ideal conditions.

4.2.2. **Table 4.1** and **Table 4.2** provide estimated completion times per repair. Repair times listed include travel between repairs and setup time, but do not include airfield damage assessment, UXO mitigation, convoy to the repair area(s), CBRN threat, extreme weather variances, equipment variances, team proficiencies, or personnel/equipment attrition. **Note:** Timelines in **Table 4.1** and **Table 4.2** are projected under ideal repair conditions. Actual repair times may differ, depending on site condition, repair size, or equipment malfunction.

Table 4.1. Repair Times per 8.5-ft x 8.5-ft x 2-ft Repair with Concrete Caps (mins).

Repair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Completed	85	96	107	118	129	140	151	162	173
Final Cure	205	216	227	238	249	260	271	282	293
Repair	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Completed	184	195	206	217	228	239	250	261	272
Final Cure	304	315	326	337	348	359	370	381	392

Table 4.2. Repair Times per 8.5-ft x 8.5-ft x 2-ft Repair with Asphalt Caps (mins).

Repair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Completed	115	129	143	157	171	185	199	213	227
Cured	175	189	203	217	231	245	259	273	287
Repair	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Completed	241	255	269	283	297	311	325	339	353
Cured	301	315	329	343	357	371	385	399	413

4.3. Command and Control. RDR has four levels of command: 1) RADR Officer in Charge (OIC), 2) Repair Chief, 3) Repair Team Lead, and 4) Crew Leads.

4.3.1. RADR OIC. The RADR OIC assists the Repair Chief by addressing unresolved problems. The OIC does this by requesting support from the Logistics Chief or Support Chief and their RADR teams (e.g., Warehouse Teams, Foreign Object Debris [FOD] Removal Team, and Aircraft Arresting System Team) or through the Civil Engineer-Unit Control Center (CE-UCC) Commander when support is required from external CE sources. The RADR OIC works closely with Operations Technicians (3E6X1) to track equipment, materials, personnel, and vehicles and ensure resupply actions happen in a timely manner to support future requirements.

4.3.2. Repair Chief. The Repair Chief actively manages multiple repair teams. The Chief's primary responsibility is ensuring the repair teams are progressing in a timely manner and address disruptions such as equipment breakdowns, material shortages, and personnel problems. The Repair Chief communicates with the Logistics Chief and Support Chief when support is required from, or needed by, logistics and support teams. He or she has direct communications with the Warehouse Team Leads supporting the repair teams. The Repair Chief contacts the RADR OIC when support is needed from external organizations (e.g., fuels and vehicle maintenance). Also, the Repair Chief informs the RADR OIC when crews have completed their primary tasks and are available to assist elsewhere.

4.3.3. Repair Team Leads. Repair Team Leads manage multiple repair crews. As with the Repair Chief, Team Leads manage repair crews and monitor operations for impediments that may prevent crews from completing their tasks on schedule. When a crew experiences problems, the Lead assists with addressing the obstacles and reports any delays to the Repair Chief.

4.3.4. Repair Crew Leads. Repair Crew Leads manage their crew to ensure all necessary equipment, materials, personnel, and vehicles are available to complete their tasks within repair timelines. The repair crew leads are:

- Debris Removal
- Upheaval Marking
- Pavement Cutting
- Excavation
- Backfilling
- Capping
- Spall Repair/Inclement Weather

4.4. Manning. There are no dedicated personnel UTCs exclusively dedicated to RADR. Teams are manned from CE beddown or base operating support forces and their applicable UTCs. **Table 4.3** identifies manning requirements for the Repair Team by crew (AFPAM 10-219V4 and AFTTP 3-32.10 provides complete airfield recovery manning requirements for various RADR capabilities).

Table 4.3. Repair Team Manpower Requirements.

Crew	No.
Repair Team Lead	1
Debris Removal	2
Upheaval Marking	3*
Pavement Cutting	6
Pavement Breaking and Excavation	3
Backfill (slash and splash)	5*
Capping (concrete)	8*
Spall Repair/Inclement Weather	3
Total	**29**
*Two individuals from Upheaval Marking Crew transfer to Backfill or Capping Crew (depending on type of repair) after completing marking task—but are NOT counted twice.	

4.5. Crater and Spall Repair UTCs. Crater and spall repair UTCs equip one Repair Team with equipment, material, and vehicles required to complete eighteen 8.5-ft x 8.5-ft repairs or two 30-ft x 30-ft repairs, and up to 300 average sized spalls (16-in in diameter and 2-in deep). These UTCs are scalable and modular to provide larger capabilities. The four crater and spall repair UTCs are:

- 4FWCR: Crater Repair Vehicles
- 4FWCM: Concrete Capping Material
- 4FWAB: Asphalt Capping Material
- 4FWSR: Spall Repair Kit

4.5.1. Crater Repair Vehicles (4FWCR). This UTC provides equipment, tools, and vehicles necessary to perform the crater repair capability. The UTC is tasked three times for a medium-, five times for a large-, and seven times for a very large-capability. **Table 4.4** lists the 4FWCR equipment and vehicles. **Note:** Tractor/trailer support from Logistics Readiness Support is required to haul CTL and excavator attachment trailers to the airfield.

Table 4.4. Repair Team Equipment and Vehicles (4FWCR).

Equipment and Vehicles	Qty
ADR Tool Trailer	1
CTL	5
CTL Broom, Hydraulic, Angle	3
CTL Bucket-MP, 78-in	5
CTL Cold Planer	1
CTL Compactor, Vibratory	1
CTL Forks, 48-in Pallet w/Carriage	2
CTL Impactor w/chisel & moil bits	2
CTL Saw, Wheel, 45-in blade	4

Equipment and Vehicles	Qty
CTL Saw, Wheel, 60-in blade	5
Dump Truck	1
FEL	2
FEL Bucket	2
FEL Forks, 48-in	2
Excavator	2
Excavator Bucket, 24-in	2
Excavator Bucket, 48-in	2
Excavator Compactor, Plate	2
Excavator Impactor, w/Chisel PT	2
Inclement Weather Kit	1
Light Cart	6
Pneumatic Roller	1
Telehandler	2
Trailer, 20-ton, 38-ft Flatbed (for CTL and Excavator Attachments)	2
Water Skid (For Dump Truck)	2
Water Truck (1,500 or 2,000-gal)	2
Water Trailer (2,000-gal)	4
Vibratory Roller	1
Volumetric Mixer	2
See **Attachment 3** for CTL and excavator attachments pre-attack utilization and storage plan and ADR tool trailer inventory.	

4.5.2. Crater Repair Material UTCs. There are two crater repair materials UTCs: 4FWCM provides repair materials for concrete caps and 4FWAB provides repair materials for asphalt caps. **Table 4.5** lists the repair material quantities.

Table 4.5. Crater Repair Materials (4FWCM and 4FWAB).

Material	Qty
4FWCM – Concrete cap materials	
Flowable-fill super sacks[1]	60
Rapid setting concrete super sacks[1]	48
4FWAB – Asphalt cap materials	
Flowable-fill super sacks[1]	84
*Pelletized asphalt super sacks[2]	48
Note 1: 12 super sacks (flowable-fill or rapid-setting concrete) per 20-ft container. **Note 2:** 16 super sacks (pelletized asphalt) per 20-ft container.	

4.5.3. Overcoming Repair Material Shortages. When it is known repair material are going to run short, there are repair deviations to help overcome the shortages; however, these deviations come at a cost. Deviating from procedures described in this chapter result in repairs achieving fewer aircraft passes before requiring additional repairs. This causes the airfield to be closed more often to repair the repairs, which may impact the air tasking order (ATO). As a result, any repair deviations should be reserved, to the greatest extent possible, for repairs furthest from the MOS centerline, at the end of a unidirectional MOS, and in the middle of a bi-directional MOS. All repairs within aircraft landing gear paths should be accomplished in accordance with prescribed procedures in Chapters 4, 5, or 6. Along with reducing the repair dimensions to the greatest extent possible while still ensuring all upheaval is removed, the following repair deviations may help overcome repair material shortages (these deviations may be used for large crater repairs).

4.5.3.1. Flowable-fill Material Shortages. The following repair deviations may help extend flowable-fill material. Recommend they be performed in the order as listed if materials are available.

4.5.3.1.1. Backfilling under a concrete cap:

- Reduce repair excavation depth from 24-in to 20-in and backfill with 10-in of flowable-fill.
- Partially backfill with two compacted 3-in lifts (6-in for large crater) of crushed stone in the bottom of the repair and finish backfill with 8-in of flowable-fill.
- Completely replace flowable-fill with crushed stone.

4.5.3.1.2. Backfilling under an asphalt cap:

- Reduce repair excavation depth from 24-in to 18-in and backfill with 14-in of flowable-fill.
- Partially backfill with two compacted 3-in lifts (6-in for large craters) of crushed stone in the bottom of the repair and finish backfill with 14-in of flowable-fill.
- Completely replace flowable-fill with crushed stone.

4.5.3.2. Rapid-Setting Concrete Capping Material Shortages. The following repair deviations may help extend rapid-setting concrete material. Recommend they be performed in the order as listed if materials are available.

- Increase backfill thickness from 14-in to 18-in and cap the repair with 6-in of rapid-set.
- Use wet placed flowable-fill method and cap repair with asphalt.
- Fill entire repair with flowable-fill.

4.5.3.3. Asphalt Capping Material Shortages. The following repair deviations may help extend asphalt repair material. Recommend they be performed in the order as listed if materials are available.

- Reclaim asphalt from suitable asphalt pavements on the installation such as parking lots, runway/taxiway shoulders, roads, etc.
- Use dry placement flowable-fill method, cap repair with rapid-set concrete.

4.5.4. Spall Repair Kit (4FWSR). This UTC provides equipment and materials to repair up to 300 spalls. **Table 6.4** lists the UTC's equipment and materials.

4.6. Arrival at the Repair Zone. The assigned Repair Team stops short of their repair zone while the remainder of the convoy continues to subsequent repair zones.

4.6.1. The Upheaval Marking Crew members places a traffic cone on each corner of the repair zone's leading edge. The Excavation, Backfill, and Capping Crews dismount and conduct a Post-Attack Reconnaissance (PAR) sweep starting at the leading edge of the repair zone and proceed to the trailing edge where a traffic cone is placed on each corner of the repair zone's trailing edge. Team members report remaining hazards to the Repair Chief.

4.6.2. If UXO mitigation is not complete within the repair zone, the PAR sweep members stop short of the UXO Mitigation Team to ensure at least 250-ft of stand-off distance and place traffic cones at that location. If UXO mitigation is complete when the Debris Removal Crew has cleared debris from all repairs between the leading and trailing set of cones, they dismount and complete the PAR sweep to the repair zone's trailing edge and place trailing cones on the corners of the repair zone's trailing edge. However, if UXO mitigation is still not complete within the repair zone, stop short of the UXO Mitigation Team to ensure at least 250-ft of stand-off distance and place traffic cones at that location. Crew members report any hazards to the Repair Team Lead.

4.7. Small Crater Repair Process. The small crater repair process is performed on repairs with dimensions 11-ft or less. **Note:** See **paragraph 4.8** for large crater repair procedures (repairs with at least one dimension greater than 11-ft).

4.7.1. Debris Removal. Two crew members clear debris from the repair zone. Debris removal begins immediately after the PAR sweep has proceeded at least 250-ft beyond the first crater to be repaired. It is imperative the Debris Removal Crew stay ahead of the Upheaval Marking Crew to prevent slowing down each subsequent process. Resources required for debris removal are listed in **Table 4.6**.

Table 4.6. Debris Removal Resources.

Position	Suitable AFSCs	Vehicle/Equipment/Tools	Vehicle/Equipment Subs
Operator	3E2X1, 3E3X1, 3E4X1	CTL with multi-purpose bucket[1]	Equipment with a bucket or a blade
Operator	3E0X1, 3E0X2, 3E1X1, 3E2X1, 3E3X1, 3E4X3, 3E6X1	FEL with multi-purpose bucket	Equipment with a bucket or a blade
Note 1: The CTL is the primary backup to support pavement cutting and can also be tasked to support spall repair with a cold planer attachment.			

4.7.1.1. Step 1: Initial debris removal. The crew works together to clear debris 15-ft around each repair the first time through the repair zone. Debris is pushed in any/all directions.

4.7.1.2. Step 2: Intermediate debris removal. Return to the first repair in the repair zone to push the previously cleared debris at least 30-ft from designated side of the MAOS. Pile heights should not exceed 36-in.

4.7.1.3. Step 3: When excavation begins on the first repair, the crew begins pushing debris excavated from the repair at least 30-ft from designated side of the MAOS. The debris removal crew follow the excavation crew to each repair to remove excavated debris throughout the repair zone. **Note:** If pavement breaking advances two or more repairs beyond the excavation process, either the FEL or CTL (depending on the repair size) begins removing broken pavement from the repairs already broken ahead of the excavator to accelerate the excavation process.

4.7.1.4. Step 4: After excavated debris has been removed, operators continue to clear debris throughout the repair zone.

4.7.1.5. Step 5: Final debris removal. After the repairs have been capped and achieve initial set, the crew thoroughly cleans around the edges of each repair pay particular attention to slurry buildup at edges of the repair.

4.7.1.6. Step 6: Once all excavated debris has been removed, the Repair Team Lead informs the Repair Chief the Debris Removal Crew has finished their primary task. If not needed elsewhere, the FEL begins loading any available warehouse dump trucks with debris to be removed from the airfield and the CTL supports other repair activities as needed (e.g., cleaning spilled backfill and capping materials). If necessary, the attachment is changed to support other activities.

4.7.2. Upheaval Determination and Marking. Upheaved pavement (**Figure 4.2**) is not always visible to the eye; therefore, upheaval determination is accomplished through Crater Profile Measurements (CPM) to ensure all damaged pavement is identified and removed. Unremoved upheaval is going to likely fail under traffic and create FOD hazards. Conversely, removing more pavement than necessary increases repair times and uses more repair material than necessary, possibly depleting repair material before all repairs are complete. Resources for upheaval determination are listed in **Table 4.7**. **Note:** It is imperative for repair teams to know airfield pavement construction features prior to an attack so upheaval marking adjustments can be made to avoid load transfer devices (e.g., dowel bars) when possible. Larger repairs need more repair materials; but avoiding load transfer devices results in quicker repairs. The Repair Team Lead determines whether or not to increase repair sizes to avoid load transfer devices and when repairs in close proximity are combined into a single repair.

Figure 4.2. Cross Section of Crater Illustrating Upheaved Pavement.

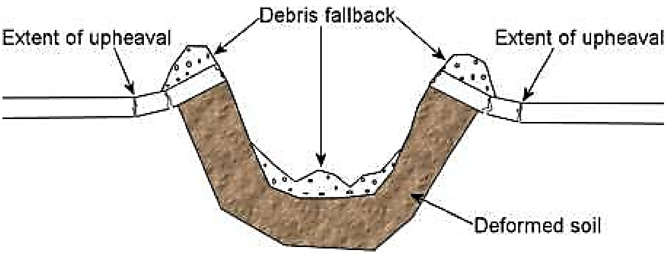


Table 4.7. Upheaval Marking Crew Resources.

Position	Suitable AFSCs	Vehicle/Equipment/Tools	Vehicle/Equipment Subs
Crew Lead	3E5X1[1]	Pickup/CPM-stanchion[3]	Any vehicle
Laborer	Any[2]	CPM-stanchion[3], broom	
Laborer	Any[2]	CPM Sight rod[3], marking material	
Note 1: Supports MAOS Marking Team after upheaval marking is complete. **Note 2**: Individuals receive just-in-time CPM training upon assignment to the crew. Supports backfilling or capping (water truck operator & helper) crews (depending on capping type) after upheaval marking is complete. **Note 3**: If line-of-sight profile measurement devices are not in the ADR tool trailer, manufacture in accordance with TO 35E2-5-1.			

4.7.2.1. Upheaval marking begins immediately after the first repair is cleared by the Debris Removal Crew. Identify extent of upheaval as described in T.O. 35E2-5-1 for craters with an apparent size of 20-ft in diameter or larger. Use the following procedures when apparent crater size is less than 20-ft in diameter. Work from the crater centerline (oriented parallel to aircraft traffic) outward in one direction and then in the other direction.

4.7.2.1.1. Step 1. Place CPM stanchions at least six paces from the crater lip on opposite sides of crater and place the CPM sight rod between the CPM stanchions at the edge of obvious upheaval with single target up. Ensure the CPM stanchions and CPM sight rod are placed on sound pavement (no upheaval), aligned along approximate crater centerline and parallel to aircraft traffic (**Figure 4.3**). Remove debris from under CPM stanchion feet and level aluminum sighting planes on top of each CPM stanchion by centering bubble in level.

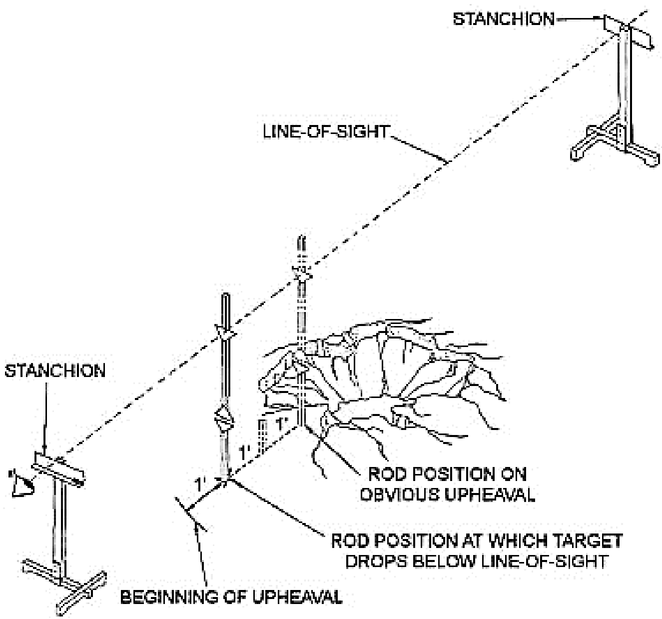
4.7.2.1.2. Step 2. The crew member at the CPM stanchion on the same side of the crater as the CPM sight rod stands approximately two (2) paces behind the CPM stanchion and sights the CPM sight rod's single target along upper edge of both CPM stanchion sighting planes.

4.7.2.1.3. Step 3. While keeping plumb, move CPM sight rod away from the crater to measure upheaval along the line-of-sight between the CPM stanchions (**Figure 4.3**). Start measurements on obvious upheaval, moving away from the crater.

4.7.2.1.4. Step 4. When reaching the upheaval starting point (e.g., when the single triangular target drops below the line-of-sight across the top of the two CPM stanchion rectangular sighting planes) clean the pavement and mark that spot.

Warning: If the triangle is more than 2-in below the line-of-sight across the top of the two T-stanchions, there is a sunken slab, and the measurement continues until the triangle rises (this is indicative of sluffing base material or could be caused by a camouflet).

Figure 4.3. Performing Crater Profile Measurements (CPM).



4.7.2.1.5. Step 5. The CPM sight rod then is moved clockwise around the crater while the CPM stanchions move laterally aligning with the rod. The CPM sight rod is set-up centered on the crater at the nine o'clock position at the edge of the obvious upheaval. The two CPM stanchions move laterally perpendicular to the MOS centerline aligning with the CPM sight rod.

4.7.2.1.6. Step 6. The crew member on the same CPM stanchion that previously sighted the upheaval performs step 2 and the crew repeats steps 3 and 4.

4.7.2.1.7. Step 7. The CPM sight rod then is moved clockwise around the crater while the CPM stanchions move laterally back to their original position. The CPM sight rod is aligned along the approximate crater centerline and parallel to aircraft traffic on the opposite side of the crater.

4.7.2.1.8. Step 8. The crew member at the CPM stanchion on the same side of the crater as the CPM sight rod performs step 2 and the crew repeats steps 3 and 4.

4.7.2.1.9. Step 9. The CPM sight rod then is moved clockwise around the crater while the CPM stanchions move laterally aligning with the rod. The CPM sight rod is set-up centered on the crater at the three o'clock position at the edge of the obvious upheaval. The two CPM stanchions move laterally perpendicular to the MOS centerline aligning with the sight rod.

4.7.2.1.10. Step 10. The same crew member performs step 2, and the crew repeats steps 3 and 4.

4.7.2.1.11. Step 11. Working as a crew, the members mark the corners of the upheaval using the upheaval marks as a guide. For small craters two members mark the corners and the third moves to and begins setting up on the next available crater. For larger craters all three members mark the corners before moving to the next available crater. Rather than marking the upheaval in shape of the upheaval pattern, the pavement is going to have a square cut parallel to the adjacent concrete slab joint (**Figure 4.4**) or parallel and perpendicular to the path of traffic in asphalt (**Figure 4.5**). Using the outermost extents of the upheaval markings, mark only the corners of the repair in both directions.

Figure 4.4. Pavement Cut Line Orientation on Concrete.

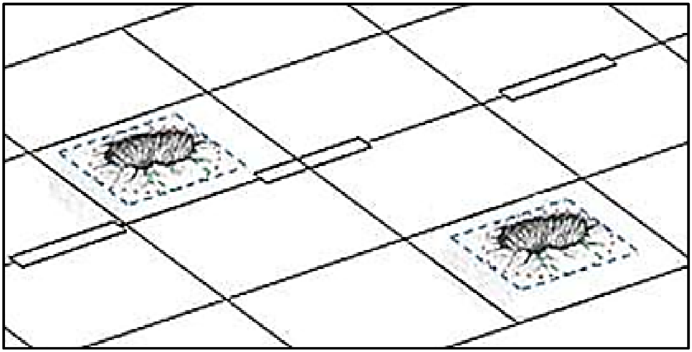
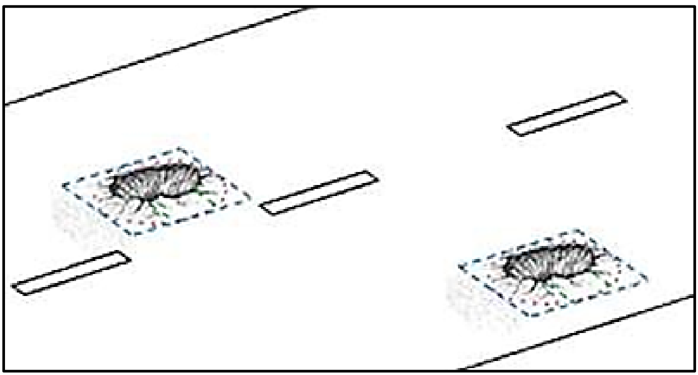


Figure 4.5. Pavement Cut Line Orientation on Asphalt.



4.7.2.2. The relative repair location drives five marking variations: 1) repair centered on slab (**Figure 4.6**) 2) repair centered between two slabs on a joint (**Figure 4.7**), 3) slab close to a joint (**Figure 4.8**), 4) slabs with load transfer devices (**Figure 4.9** thru **Figure 4.13**), and 5) repairs in close proximity (**Figure 4.14**).

Figure 4.6. Repair Centered on Slab.

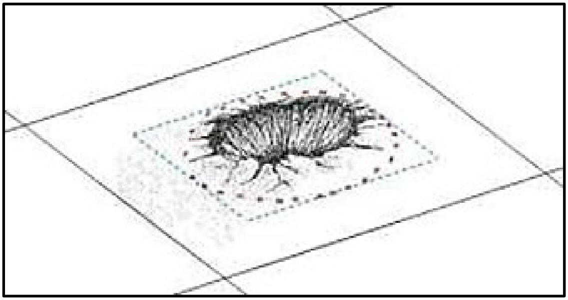
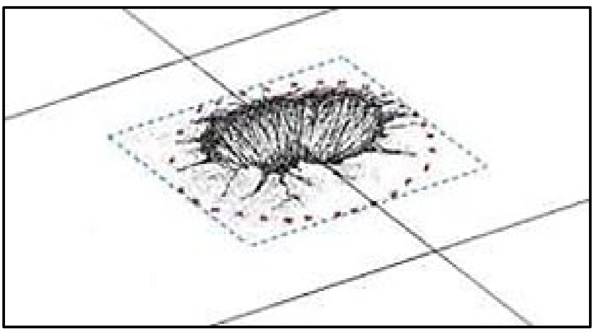
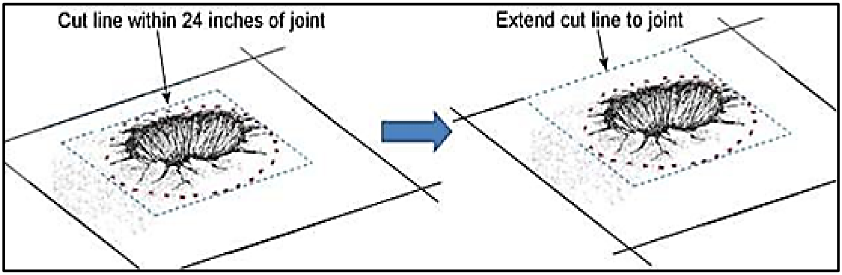


Figure 4.7. Repair Centered Between 2 Slabs on a Joint.



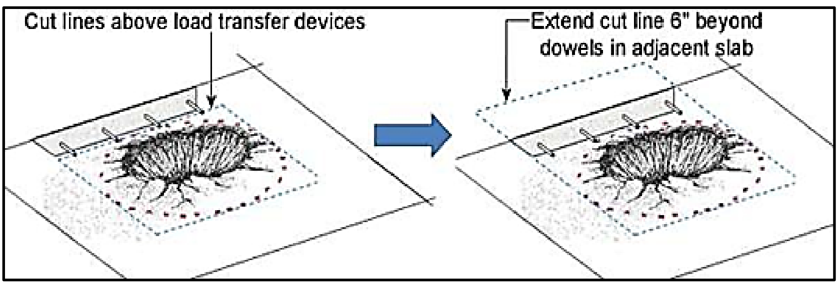
Note: Re-established joint after return of normal operations in accordance with UFC 3-250-08FA, Standard Practice for Sealing Joints and Cracks in Rigid and Flexible Pavements.

Figure 4.8. Cut Lines <24-in of a Joint (No Material Shortage or Load Transfer Device).



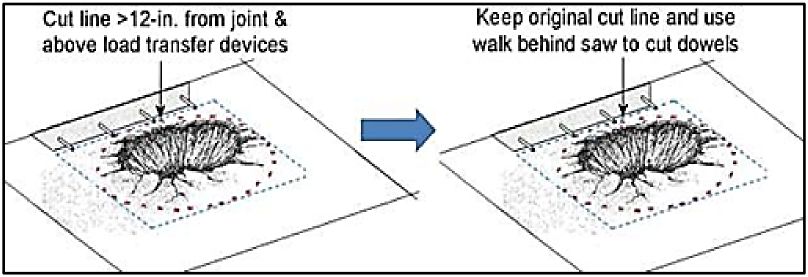
Note: When repair material is not limited, extend cut lines to joint when no load transfer devices are present.

Figure 4.9. Cut Lines Above Load Transfer Devices (No Material Shortage).



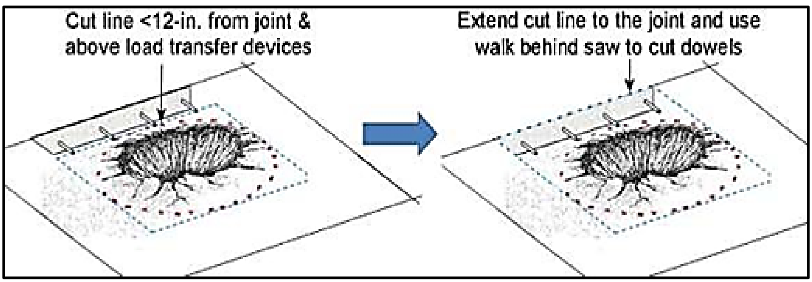
Note: When repair material quantity is not limited (or when a walk behind saw is not available) move cut lines 6-in beyond load transfer devices in the adjacent slab to expedite the process. Use CTL with wheel saws to perform cuts.

Figure 4.10. Cut Line >12-in from Joint (Material Shortage).



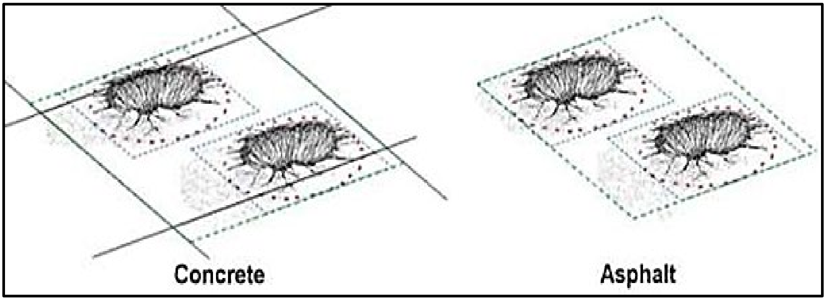
Note: When cut lines are greater than 12-in from the joint and repair material quantity is limited, use walk a behind saw to cut the line across the load transfer devices and use the CTL and wheel saws to perform remaining cuts. Place cones at repairs containing load transfer devices to notify the walk behind saw operators load transfer devices are present.

Figure 4.11. Cut Line <12-in from Joint (Material Shortage).



Note: If cut line is less than 12-in from the joint, move cut line to the joint and use the walk behind saw to cut across the load transfer devices; use the CTL and wheel saws to perform remaining cuts. After marking cut lines measure length and width of cut lines and report results to the supporting Warehouse Lead. Place cones at craters containing load transfer devices to notify the walk behind saw operators load transfer devices are present.

Figure 4.12. Multiple Repairs in Close Proximity.



Note: If distance between repairs in close proximity prevents cutting with CTL and saw attachment, use walk behind saw to cut two closest parallel sides of the repair. When the walk behind saw cannot safely fit between two repairs, create a single large repair.

4.7.2.3. Once all upheaval has been determined and marked within the repair zone, the Repair Team Lead informs the Repair Chief the Upheaval Marking Crew has finished their primary task and have reported to their next assignment (see **Table 4.7**).

4.7.3. Pavement Cutting. Pavement cutting is the most critical step in the repair process <u>in regard to meeting timelines</u>. Proper pavement cutting impacts the efficiency of the excavation and capping processes. Removing more pavement than necessary may increase the time to complete the repair and could enlarge repairs to the extent repair materials are exhausted. **Table 4.8** identifies resources required for pavement cutting.

Table 4.8. Pavement Cutting Resources.

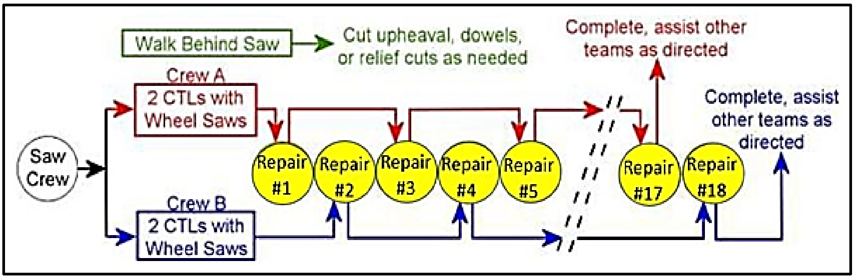
Position	Suitable AFSCs	Vehicles/Equipment/Tools	Vehicle/ Equipment Subs
Operator	3E2X1, 3E4X1	CTL with wheel saw	Walk behind saw
Operator	3E2X1, 3E4X1	CTL with wheel saw	Walk behind saw
Operator	3E2X1, 3E4X1	CTL with wheel saw	Walk behind saw
Operator	3E2X1, 3E4X1	CTL with wheel saw	Walk behind saw
Spotter	Any	Shovel, pavement cutting alignment aid, and dust mask	
Spotter	Any	Shovel, pavement cutting alignment aid, and dust mask	
		*Walk behind saw with water source	
* The walk behind saw requires additional training; normally 3E2X1s receive this training on a regular basis.			

4.7.3.1. Saw Attachment Descriptions. The CTL saw attachments come in 45-in (SW345) and 60-in (SW360) diameter blades. The 45-in blade has a maximum cutting depth of 17-in and the 60-in blade cuts to a depth of 23-in; the kerf of each blade is 3-in wide. If pavement thickness is 17-in or less it is recommended to use the 45-in blade for ease of operation. The wheel saw blade may be shifted side-to-side for alignment purposes. If the blade is shifted to either side to the extent that debris from the sawing process is in line with the CTL tracks, the spotter should remove the debris with a shovel before the CTL tracks reach the debris.

4.7.3.2. Walk Behind Saw. The walk behind saw requires a dedicated water source. Although the saw has been retrofitted with an internal water pump it does not provide sufficient water for larger blades (36-in and 42-in); therefore, the water source should have its own water pump capable of providing sufficient pressure.

4.7.3.3. Process. Cutting speed of the wheel saw in 18-in thick Portland Cement Concrete (PCC) is approximately one foot per minute (time may be affected by concrete strength, aggregate hardness, or pavement thickness). The six member crew is evenly divided into two sub crews (A and B) composed of two CTL operators and one spotter. The two sub crews work on separate repairs simultaneously finishing two repairs (**Figure 4.13**). The pavement cutting sub-crews start with CTLs facing each other on parallel sides of a marked repair. The pavement cutting steps are as follows:

Figure 4.13. Pavement Cutting Process.



4.7.3.3.1. Step 1: The spotter positions the ground-target alignment aid 16-in beyond the end of the cut line when using the 45-in blade, or 14-in for the 60-in blade, with the flat end of base towards the cut (**Figure 4.14**). These measurements result in an approximate 4-in overcut when the saw shroud contacts the ground-target alignment aid.

4.7.3.3.2. Step 2: The CTL operator aligns the alignment aids, attached to the top of the wheel saw, with the ground-target stand alignment aid (**Figure 4.14**) and lowers the wheel saw blade until the blade is level and approximately 1-in above the pavement. **Note:** The alignment aids attached to the top of the wheel saw are mounted using magnetic bases and may move during sawing operations. Periodically, ensure the alignment aids have not moved, and if so, realign them to ensure a straight line is cut. If alignment aids continually move and become unaligned, use alternate methods to securely attach them to the wheel saws.

Figure 4.14. Pavement Cutting Alignment Aids.

4.7.3.3.3. Step 3: The spotter guides the CTL operator to position the wheel saw above the cut line to where an overcut of approximately 4-in is going to occur. This is accomplished for the 45-in wheel saw by aligning a mark placed 12-in (14-in for the 60-in wheel saw) from the rear plate of the shroud with the start of the pavement cut line. The blade is going to travel slightly rearward when lowering and should provide the 4-in overcut at the start of each cut line. **Note:** It is imperative overcuts be kept to approximately 4-in, anything less potentially adds time to break pavement from the repair corners. Conversely, overcuts longer than 4-in adds precious time to the cutting process, consumes large quantities of rapid-set material to repair the overcuts, has the potential to cause FOD after repairing the overcut, and reduces the number of repairs that can be cut before the conical cutting bits require replacement.

4.7.3.3.4. Step 4: Set cutting depth at the minimum position (blade between 6 and 8-in. below shroud). Lower the saw close to the ground so the full length of the shroud is parallel to the pavement surface.

4.7.3.3.5. Step 5: At low idle, activate the control for the saw blade rotation and continuous flow. Gradually increase the engine speed to high idle.

4.7.3.3.6. Step 6: Slowly plunge the wheel saw to full depth. When full cutting depth is reached, move forward at a SLOW speed. Increase forward speed until an optimum working speed is reached. The wheel saw may stall if traveling too fast. Spotters remove cutting debris that piles in front of the shrouds and CTL tracks. **Note:** The spotter ensures the CTL's tracks are flat on the pavement (not back on the heels of the tracks) during the cutting process to limit/reduce track slippage.

Warning: Keep the shroud in contact with the pavement while cutting. Failure to do so could cause debris (i.e., chunks of concrete) to be discharged from underneath the shroud causing injury to personnel. In addition, if the shroud is kept raised above the surface, any object unintentionally entering the shroud (i.e., shovel) may be launched by the rotating saw blade, which may cause injury to personnel.

4.7.3.3.7. Step 7: The operators cut in opposite directions on parallel cut lines (**Figure 4.15**). On smaller repairs, the operators may need to side shift the wheel saws towards the repair to create the necessary clearance for two CTLs to cut simultaneously. Spotters remove cutting debris that piles in front of the shrouds and CTL tracks.

Caution: If the shroud and/or tracks of the CTL travel over debris the blade is going to rise and decrease the cutting depth and may cause a curved cut, which may cause the blade to bind.

Figure 4.15. Cutting Parallel Lines Simultaneously.

4.7.3.3.8. Step 8: The CTL operators stop the cutting process when the wheel saw shroud contacts the alignment aids, which results in an overcut of approximately 4-in.

4.7.3.3.9. Step 9: The CTL operators then reposition on the two remaining cut lines and make cuts in the same manner as described above. Spotters inspect the wheel saw bits and wheel saw wearing shoes after each side of a repair is cut to determine if the bits and/or shoes need replacing. If the CTL operators experience an increase in cutting times, or if the blade begins to spark excessively during the cutting process, the most likely cause is worn bits. At this point the spotter inspects the bits and directs the CTL operator to exchange the wheel saw with a spare from the attachment trailer(s). Designated individuals (Wing mobile vehicle maintenance personnel if available) replace bits to ready it for the next attachment replacement if needed.

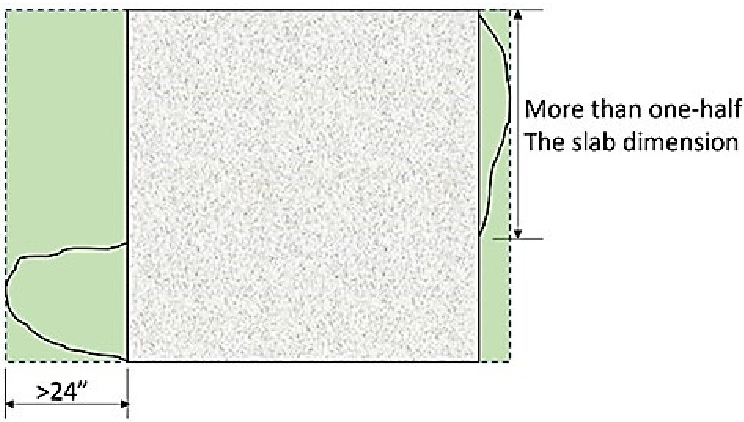
4.7.3.3.10. Step 10: Upon completion of the final cuts, the CTL operators move (leapfrog) past the other pavement cutting crew to the next repair and wait to be lined up by the spotter as described above.

4.7.3.3.11. Step 11: This process continues until all repairs (up to 18) have been cut in the team's repair zone.

4.7.3.3.12. Step 12: The Repair Team Lead informs the Repair Chief when the Pavement Cutting Crew has finished their primary tasks so they may be assigned to other crews/teams as necessary.

4.7.3.3.13. If an edge is damaged during the cutting process, cut out additional damage when greater than 24-in or more than half the length of the slab. Otherwise, complete the repair and treat the additional damage as a spall. (**Figure 4.16**)

Figure 4.16. Additional Damage (diagram/picture).



4.7.3.3.14. When cut lines fall within areas containing load transfer devices (e.g., dowels), use the walk behind saw (**Figure 4.17**) to cut the load transfer devices. The walk behind saw requires additional training; normally 3E2X1s receive this training on a regular basis. Walk behind saw cutting speed is significantly reduced when cutting through high strength concrete and load transfer devices.

4.7.3.3.15. When cutting a large crater, it is advisable to cut two adjoining sides to allow breaking to begin while the other sides are cut.

Figure 4.17. Walk Behind Saw.

4.7.4. Pavement Breaking and Excavation. This crew is responsible for breaking the damaged pavement within the cut lines and removing the disturbed subsurface material.

4.7.4.1. Resources. **Table 4.9** identifies resources required for the pavement breaking and excavation process.

Table 4.9. Pavement Breaking and Excavation Resources.

Position	Suitable AFSCs	Vehicle/Equipment/Tools	Vehicle/ Equipment Subs
Operator	3E2X1	Excavator with impactor	Tracked excavator, backhoe, or CTL with impactor
Operator	3E2X1	Excavator with bucket	Tracked excavator, backhoe, CTL, or FEL
Spotter	Any	Shovel, tape measure, & marking paint	
Note: Pavement breaking with impactor attachment may not be necessary in asphaltic materials. After pavement cutting, an excavator with bucket or FEL may be sufficient to excavate repair without breaking operations. **Note:** Field experimentation has shown using a 3E2X1 as a spotter accelerates excavation times and provides higher quality.			

4.7.4.2. Pavement Breaking. Pavement breaking (**Figure 4.18**) can begin as soon as pavement cutting is complete on the first repair. On large repairs, breaking may begin when the first sides of the repair are complete. **Note:** If the repair is going to have an asphalt cap, the Repair Team Lead informs the Warehouse 1 Lead pavement breaking is about to commence. The Warehouse 1 Lead directs the supporting batch plant to begin batching operations to ensure asphalt is ready and available on the airfield when needed.

4.7.4.2.1. Step 1: Break pavement into pieces suitable for buckets on excavating equipment. **Note:** Depending on the length of the saw overcuts, the slab may not be free floating, and special attention should be paid to breaking the corners.

Figure 4.18. Excavator Performing Pavement Breaking.

4.7.4.2.2. Step 2: When pavement has been suitably broken, the operator moves to the next available repair location to begin pavement breaking. **Note:** When the operator excavating the repair is not keeping up, use the breaker attachment to flip-out as much of the broken material as possible until the operator excavating the repairs catches up.

4.7.4.2.3. Step 3: Repair Team Lead informs the Repair Chief when pavement breaking is completed on all repairs so personnel/vehicles may be assigned to other crews as necessary.

4.7.4.3. Excavation. As soon as the pavement breaking is complete on the first repair, the excavation crew begins excavating the repair. To aid the excavation process, lines are marked 24-in up the sides of the bucket when the bucket is sitting flat on the ground. The lines provide a visual reference to guide the excavator operator (**Figure 4.19**).

Figure 4.19. Excavator Bucket with 24-In. Reference Marks.

4.7.4.3.1. Step 1: Set up excavator perpendicular to the edge of the repair, with the boom/stick joint above the near edge of the repair. Excavate repair with spotter guidance. Attempt to make repair walls as vertical as possible with the bucket. Be careful not to damage pavement edges, especially asphalt surfaces. **Note:** If base materials are sluffing to the point the adjacent slab is undercut, additional pavement may need to be removed.

4.7.4.3.2. Step 2: Place removed debris adjacent to the repair where it is removed by the Debris Removal Crew.

4.7.4.3.3. Step 3: Excavation is complete when reaching 24-in in depth (even with the line on the bucket). The operator should use the bucket to compact any loose material. The operator then proceeds to the next repair ready for excavation. **Note:** If repair is excavated to a depth greater than 24-in, notify the Repair Team Lead immediately for guidance. The Repair Team Lead may decide to backfill the over-excavation with flowable-fill material depending on availability. Standard practice is to use choke ballast and/or crushed stone to return the excavation to a finished depth of 24-in prior to the backfill process. Refer to TSPWGM 3-270-01.3-270-07, *Airfield Damage Repair*, for guidance on crushed stone or ballast rock backfill.

4.7.4.3.4. Step 4: The spotter cleans corners and vertical faces as necessary and levels the bottom of the excavation with a shovel. The spotter measures the length, width, and depth of the repair and reports the measurement to the Warehouse Team Lead (if steps are taken to correct over excavation the corrected depth needs to be reported to the Warehouse Team Lead). Finally, the spotter marks the backfill depth on the walls of the excavated repair with spray paint obtained during pre-attack action and moves to the next repair. **Note:** Proper backfill depth for a concrete cap is 10-in below the surrounding pavement and 4-in below surrounding pavement for an asphalt cap.

4.7.4.3.5. Step 5: Repair Team Lead informs the Repair Chief when excavation crew has finished their primary tasks so they may be assigned to other crews/teams as necessary.

4.7.5. Backfill. The RDR backfill process utilizes a flowable-fill material in place of traditional crushed stone. The flowable-fill material is a medium strength, high viscosity, excavatable, rapid-setting, cementitious backfill material. The material is packaged in 3,000-lb (approximately 1-cy) super sacks and is used beneath rapid-setting concrete or asphalt.

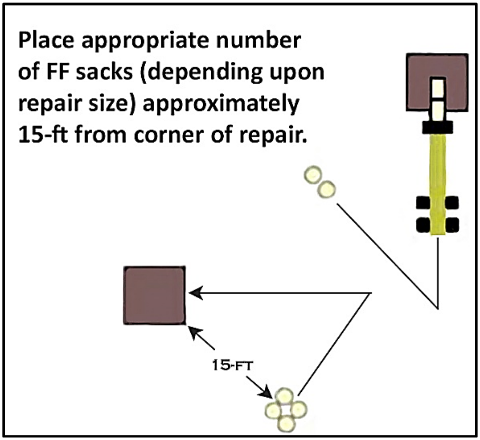
4.7.5.1. Backfill under Rapid-Setting Concrete Cap. When the repair is capped with rapid-setting concrete, flowable-fill is placed using the dry placement technique commonly known as "slash and splash". Put simply, a 3,000-lb super sack of flowable-fill is suspended over the excavated area, the bag is "slashed" releasing the material into the repair and manually hand spread/leveled and "splashed" with 50-gal of water before adding the next super sack. **Table 4.10** identifies resources required for the backfill process under a rapid-setting concrete cap. **Note:** Supply of flowable-fill material provided with each RDR capability is based upon a pre-determined number of repairs plus 10 percent. The excavation depth of each repair is calculated at 24-in. Repeated over-excavation may rapidly lead to a flowable-fill shortage.

Table 4.10. Resources for Backfill under Rapid-Setting Concrete.

Position	Suitable AFSCs	Vehicle/Equipment/Tools	Vehicle and Equipment Subs
Lead	3E2X1	Utility knife, rake	-
Operator	3E2X1, 3E4X1, 3E4X3	Water truck, water flow meter*, & nozzle	Any portable water source
Operator	3E1X1, 3E6X1	Telehandler	Any forklift
Laborer	Any	Utility knife, rake	-
Laborer	Any	Utility knife, rake	-
*If a water flow meter is not available, time how long it takes the water truck to fill a 55-gal drum. Add water at the same rate per super sack.			

4.7.5.1.1. The supporting warehouse determines and delivers the required repair material to the repair zone (see AFTTP 3-32.18, *RADR Warehouse Operations*, for detailed warehouse operations). The warehouse telehandler operator at the repair zone unloads super sacks from warehouse trailers and places them in a designated location identified by the Repair Team Lead. If the next loaded trailer has not arrived at the repair zone by the time the previous trailer is unloaded, the warehouse telehandler operator may assist the repair team by placing super sacks diagonally from a repair corner, approximately 15-ft away (**Figure 4.20**). This leaves room for pavement cutting, breaking, and excavating processes if not already complete. Align super sack handles so the backfill crew telehandler forks can slide through both sacks without readjusting position. **Table 4.11** displays the expected consumption of flowable-fill when used under a rapid-setting concrete cap (14-in of flowable-fill). The table assumes excavation depth is 24-in.

Figure 4.20. Flowable-fill Super Sack Placement.



4.7.5.1.2. Step 1: Position the water truck at the repair area out of the way of any repair operations. Connect a 1.5-in by 50-ft hose with water flow meter to the water truck (utilizing the water flow meter ensures the proper amount of water is added for each super sack of material). **Note:** Recommend water truck driver operate water pump and monitor the water flow meter to know when to stop adding water to the repair.

4.7.5.1.3. Step 2: The telehandler operator is guided by a spotter to lift one or two super sack(s). The operator lifts the super sack(s) (telehandlers are capable of lifting two super sacks simultaneously, but only empty one sack at a time) from near side of the repair and suspends it just inside the repair edge to allow the spotter to "slash" the super sack on the two sides parallel to the forks to help spread the material (Figure 9.21). Remove any sack remnants that may fall into the repair. **Note:** The telehandler can lift the two super sacks on tires (without outriggers deployed) as long as the boom is not extended beyond 15-ft.

Table 4.11. Flowable-fill Consumption Rate under Rapid-Setting Concrete Cap.

L x W (in feet)	**8**	**8.5**	**9**	**9.5**	**10**	**10.5**	**11**	**11.5**	**12**	**12.5**	**13**	**13.5**	**14**	**14.5**	**15**
8	2.49	2.64	2.80	2.96	3.11	3.27	3.42	3.58	3.73	3.89	4.04	4.20	4.36	4.51	4.67
8.5	2.64	2.81	2.98	3.14	3.31	3.47	3.64	3.80	3.97	4.13	4.30	4.46	4.63	4.79	4.96
9	2.80	2.98	3.15	3.33	3.50	3.68	3.85	4.03	4.20	4.38	4.55	4.73	4.90	5.08	5.25
9.5	2.96	3.14	3.33	3.51	3.69	3.88	4.06	4.25	4.43	4.62	4.80	4.99	5.17	5.36	5.54
10	3.11	3.31	3.50	3.69	3.89	4.08	4.28	4.47	4.67	4.86	5.06	5.25	5.44	5.64	5.83
10.5	3.27	3.47	3.68	3.88	4.08	4.29	4.49	4.70	4.90	5.10	5.31	5.51	5.72	5.92	6.13
11	3.42	3.64	3.85	4.06	4.28	4.49	4.71	4.92	5.13	5.35	5.56	5.78	5.99	6.20	6.42
11.5	3.58	3.80	4.03	4.25	4.47	4.70	4.92	5.14	5.37	5.59	5.81	6.04	6.26	6.48	6.71
12	3.73	3.97	4.20	4.43	4.67	4.90	5.13	5.37	5.60	5.83	6.07	6.30	6.53	6.77	7.00
12.5	3.89	4.13	4.38	4.62	4.86	5.10	5.35	5.59	5.83	6.08	6.32	6.56	6.81	7.05	7.29
13	4.04	4.30	4.55	4.80	5.06	5.31	5.56	5.81	6.07	6.32	6.57	6.83	7.08	7.33	7.58
13.5	4.20	4.46	4.73	4.99	5.25	5.51	5.78	6.04	6.30	6.56	6.83	7.09	7.35	7.61	7.88
14	4.36	4.63	4.90	5.17	5.44	5.72	5.99	6.26	6.53	6.81	7.08	7.35	7.62	7.89	8.17
14.5	4.51	4.79	5.08	5.36	5.64	5.92	6.20	6.48	6.77	7.05	7.33	7.61	7.89	8.18	8.46
15	4.67	4.96	5.25	5.54	5.83	6.13	6.42	6.71	7.00	7.29	7.58	7.88	8.17	8.46	8.75

Figure 4.21. Spotter "Slashing" Super Sack.

4.7.5.1.4. Step 3: When the super sack is slashed, a laborer directs the telehandler operator to repeatedly boom in and out to provide an even placement of material. Laborers assist with spreading and leveling the material.

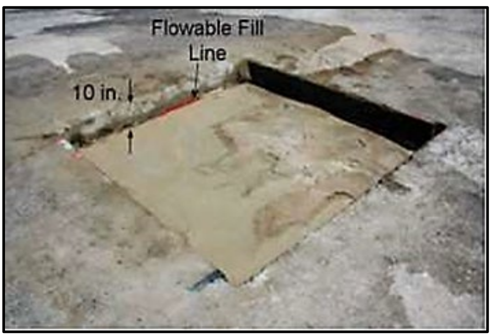
4.7.5.1.5. Step 4: While a super sack is being emptied, the water truck operator sprays 25-gal of water into the dropping material. (**Figure 4.22**). After the super sack is emptied spray the remaining 25-gal of water into the flowable-fill material in a manner to assist with leveling the material and to fully hydrate it. Allow water to percolate through the dry material layer until little surface water is apparent.

4.7.5.1.6. Step 5: Once the proper amount of water has been added, the laborers immediately level the surface of the backfill with rakes/shovels.

9.7.5.1.7. Step 6: Repeat this process as each super sack is added until reaching the backfill mark (**Figure 4.23**) made by the Excavation Crew (10-in from the surrounding pavement surface). **Note:** Each super sack is going to raise the level of flowable-fill in an 8.5-ft X 8.5-ft repair by approximately 5-in. If the repair does not require a full super sack of material before reaching the proper backfill height, slash the super sack at approximately one quarter from the top of the super sack to control the amount of material dispensed. If more material is still required, slash the super sack again halfway down. When the flowable-fill material reaches its proper height, adjust the water being added according to the estimated amount of material added from the partial super sack (e.g., only add 25-gal if only half of a super sack was used). Use remaining super sack material in the next repair.

Figure 4.22. Adding Water to Flowable-fill.

Figure 4.23. Backfill Complete.



4.7.5.1.8. Step 7: After all flowable-fill material is placed in the repair and leveled, remove any material that may have entered into the overcuts at the corners of the repair.

4.7.5.1.9. Step 8: Repair Team Lead informs the Repair Chief when the backfill crew has finished their primary tasks so they may be assigned to other crews/teams as necessary.

4.7.5.2. Backfill under an Asphalt Cap. The process for backfilling beneath an asphalt cap is accomplished with a wet placement technique utilizing the volumetric mixer **Figure 4.24**. The process uses 70-gal of water per flowable-fill super sack. **Table 4.12** identifies the Backfill Crew resources required for backfilling a repair capped with asphalt. **Table 4.13** shows the expected consumption of flowable-fill material when used under an asphalt cap (20-in of flowable-fill). The table assumes the excavation depth is 24-in. **Note:** For information on Volumetric Mixer operational procedures, mixer components, maintenance, and operational tips, scan the QR code in **Figure 4.24**.

Figure 4.24. Volumetric Mixer.

Table 4.12. Backfill under Asphalt Resources.

Position	Suitable AFSCs	Vehicle/ Equipment/Tools	Vehicle and Equipment Subs
Operator	3E0X2, 3E2X1, 3E4X1	Dump truck with water skid	Any vehicle capable of towing volumetric mixer
Operator	3E1X1, 3E6X1	Telehandler	Any forklift, excavator, or FEL (with forks or boom attachments)
Operator	3E2X1	Volumetric mixer, rake	Transit mixer
Operator	3E2X1, 3E4X1, 3E4X3	Water truck	Any portable water source
Laborer	Any	Concrete come-a-long and rake	Shovel and mixing hoe
Laborer	Any	Concrete come-a-long and rake	Shovel and mixing hoe
Laborer	Any	Concrete come-a-long and rake	Shovel and mixing hoe
Laborer	Any	Concrete come-a-long and rake	Shovel and mixing hoe

Table 4.13. Flowable-fill Super Sack Consumption Rate Under Asphalt Cap.

L x W (in feet)	**8**	**8.5**	**9**	**9.5**	**10**	**10.5**	**11**	**11.5**	**12**	**12.5**	**13**	**13.5**	**14**	**14.5**	**15**
8	3.56	3.78	4.00	4.22	4.44	4.67	4.89	5.11	5.33	5.56	5.78	6.00	6.22	6.44	6.67
8.5	3.78	4.01	4.25	4.49	4.72	4.96	5.19	5.43	5.67	5.90	6.14	6.38	6.61	6.85	7.08
9	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25	7.50
9.5	4.22	4.49	4.75	5.01	5.28	5.54	5.81	6.07	6.33	6.60	6.86	7.13	7.39	7.65	7.92
10	4.44	4.72	5.00	5.28	5.56	5.83	6.11	6.39	6.67	6.94	7.22	7.50	7.78	8.06	8.33
10.5	4.67	4.96	5.25	5.54	5.83	6.13	6.42	6.71	7.00	7.29	7.58	7.88	8.17	8.46	8.75
11	4.89	5.19	5.50	5.81	6.11	6.42	6.72	7.03	7.33	7.64	7.94	8.25	8.56	8.86	9.17
11.5	5.11	5.43	5.75	6.07	6.39	6.71	7.03	7.35	7.67	7.99	8.31	8.63	8.94	9.26	9.58
12	5.33	5.67	6.00	6.33	6.67	7.00	7.33	7.67	8.00	8.33	8.67	9.00	9.33	9.67	10.00
12.5	5.56	5.90	6.25	6.60	6.94	7.29	7.64	7.99	8.33	8.68	9.03	9.38	9.72	10.07	10.42
13	5.78	6.14	6.50	6.86	7.22	7.58	7.94	8.31	8.67	9.03	9.39	9.75	10.11	10.47	10.83
13.5	6.00	6.38	6.75	7.13	7.50	7.88	8.25	8.63	9.00	9.38	9.75	10.13	10.50	10.88	11.25
14	6.22	6.61	7.00	7.39	7.78	8.17	8.56	8.94	9.33	9.72	10.11	10.50	10.89	11.28	11.67
14.5	6.44	6.85	7.25	7.65	8.06	8.46	8.86	9.26	9.67	10.07	10.47	10.88	11.28	11.68	12.08
15	6.67	7.08	7.50	7.92	8.33	8.75	9.17	9.58	10.00	10.42	10.83	11.25	11.67	12.08	12.50

Note: The warehouse telehandler operator at the repair zone unloads super sacks from warehouse trailers and places them in a designated location identified by the Repair Team Lead. If the next loaded trailer has not arrived at the repair zone by the time the previous trailer is unloaded, the warehouse telehandler operator may assist the repair team telehandler that loads the volumetric mixer by placing the appropriate number of super sacks, near the volumetric mixer.

4.7.5.2.1. Step 1: Position the water truck and volumetric mixer (pulled by dump truck with a water skid) at the repair area. It is best to keep the dump truck and volumetric mixer parallel to the MOS centerline.

4.7.5.2.2. Step 2: As the volumetric mixer is positioned at the repair location, the mixer operator ensures mixer controls are set to flowable-fill. The mixer operator directs placement of backfill by swinging the mixer chute and having the dump truck operator pull forward or backwards as needed. The mix has a very high slump (very fluid). The mix consistency appears similar to a thin slurry (**Figure 4.25**). **Note:** Perform steps in **Attachment 5** if flowable-fill sets-up on the auger and requires emergency swap out (wear proper personal protective equipment and be aware of pinch points around locking pins/plates near mixing well).

Figure 4.25. Backfilling Repair.

4.7.5.2.3. Step 3: As flowable-fill material and mixing water are consumed; the mixer operator is going to direct the repair team telehandler and water truck operators to tender the mixer.

Note: Use the water skid in the bed of the dump truck to tender the water supply tanks when no water truck or trailer is available. As time allows, tender the water in the water skid.

Note: Some super sacks are lined with foil. Try to avoid any foil liner from getting into the mixer's hopper. Remove any pieces of foil liner that may fall into the mixer.

4.7.5.2.4. Step 4: When the required backfill level is reached (4-in from the top of the surrounding pavement, as marked by the excavation team) the laborers ensure the backfill material is in-plane with to the parent surface to keep a consistent depth throughout the repair (**Figure 4.26**).

Figure 4.26. Backfill Nearing Completion.

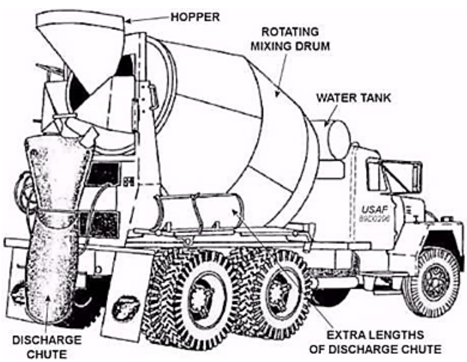
4.7.5.2.5. Step 5: After all backfill material is placed in the repair, remove any backfill material that may have entered into the overcuts at the corners of the repair.

4.7.5.2.6. Step 6: Repair Team Lead informs the Repair Chief when personnel have finished their tasks so they can be assigned to other crews/teams as necessary.

4.7.5.3. Placing a Backfill (Flowable-Fill) Using a Transit Mixer (**Figure 4.27**) in Place of Volumetric Mixer.

4.7.5.3.1. Step 1: Loading Transit Mixer. Add 70-gal of water to the drum (per super sack of flowable-fill material) before adding any flowable-fill material. For example, if mixing three (3) super sacks of flowable-fill material, then the total amount of water added to the drum at once is 210-gal. Once the water has been added to the drum, add a citric acid slurry into the drum (mix 1-lb of citric acid for each super sack of flowable-fill, (or 3-lb total for this scenario) in a 5-gal bucket with a couple gallons of water). **Note:** Do not exceed a three (3) super sack mix, as the material is going to set-up too fast before you can place the mix.

Figure 4.27. Transit Mixer.



4.7.5.3.1.1. Unlike the simplified volumetric mixer, there is limited visibility of the mix in the transit mixer; therefore, the baseline described in the paragraph above should be followed until it becomes obvious the mix is too wet or too dry. When the baseline mix is too dry or too wet, the Repair Team Lead may direct more water and/or citric acid (slurry) be added to the mix. In colder climates less citric acid (slurry) may be required, or not needed at all. Conversely, where temperatures are excessively hot, or the drum is hot, slightly more water may be required. Additionally, 60-gal of water may be sufficient in high humidity. Experimentation may be required until you achieve the proper mix.

4.7.5.3.1.2. The telehandler operator raises the super sack 12- to 18-in above the transit mixer's hopper. The helper, on the catwalk platform at top of the transit mixer's drum, guides the telehandler operator to center super sack above the hopper. **Note:** Keeping the sack 12- to18-in above the fill point helps prevent material spillage and keeps dust to a minimum.

4.7.5.3.1.3. With the super sack suspended above the hopper, the helper cuts two (2) 10- to 12-in incisions in a crisscross pattern in the center of the bottom of the super sack allowing the flowable-fill mix to readily flow into the drum (also known as charging). The telehandler operator then retrieves another super sack as needed to load in the transit mixer. Repeat until no more than three (3) super sacks of flowable-fill material has been loaded (charged) into the drum.

4.7.5.3.2. Step 2: Mixing. The transit truck operator sets the charging drum speed to Medium, or 7- to 9-rpm. This speed is optimal to rapidly route all dry mix to the bottom of the drum and provide a more consistent/uniform mix. **Note:** The flowable-fill materials is going to start reacting within minutes after loaded. Using the 3-cubic yard (cy) mix scenario as above, the operator has approximately 10- to 12-min to have all material discharged from the point material was added or the mix will start setting inside the drum.

4.7.5.3.3. Step 3: Transporting Mix to Repair Site. After flowable-fill material has been loaded and mixed, transport with drum turning between 2- and 3-rpm (agitating speed). Driving with drum at higher RPM poses risks to mixer operator and bystanders. **Note:** Recommend materials be mixed at or as close the repair site to prevent premature setup of material.

4.7.5.3.4. Step 4: Discharging Mix. After arriving at the repair site the drum should be set at approximately 7-rpm until all material has been discharged. The mixture is extremely wet with a high slump causing the initial discharge to be mostly liquid, which has a tendency to splash about. Therefore, attempt to contain the mix in the repair and prevent surrounding surfaces from being splashed. **Note:** When all repair material has been discharged the operator is going to abruptly flush the drum with water and quickly drive to a designated washout location so any remaining residue can be removed. While at the washout station, the operator should also pay particular attention to removing any materials that may have spilled on the exterior of the truck during drum charging operations. It is vital the entire transit truck and mixer be thoroughly cleaned. The drum capacity and efficiency is reduced if concrete layers are allowed to accumulate in the drum. Also, bearings and idlers may become seized, hinge points may not fold easily, and chute sections may become difficult to connect. After completing cleaning operations, the operator should inspect the vehicle for damage and make any necessary repairs.

4.7.6. Capping Repair. The capping process is accomplished with either asphalt or rapid-setting concrete. The capping material should match the in situ material, but when a material shortage is experienced, mis-matching the capping material and in situ material is allowable (rapid-setting concrete may be used to cap a repair on an asphalt surface and vice-versa; however, life of the repairs may be diminished). Capping begins once the flowable-fill material (using the "slash and splash" method) achieves an initial set of 15-min when capping with concrete and 30-min when capping with asphalt (wet flowable-fill placement). Ensure no water sheen is on the flowable-fill surface and it has set enough to support foot traffic (leaves no footprints).

4.7.6.1. Placing Rapid-Setting Concrete Cap with Volumetric Mixer. A rapid-setting concrete cap is placed using the volumetric mixer and a rapid-setting concrete mix. The dry placed flowable-fill backfill method (Slash and Splash) requires 15-min to achieve initial set before adding the rapid-setting concrete. The rapid-setting concrete for repair is packaged in 3,000-lb (approximately 1-cy) super sacks. The water to rapid-setting concrete material ratio is approximately 50-gal of water to one (1) super sack. The rapid-setting concrete material has an initial set time of 45-min (at which time it can support a 2.5-ton vehicle) and a fully operational cure time of 2-hr. **Table 4.14** identifies resources required to place a rapid-setting concrete cap. **Table 4.15** shows the expected consumption of rapid-setting concrete when placing a 10-in thick cap. The table assumes the excavation depth is 24-in. **Note:** For information on Volumetric Mixer operational procedures, mixer components, maintenance, and operational tips, scan the QR code in **Figure 4.24**.

4.7.6.1.1. Step 1: Position the water truck and volumetric mixer (pulled by dump truck with a water skid) at the repair area. It is best to keep the dump truck and volumetric mixer parallel to the MOS centerline.

Table 4.14. Rapid-Setting Concrete Cap Resources.

Position	Suitable AFSCs	Vehicle/ Equipment/Tools	Vehicle and Equipment Subs
Operator	3E0X2, 3E2X1, 3E4X1	Dump truck with water skid	Any vehicle capable of towing volumetric mixer
Operator	3E1X1, 3E6X1	Telehandler	Any forklift, excavator, or FEL (with forks or boom attachments)
Operator	3E2X1	Volumetric mixer, rake	Transit mixer
Operator	3E2X1,3E4X1, 3E4X3	Water truck	Any portable water source

Laborer	Any	*Screed, bucket, and hand trowels	
Laborer	Any	*Concrete come-a-long and rake ***Concrete rake and square shovel	
Laborer	Any	***Concrete rake and square shovel	
Laborer	Any	***Concrete rake and square shovel	

*Telehandler forklift is able to raise super sacks high enough to reach the puncture spikes on the volumetric mixer. However, any forklift able to raise super sacks over the mixer's edge allows the sacks to be cut open by hand.

**To prevent the rapid-set from setting up while using a transit mixer, mixing should be performed with an extreme sense of urgency once water is added.

***An inventory of the ADR tool trailer is listed in **Attachment 2**.

Note: The warehouse telehandler operator at the repair zone unloads super sacks from warehouse trailers and places them in a designated location identified by the Repair Team Lead. If the next loaded trailer has not arrived at the repair zone by the time the previous trailer is unloaded, the warehouse telehandler operator may assist the repair team telehandler that loads the volumetric mixer by placing the appropriate number of super sacks, near the volumetric mixer.

Note: The water truck operator maintains water supply and admixtures.

Note: Use the water skid in the bed of the dump truck to tender the water supply tanks when no water truck or trailer is available. As time allows, tender the water in the water skid.

Note: Some super sacks are lined with foil. Try to avoid any foil liner from getting into the mixer's hopper. Remove any pieces of foil liner that may fall into the mixer.

Note: Begin placing concrete on low end of each repair.

Figure 4.28. Rapid-Setting Concrete Capping Process.

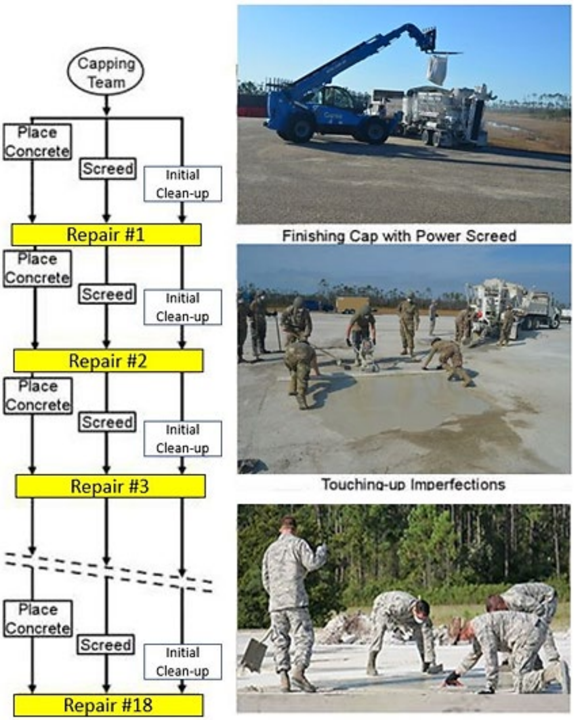


Table 4.15. Rapid-Setting Concrete Super Sack Consumption Rate for 10-in Cap.

L x W (in feet)	**8**	**8.5**	**9**	**9.5**	**10**	**10.5**	**11**	**11.5**	**12**	**12.5**	**13**	**13.5**	**14**	**14.5**	**15**
8	2.13	2.27	2.40	2.53	2.67	2.80	2.93	3.07	3.20	3.33	3.47	3.60	3.73	3.87	4.00
8.5	2.27	2.41	2.55	2.69	2.83	2.98	3.12	3.26	3.40	3.54	3.68	3.83	3.97	4.11	4.25
9	2.40	2.55	2.70	2.85	3.00	3.15	3.30	3.45	3.60	3.75	3.90	4.05	4.20	4.35	4.50
9.5	2.53	2.69	2.85	3.01	3.17	3.33	3.48	3.64	3.80	3.96	4.12	4.28	4.43	4.59	4.75
10	2.67	2.83	3.00	3.17	3.33	3.50	3.67	3.83	4.00	4.17	4.33	4.50	4.67	4.83	5.00
10.5	2.80	2.98	3.15	3.33	3.50	3.68	3.85	4.03	4.20	4.38	4.55	4.73	4.90	5.08	5.25
11	2.93	3.12	3.30	3.48	3.67	3.85	4.03	4.22	4.40	4.58	4.77	4.95	5.13	5.32	5.50
11.5	3.07	3.26	3.45	3.64	3.83	4.03	4.22	4.41	4.60	4.79	4.98	5.18	5.37	5.56	5.75
12	3.20	3.40	3.60	3.80	4.00	4.20	4.40	4.60	4.80	5.00	5.20	5.40	5.60	5.80	6.00
12.5	3.33	3.54	3.75	3.96	4.17	4.38	4.58	4.79	5.00	5.21	5.42	5.63	5.83	6.04	6.25
13	3.47	3.68	3.90	4.12	4.33	4.55	4.77	4.98	5.20	5.42	5.63	5.85	6.07	6.28	6.50
13.5	3.60	3.83	4.05	4.28	4.50	4.73	4.95	5.18	5.40	5.63	5.85	6.08	6.30	6.53	6.75
14	3.73	3.97	4.20	4.43	4.67	4.90	5.13	5.37	5.60	5.83	6.07	6.30	6.53	6.77	7.00
14.5	3.87	4.11	4.35	4.59	4.83	5.08	5.32	5.56	5.80	6.04	6.28	6.53	6.77	7.01	7.25
15	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25	7.50

4.7.6.1.3. Step 2: As the volumetric mixer is positioned at the repair location, the mixer operator ensures mixer controls are set to rapid-setting concrete and required admixtures are on-board (See **paragraph 5.2** on admixtures). The mixer operator directs the placement of the rapid-setting concrete by swinging the mixer chute and by having the dump truck operator pull forward or backward as needed. The mix has a very high slump (very fluid). The mix consistency is going to appear to be similar to a slurry (see **Figure 4.25**).

Note: Perform steps in **Attachment 5** if rapid-setting concrete sets-up on the auger and requires emergency swap out (wear proper personal protective equipment and be aware of pinch points around locking pins/plates near mixing well).

Note: Ensure overcuts are filled with quality material while the cap is placed. A strong FOD potential exists if slurry fills overcuts before being packed with rapid-setting concrete.

Note: When a repair crosses a runway crown, a joint needs to be established at the peak of the crown to achieve the proper slope on each side of the crown.

Note: The volumetric mixer requires periodic cleaning. Failure to periodic clean the mixer will result in operational failure.

4.7.6.1.4. Step 3: As rapid-setting concrete material and mixing water are consumed; the mixer operator should direct the repair team telehandler and water truck operators to tender the mixer.

4.7.6.1.5. Step 4: Three remaining personnel screed the repair. (**Figure 4.29**), ensuring the screed does not ride on excess material at the repair edges. They also perform initial clean-up around the repair.

Figure 4.29. Finishing Cap with Power Screed.

4.7.6.1.6. Step 5: The Debris Removal Crew thoroughly cleans around repairs after the initial set. Pay particular attention to slurry buildup at edges of the repair.

4.7.6.1.7. Step 6: Perform Repair Quality Criteria (RQC) checks as described in T.O. 35E2-5-1 and report results up the chain to the EOC.

4.7.6.1.8. Step 7: Repair Team Lead records completion time of each cap. **Note:** The rapid-setting concrete material has an initial set time of 45-min in fair weather and is capable of supporting a 2.5-ton vehicle for support teams operations. As the caps reach the initial set time, the Repair Team Lead directs one of the team members to move the repair zone marking cones up to the next uncured repair. This signals the support teams the area is available. Full cure time for aircraft traffic is 2-hr.

4.7.6.1.9. Step 8: Repair Team Lead informs the Repair Chief when the capping crew has finished their primary tasks so they may be assigned to other crews/ teams as necessary.

4.7.6.2. Placing a Cap Using a Transit Mixer in Place of Volumetric Mixer.

4.7.6.2.1. Step 1: Loading Transit Mixer. Add 50-gal of water to the drum (per super sack of rapid-setting concrete material) before adding any rapid-setting concrete material (see **Figure 4.27**). For example, if mixing three (3) super sacks of rapid-setting concrete material, then the total amount of water added to the drum at once is 150-gal. Once the water has been added to the drum, add a citric acid slurry into the drum (mix 3-lb of citric acid for each super sack of rapid-setting concrete material, (or 9-lb total for this scenario) in a 5-gal bucket with a couple gallons of water).

Note: Do not exceed a three (3) super sack mix, as the material is going to set-up too fast before you can place the mix.

Note: Unlike the simplified volumetric mixer, there is limited visibility of the mix in the transit mixer; therefore, the baseline described in the paragraph above should be followed until it becomes obvious the mix is too wet or too dry. When the baseline mix is too dry or too wet, the Repair Team Lead may direct more water and/or citric acid (slurry) be added to the mix. In colder climates less citric acid (slurry) may be required, or not needed at all. Conversely, where temperatures are excessively hot, or the drum is hot, slightly more water may be required. Additionally, 45-gal of water may be sufficient in high humidity. Experimentation may be required until you achieve the proper mix.

4.7.6.2.1.1. The telehandler operator raises the super sack 12- to 18-in above the transit mixer's hopper. The helper, on the catwalk platform at top of the transit mixer's drum, guides the telehandler operator to center super sack above the hopper. **Note:** Keeping the sack 12- to18-in above the fill point helps prevent material spillage and keeps dust to a minimum.

4.7.6.2.1.2. With the super sack suspended above the hopper, the helper cuts two (2) 10 to 12-in incisions in a crisscross pattern in the center of the bottom of the super sack allowing the rapid-setting concrete mix to readily flow into the drum (also known as charging). The telehandler operator then retrieves another super sack as needed to load in the transit mixer. Repeat until no more than three (3) super sacks of rapid-setting concrete material has been loaded (charged) into the drum.

4.7.6.2.2. Step 2: Mixing. The transit truck operator sets the charging drum speed to Medium, or 7- to 9-rpm. This speed is optimal to rapidly route all dry mix to the bottom of the drum and provide a more consistent/uniform mix. **Note:** The rapid-setting concrete materials is going to start reacting in approximately 3-min after loading. Using the 3-cy mix scenario as above, the operator has approximately 9-min to have all material discharged from the point material was added or the concrete mix is going to start setting up inside the transit mixer.

4.7.6.2.3. Step 3: Transporting Mix to Repair Site. After rapid-setting concrete material has been loaded and mixed, transport with drum turning between 2- and 3-rpm (agitating speed). Driving with drum at higher RPM poses risks to mixer operator and bystanders. **Note:** Recommend materials be mixed at or as close the repair site to prevent premature setup of material.

4.7.6.2.4. Step 4: Discharging Mix. After arriving at the repair site, the drum should be set at approximately 7-rpm until all material has been discharged. The mixture is extremely wet with a high slump causing the initial discharge to be mostly liquid, which has a tendency to splash about. Therefore, attempt to contain the mix in the repair and prevent surrounding surfaces from being splashed. **Note:** When all repair material has been discharged, the operator should abruptly flush the drum with water and quickly drive to a designated washout location so any remaining residue can be removed. While at the washout station, the operator should also pay particular attention to removing any materials that may have spilled on the exterior of the truck during drum charging operations. It is vital the entire transit truck and mixer be thoroughly cleaned. The drum capacity and efficiency is reduced if concrete layers are allowed to accumulate in the drum. Also, bearings and idlers may become seized, hinge points may not fold easily, and chute sections may become difficult to connect. After completing cleaning operations, the operator should inspect the vehicle for damage and make any necessary repairs.

4.7.6.3. Asphalt Cap. The asphalt cap is placed at a compacted thickness of 4-in with asphalt produced by the asphalt recyclers. The wet placed flowable-fill backfill method requires 30-min to achieve initial set before the asphalt is placed. **Table 4.16** identifies resources required for the asphalt cap. **Table 4.17** shows the expected consumption of asphalt when placing a 4-in thick cap. The table assumes excavation depth is 24-in. **Note:** Recycled asphalt from suitable asphalt pavements on the installation such as parking lots, runway/taxiway shoulders, roads, etc. may be used as substitute material.

Table 4.16. Asphalt Cap Resources.

Position	Suitable AFSCs	Vehicle/ Equipment/Tools	Vehicle and Equipment Subs
Lead	3E2X1	*** Lute, square shovel	
Operator	3E0X1, 3E0X2, 3E1X1, 3E2X1, 3E3X1, 3E4X3, 3E6X1	FEL W/multi-purpose bucket	*CTL with bucket W/multi-purpose bucket
Operator	3E0X1, 3E2X1	Vibratory roller	CTL with compactor
Operator	3E0X1, 3E2X1	Pneumatic roller	**Dump truck with bed loaded
Operator	3E2X1, 3E4X1, 3E4X3	Water truck	Any portable water source
*The track impressions left behind by the CTL roll out as long as the CTL drives directly on and off of the un-compacted repair and does not turn. **Testing has shown a vibratory roller alone is capable of achieving density on a smaller, confined asphalt repair area. *** ADR Tool Trailer			

Table 4.17. Asphalt Consumption Rate for 4-in Cap (Tons).

W x L (in feet)	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
8	1.58	1.68	1.78	1.88	1.98	2.08	2.18	2.28	2.38	2.48	2.58	2.68	2.78	2.88	2.98
8.5	1.68	1.79	1.89	2.00	2.10	2.21	2.31	2.42	2.52	2.63	2.73	2.84	2.95	3.05	3.16
9	1.78	1.89	2.00	2.12	2.23	2.34	2.45	2.56	2.67	2.78	2.90	3.01	3.12	3.23	3.34
9.5	1.88	2.00	2.12	2.23	2.35	2.47	2.59	2.70	2.82	2.94	3.06	3.17	3.29	3.41	3.53
10	1.98	2.10	2.23	2.35	2.48	2.60	2.72	2.85	2.97	3.09	3.22	3.34	3.47	3.59	3.71
10.5	2.08	2.21	2.34	2.47	2.60	2.73	2.86	2.99	3.12	3.25	3.38	3.51	3.64	3.77	3.90
11	2.18	2.31	2.45	2.59	2.72	2.86	2.99	3.13	3.27	3.40	3.54	3.68	3.81	3.95	4.08
11.5	2.28	2.42	2.56	2.70	2.85	2.99	3.13	3.27	3.42	3.56	3.70	3.84	3.98	4.13	4.27
12	2.38	2.52	2.67	2.82	2.97	3.12	3.27	3.42	3.56	3.71	3.86	4.01	4.16	4.31	4.46
12.5	2.48	2.63	2.78	2.94	3.09	3.25	3.40	3.56	3.71	3.87	4.02	4.18	4.33	4.49	4.64
13	2.57	2.73	2.90	3.06	3.22	3.38	3.54	3.70	3.86	4.02	4.18	4.34	4.50	4.67	4.83
13.5	2.67	2.84	3.01	3.17	3.34	3.51	3.68	3.84	4.01	4.18	4.34	4.51	4.68	4.84	5.01
14	2.77	2.95	3.12	3.29	3.47	3.64	3.81	3.98	4.16	4.33	4.50	4.68	4.85	5.02	5.20
14.5	2.87	3.05	3.23	3.41	3.59	3.77	3.95	4.13	4.31	4.49	4.67	4.84	5.02	5.20	5.38
15	2.97	3.16	3.34	3.53	3.71	3.90	4.08	4.27	4.46	4.64	4.83	5.01	5.20	5.38	5.57

4.7.6.3.1. Step 1: As soon as the first repair has been backfilled, the Repair Team Lead requests the Warehouse 1 Lead send the first load of asphalt. At this time, the warehouse dispatches a loaded dump truck to the repair team's location. The Repair Team Lead communicates with the Warehouse 1 Lead to schedule future asphalt deliveries.

4.7.6.3.2. Step 2: When asphalt arrives at the repair location, the asphalt temperature is checked with a temperature gun to ensure it is at least 280 degrees Fahrenheit (F). The driver is directed where to dump asphalt by the Asphalt Capping Crew Lead, preferably, directly into the repair, without backing into the repair itself.

4.7.6.3.3. Step 3: The FEL operator sets up on the leading edge of the repair (parallel to the MAOS centerline). The FEL operator roughly spreads the asphalt in the repair under the direction of a spotter (leaving more than 2-in of material above the existing pavement); the operator then screeds the un-compacted material leaving approximately 1.5-in, ± 0.25-in, of asphalt above surrounding pavement. This is best accomplished by placing a 1.5-in guide (wooden block, dowels, etc.) on the leading edge of surrounding pavement, gently placing the front of the fully dumped FEL bucket on the guide, and slowly pushing material forward. This can also be accomplished in reverse by placing the back edge of the open clamshell on the guide and pulling the material backwards, as show in (**Figure 4.30**).

Note: The FEL screeds the cap as long as the wheels of the loader are not placed on the un-compacted asphalt. If the repair is too wide for the loader, the asphalt is placed and rough leveled with the FEL and the finish screeding is done with a CTL with a bucket and/or by hand with lutes.

4.7.6.3.4. Step 4: During placement and screeding of the asphalt, other crew members assist with placing, cleaning, and preparing edges using lutes and/or square shovels.

Figure 4.30. Loader Screeding Asphalt Cap.

4.7.6.3.5. Step 5: The asphalt cap is rolled with a vibratory roller and a pneumatic roller parallel to the crown of the runway, assisted by other crew members who monitor asphalt temperature and cleans the edges. Conduct rolling as follows:

- (a) 0.5 pass (longitudinal with crown of runway) with vibratory roller, no vibration (asphalt temperature should be 160 degrees F or greater)

- (b) 2.5 passes (longitudinal with crown of runway) with vibratory roller, vibration on (asphalt temperature should be 160 degrees F or greater)

- (c) 2 passes (longitudinal with crown of runway) with pneumatic roller

- (d) 3 passes with vibratory roller, no vibration

- (e) Between passes, other crew members are going to trim any excess asphalt from edges with a square head shovel. This process is repeated until all caps are complete.

Note: One pass is equal to traveling across the repair and then returning to the original starting position in the same lane. Accomplish each pass for every lane across entire width of the repair, before moving on to the subsequent pass for the step being performed. Overlap the previous pass by approximately 12-in until the entire repair cap has received the pass. For example, if you are on step c of rolling process, the entire repair would receive pass one before moving on to pass two in the same lane.

Note: If check cracking is noted in the asphalt cap or if there is evidence of chipping of concrete edges, grooves, or joints, turn off vibration and add an additional half pass for step “a” and decrease step “b” to only two passes.

Note: If rolling in inclement weather with a tarp a spotter is required to ensure the proper pass overlap is maintained. The spotter also readjusts the tarp as it has a tendance to shift and wrinkle during the first few passes.

4.7.6.3.6. Step 6: Thoroughly clean around edges of repair to remove excess asphalt and debris.

4.7.6.3.7. Step 7: Perform RQC checks by conducting line-of-sight profile measurements as described in T.O. 35E2-5-1 and report results up the chain to the EOC.

4.7.6.3.8. Step 8: The natural cooling process takes approximately 2-hrs to bring asphalt temperature to 150 degrees F (depending on environmental conditions). To reduce cooling time, the water truck operator may flood the last five repairs with water. The repairs are repeatedly flooded whenever the asphalt begins to develop dry areas. The water truck operator is going to flood a repair briefly and move to the next repair alternating between repairs as required. The repairs are ready for vehicle traffic when asphalt temperature reaches 150 degrees F, or less. At this time, the cones identifying the repair zone are removed, which signals the support teams the work area is open. The repair is ready to receive aircraft traffic when the asphalt temperature falls to 125 degrees F or is no hotter than the surrounding pavement when it is 125 degrees F or hotter.

Note: In extreme weather conditions, water cooling might need to be used.

Note: Water cooling reduces the integrity of the asphalt caps.

Note: The pavement should be dry before pavement striping begins.

4.7.6.3.9. The Repair Team Lead informs the Repair Chief when personnel have finished their tasks so they may be reassigned to other crews as necessary.

4.8. Processes for Repairs Larger than 11-ft. When any side of a repair is wider than 11-ft, the large repair process described in this chapter is used. These procedures are predicated on equipment and tools in the ADR tool trailer (see **Table A2.2**). Paving lane widths should not exceed 11-ft to keep the repair manageable when using rapid-setting concrete, and because the screed in the tool trailer is only 12-ft long. The debris removal and upheaval marking processes are performed in the same manner as the small repair; the modifications to the remaining processes (e.g., pavement cutting, excavation, backfill, and capping) are explained below. After debris is removed and upheaval marked, perform the following processes.

4.8.1. Pavement Cutting. The pavement cutting process is modified when the repair is large enough to safely use four CTLs simultaneously to cut pavement around a single large repair (approximately 15-ft x 15-ft or larger). In other words, each CTL cuts one of the four repair sides (**Figure 4.31**).

4.8.2. Excavation. Breaking and excavating may take place simultaneously when the repair is approximately 15-ft x 15-ft or larger). **Figure 4.32** shows pavement breaking and excavating taking place simultaneously; the Debris Removal Crew is clearing excavated material away from the repair.

Figure 4.31. Pavement Cutting Four Sides of Large Repair Simultaneously.

Figure 4.32. Breaking and Excavating Large Repair Simultaneously.

4.8.3. Backfill. Backfill may be accomplished with flowable-fill and/or crushed stone material.

4.8.3.1. Flowable-fill. The Backfill Crew may add one individual (forklift operator) when repairs are 15-ft x 15-ft or larger for a total of six members (**Table 4.18**). If one of the RADR warehouses is located on semi-improved surfaces, its warehouse forklift may be transferred to the repair team, or when a capping team is not placing an asphalt cap its loader may be used with a fork attachment.

Perform dry flowable-fill using the "slash and splash" method described in **paragraph 4.7.5.1.3**.

Table 4.18. Recommended Flowable-fill Backfill Resources.

Position	Suitable AFSCs	Vehicle/Equipment/Tools
Lead	3E2X1	Utility knife and rake
Operator	3E2X1, 3E4X1, 3E4X3	Water truck, water flow meter
Operator	3E1X1, 3E6X1	Telehandler
Operator*	3E1X1, 3E6X1	Telehandler/FEL with forks
Laborer	Any	Utility knife and rake
Laborer	Any	Utility knife and rake
*Added personnel for large crater repair.		

4.8.3.2. Crushed Stone. See **Table 4.19** for crushed stone backfill resources. One laborer compacts the crushed stone backfill. In addition, the backfill crew may use a FEL, operated by the other laborer, to assist with leveling the crushed stone backfill.

Note: For crush-stone backfill procedures, refer to Technical Order (T.O.) 35E2-5-1, Crush-Stone Crater Repair and Line-of-Sight Profile Measurement for Rapid Runway Repair.

Note: When using the CTL's roller attachment for compacting crushed stone, lifts should be no thicker than 3-in. Lifts may be 4- to 6-in if an excavator with a compactor plate attachment is used.

Table 4.19. Recommended Crushed Stone Backfill Resources.

Position	Suitable AFSCs	Vehicle/Equipment/Tools
Lead	3E2X1	
Operator	3E2X1, 3E3X1, 3E4X1	CTL with compactor (possibly from Debris Removal Crew)
Operator	3E0X1, 3E0X2, 3E1X1, 3E2X1, 3E3X1, 3E4X3	FEL (from Capping Crew or Debris Removal Crew)
Laborer	Any	Hand tools
Laborer	Any	Plate compactor, hand tools

4.8.4. Capping.

4.8.4.1. Concrete Cap Repair. Two capping crew laborers prepare plastic forms after the paving lanes' sizes have been determined. Crew responsibilities are described in **Table 4.20**.

Table 4.20. Large Repair Concrete Capping Resources.

Position	Suitable AFSCs	Vehicle/Equipment/Tools
Operator	3E0X2, 3E2X1, 3E4X1	Dump truck with water skid; tows volumetric mixer
Operator	3E1X1, 3E6X1	Telehandler
Operator	3E2X1	Volumetric mixer
Operator	3E2X1, 3E4X1, 3E4X3	Water truck
Laborer	Any	Hand tools
Laborer	Any	Plastic forms, finishing tools
Laborer	Any	Plastic forms, finishing tools
Laborer	Any	Hand tools

4.8.4.1.1. Due to the nature of rapid setting concrete material, two laborers install plastic concrete forms to divide the repair into manageable sections. Repairs should be divided similar to those illustrated in **Figure 4.33**. The length of a formed section should be no greater than 15-ft.

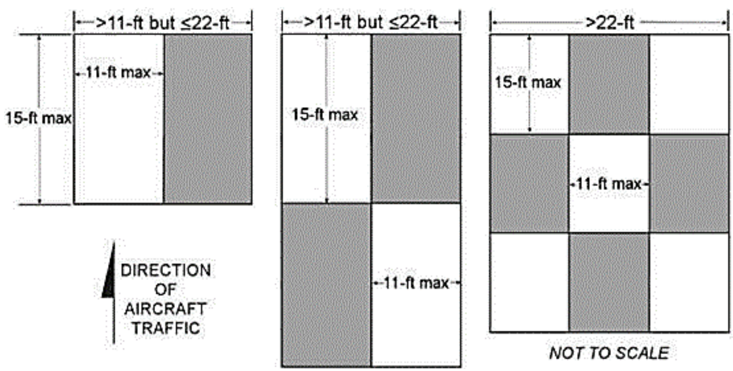
Note: When a repair crosses a crown, a joint is going to be established at the peak of the crown to achieve the proper slope on each side of the crown.

Note: Begin placing concrete on low end of each paving lane.

4.8.4.1.2. Place concrete in all shaded or unshaded sections of **Figure 4.33** first. After curing enough to walk on without leaving footprints, remove forms and place concrete in remaining sections.

4.8.4.1.3. Step 1: Determine size requirements for the plastic concrete forms, using **Figure 4.33** as recommendations.

Figure 4.33. Dividing Large Repairs for Multiple Pours with 12-ft Screed.



4.8.4.1.4. Step 2: Laborers begin cutting the plastic concrete forms to proper length using a reciprocating saw (**Figure 4.34**). Stack one 4-in and one 6-in tall forms using the stacking accessory shown in **Figure 4.35**.

Figure 4.34. Cutting Forms to Proper Length.

Figure 4.35. Stacking Pocket Accessory for Plastic Concrete Forms.

4.8.4.1.5. Step 3: Place stacked forms on top of the backfill after the 15-min initial set of flowable-fill. Hammer form pins through stacking pocket accessories as shown in **Figure 4.36**. **Note:** Form stake holes might need to be pre-drilled using the rotary hammer drill and bit (in the ADR tool trailer) to ensure hammering the form stakes does not cause any cracking/breaking of the flowable-fill material.

Figure 4.36. Installing Form Stakes.

4.8.4.1.6. Step 4: Use a string line to ensure forms are in plane with surrounding pavement (**Figure 4.37**). Temporarily fill empty spaces beneath forms with fill material to prevent concrete flowing beneath the forms (**Figure 4.37**).

4.8.4.1.7. Step 5: If temperature is 75 degrees F or higher, add citric acid, in anhydrous powder form, to the volumetric mixer's mix water tanks as identified in **Table 5.1** to increase the working time of the rapid-setting concrete (see **paragraph 5.2**). **Note:** Mix citric acid with a small amount of water until it becomes a slurry before adding to the water tanks.

Figure 4.37. Checking Form Height with String Line.

4.8.4.1.8. Step 6: Forms may need to be reused; therefore, spray concrete release agent on form faces and bottom grooves on backside of the forms. Concrete release agent is found in the ADR tool trailer. **Note:** Stop dump truck and volumetric mixer parallel to the MOS or taxiway centerline to prevent the need to back the volumetric mixer and/or clog traffic lanes.

4.8.4.1.9. Step 7: Fill the first formed section with rapid setting concrete (**Figure 4.38**). Finish the rapid setting concrete cap with a screed bar and hand tools (**Figure 4.39**). Only minimal finishing of the repair using hand tools is required.

4.8.4.1.10. Step 8: Fill the quadrant diagonally across from the quadrant just placed (labeled "Fill this quadrant next" in **Figure 4.39**) and minimally finish with screed and hand tools.

4.8.4.1.11. Step 9: Once the first two quadrants have cured enough to walk on without leaving footprints, remove plastic forms and attach expansion board material to the side of concrete slabs to create a joint between all four of the slabs.

Figure 4.38. Placing Rapid-Setting Concrete Cap with Volumetric Mixer.

Figure 4.39. First Quadrant Placed within Framework.

4.8.4.1.12. Step 10: Fill the remaining two quadrants with rapid-setting concrete and minimally finish with hand tools. **Note:** Perform steps in **Attachment 5** if rapid-setting concrete sets-up on the auger and requires emergency swap out (wear proper personal protective equipment and be aware of pinch points around locking pins/plates near mixing well).

4.8.4.2. Asphalt Cap Repair. Research, development, test, and evaluation for large crater repair with asphalt caps were still underway at the time of this writing. Procedures will be added to this TTP when finalized.

4.9. Crushed Stone Repair. When flowable-fill and/or rapid-setting concrete materials are depleted or in short supply, crushed-stone repairs may be required. Perform crushed-stone repairs in accordance with T.O. 35E2-5-1. Perform crushed stone crater repair steps with RADR crews as shown in **Table 4.21**.

Table 4.21. Crushed-Stone Repair Steps and Responsible Crews.

Crushed Stone Repair Steps	Responsible Crew
1. Initial Debris Removal	Debris Removal
2. Initial Upheaval Marking	Upheaval Marking
3. Breaking and Excavating	Pavement Breaking and Excavation
4. Intermediate Upheaval Check	Upheaval Marking
5. Debris Backfill	Backfill/Warehouse (dump trucks)
6. 18-in Vertical Edges	Backfill
7. Three 7-in Lifts	Backfill
8. Compact (preform after each lift)	Backfill
9. Grade 1-in above surface	Capping
10. Final Compaction	Capping
11. Check Repair Quality Criteria (RQC)	Upheaval Marking
12. Dynamic Cone Penetrometer (DCP)	Upheaval Marking
13. Sweep	FOD Team

4.10. FOD Cover Construction and Installation. Refer to T.O. 35E2-2-7, AM-2 Airfield Landing Mat and Accessories, when covering crushed-stone repairs for AM-2 matting or Fiber Reinforced Polymer (FRP) Panels FOD covers. For additional information, refer to Tri-Service Pavement Working Group Manual (TSPWG-PM) 3-270-01.3-270-07, *O&M: Airfield Damage Repair*, on the Whole Building Design Guide, DOD Supplemental Technical Documents at https://www.wbdg.org/taxonomy/term/59/all?field_status_value=1&field_series_value_selective=All&order=title&sort=desc.

Chapter 5

CRATER REPAIR IN EXTREME CONDITIONS

5.1. Rainy or Humid Conditions.

5.1.1. Rapid-Setting Concrete Cap Repair. Perform the rapid-setting concrete repairs from debris removal through the excavation process in the same manner as described in **Chapter 4**. **Note:** Lumber crayons (in place of paint or other marking media) in the ADR trailer should be used when marking upheaval to prevent the marks from being washed away by the wet conditions.

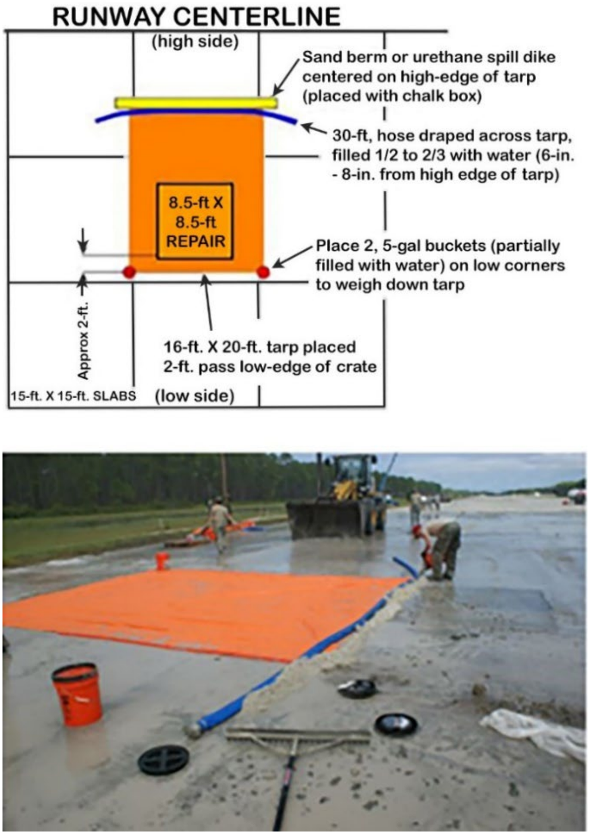
5.1.1.1. Water Removal. This can be accomplished by scooping as much water out of the repairs with the excavator bucket, using vacuum sweeper (rear hose), a shop vac, or water pump, as possible. If the bottom of the repair still has standing water, or the soil is saturated, place just enough dry flowable-fill material in the bottom of the repair to soak up the remaining moisture. Then, backfill the repairs in the same manner as described in **paragraph 4.7.5**. After the repairs has been backfilled, (i.e., 10-in below the surrounding pavement) perform the water mitigation procedures described in **paragraph 5.1.1.2**.

5.1.1.2. Water Mitigation. Water mitigation is the process of implementing materials and procedures to eliminate water intrusion during repair operations. The capabilities are delivered via the Inclement Weather Kit within the 4FWCR, Crater Repair Vehicles UTC. The capabilities include equipment, material, and procedures for grooved and un-grooved pavement.

5.1.1.2.1. Water Mitigation Crew. Water mitigation is a three-person crew re-tasked from the Spall Repair Crew.

5.1.1.2.2. Water Mitigation Employment. The Water Mitigation Crew employs the Inclement Weather Kit components (these three individuals are now tasked to keep water out of each repair during the backfill curing time, capping process, and capping curing time. (**Table A3.3**). Employ components for each repair as illustrated in **Figure 5.1**. See **Attachment 3** for a comprehensive list of RADR tools and components.

Figure 5.1. Water Mitigation Kit Components Employed.



Note: The Inclement Weather Kits have urethane spill dikes that may be used to robust the configuration illustrated in **Figure 5.1**.

Note: Use dry sand when using the chalk-box to place the sand berm. When dry sand is not available use alternate methods (i.e., water hose, urethane spill dikes, or wet sand (placed manually).

5.1.1.2.3. Water Mitigation Kit Pre-Employment. The Inclement Weather Kit requires preparatory actions prior to implementation. These actions are best accomplished pre-attack, however, are dependent on the ability to store and transport the materials.

5.1.1.2.3.1. Sand is utilized to fill in grooved pavement and act as a water dam. The kit includes a chalk box (an athletic dry line marker) which requires dry fine-grained sands. If used, sand needs to be sieved and bucketized (the buckets are included in the kit).

5.1.1.2.3.2. The fire hoses should be 1/2 to 2/3 filled with water and capped. These should not roll and need to be transported in a truck or on a trailer.

5.1.1.2.3.3. Each canopy requires four anchor bags to be filled with sand.

5.1.1.2.3.4. 5-gal buckets need to be partially filled with water or sand to act as tarp anchors.

5.1.1.2.4. Implementing Water Mitigation Components.

5.1.1.2.4.1. 2- to 4-cy of sand is placed directly adjacent to the repair zone. More sand is required if the actions above were not accomplished pre-attack and are performed in real-time at the place of employment.

5.1.1.2.4.2. A berm is created 10-ft from the edge of the repair on the high side of the pavement structure. If the pavement is non-grooved the urethane spill dikes may be utilized, or sand can be placed by shovel or chalk box. If the pavement is grooved, sand is utilized to fill in the grooves and create the berm. The berm should be 2- to 3-ft wider than then repair.

5.1.1.2.4.3. The tarp is then unfurled on the high side of the repair, but not over the repair. The leading edge of the tarp should be close to the berm. The water-filled fire hose is then placed atop the tarp, acting as an additional berm and tarp anchor. The fire hose can be partially arced to deflect the surface water away from the repair.

5.1.1.2.4.4. Prior to unfurling the tarp across the repair, as much water is removed by dipping, vacuuming, or blowing. On larger repairs, a cone may be place in the repair to keep the tarp from sagging.

5.1.1.2.4.5. Once the tarp is completely unfurled across the repair, a 5-gal bucket is placed on each corner to act as anchors.

5.1.1.2.4.6. In extreme conditions, the canopies can be placed over each repair. The canopies are removed during capping operations. They are not needed again for asphalt repairs but may be reinstalled (at the lowest height possible) to keep rainwater from inhibiting the initial concrete curing.

5.1.1.3. Capping the Repair. The volumetric mixer is going to be loaded under cover and then covered during transport to prevent rain from entering the hopper. Travel time from the covered area to the airfield is going to more than likely require the spare volumetric mixer to be put into a rotational delivery of capping material along with the primary mixer to reduce time between deliveries. Perform the following steps to cap the repair in wet weather:

Note: The inclement weather bag break is still in research and development. Expect fielding in FY25.

Note: Warehouse operations should be factored in when determining covered tendering locations. Rapid-setting concrete is going to be delivered to the covered tendering location while flowable-fill is going to continue to be hauled to the repair area. Upon designating the covered tendering location updated warehouse delivery procedures should be developed.

5.1.1.3.1. Step 1: While under cover, load the volumetric mixer(s) with rapid-setting material, remove spike and cover the hopper with the hardtop tarp. In a light rain, the spikes can be left in and utilize the soft, canopy tarp.

Note: Water tendering of the volumetric mixer(s) can happen during dry tendering under cover or at the repair location.

Note: Be cognizant of washout water, ensure no excess water gets into the repair(s). Do not wash out on the high side of the repair(s) (not to overwhelm the water mitigation components).

Note: Recommend drier mix during placement.

5.1.1.3.2. Step 2: When the volumetric mixer arrives at repair, the Water Mitigation Crew use blowers from the Inclement Weather Kit to remove water from the tarp and then remove the tarp by folding the tarp from the low side of the repair towards the high side without disturbing the sand berm, the urethane spill dikes, and/or water hose.

5.1.1.3.3. Step 3: Use blowers to blow any water from the repair before placing capping material.

5.1.1.3.4. Step 4: Begin placing capping material in the repair as described in **Chapter 4**. When rapid-setting concrete material has been exhausted, the volumetric mixer is returned to the covered area to be tendered. The second loaded volumetric mixer should be at the repair site when the first volumetric mixer departs to the covered area for tendering. Continue placing capping material from the second volumetric mixer for the remaining repairs and repeat this process until all repairs have been capped. **Note:** Don't start capping process unless you know you can complete the repair or wait for the other volumetric mixer to return from tendering before starting.

5.1.1.3.5. Step 5: After screeding the repair, recover the repair. The water mitigation remains in place during the entire initial curing period. Once all the repairs are capped, the Water Mitigation Crew Spall Repair Crew begins spall repair process with help from other repair crews.

5.1.2. Asphalt Cap Repair. Perform the asphalt repairs, from debris removal through the excavation process, in the same manner as described for rapid set in **Chapter 4**. **Note:** Lumber crayons (in place of paint or other marking media) in the ADR trailer should be used when marking upheaval to prevent the marks from being washed away by the wet conditions.

5.1.3. Capping the Repair.

5.1.3.1. Step 1: After the 30-min initial backfill cure time, the Water Mitigation Crew use blowers from the Inclement Weather Kit to remove water from the tarp and then remove the tarp by folding the tarp from the low side of the repair towards the high side without disturbing the sand berm, the urethane spill dikes, and/or water hose.

5.1.3.2. Step 2: Use blowers to blow any water from the repair before placing asphalt capping material.

5.2. Admixtures. Admixtures might be required to be added to the rapid-setting concrete and/or the flowable-fill materials depending on temperatures.

5.2.1. Heat Above 74 Degrees F. In warmer climates, an additive with the ability to extend set time of rapid-setting concrete is required. If the rapid-setting concrete sets too quickly, the concrete could cause malfunction of the volumetric concrete mixer or not allow sufficient placement time for the repair. This same additive is not required for flowable-fill but can be used to slow flowable-fill set time in case of an emergency. The additive used for slowing set time is citric acid (anhydrous) in powder form. The material is typically purchased in 50-lb bags but is stored in 6-gal buckets within the 4FWCM UTC with the rapid-setting concrete.

5.2.1.1. The dosage rates are shown in **Table 5.1**. The citric acid should be added to an empty 5-gal bucket along with 1- to 2-gal of water and stirred briefly before adding to the volumetric mixer water tanks.

Warning: *Do not* overdose citric acid by more than 20% by volume or the citric is going to turn into an accelerator (causing the rapid-setting concrete to set faster).

Table 5.1. Citric Acid Dosage for Rapid-Setting Concrete.

Ambient Temperature (°F)	Citric Acid Dosage (lbs. per 50-gal of mix water)
Below 75	0
75-80	1
80-85	2
85 and above	3

5.2.1.2. To reduce logistics of measuring citric acid during repairs, citric acid is packaged as shown in **Figure 5.2**. A plastic scoop that holds approximately 1-lb of citric acid is stored inside the bucket so the citric acid can be measured easily before adding to the mix water tanks. Instructions are displayed on the outside of the bucket as a quick reference.

Note: Recommend filling the volumetric mixer mixing water tanks in 50-gal increments for easier citric acid calculations.

Note: If citric acid is used, the volumetric mixer mixing water system should be washed out after use.

Figure 5.2. Citric Acid Bucket Kit.

5.2.1.3. In hot climates, draw water early in the morning and if not used immediately, place water vessel under cover to shield from the sun. If necessary, ice may be added to the water to cool below 70 degrees F.

5.2.2. Cold Weather Below 50 Degrees F. In colder climates, an additive with the ability to accelerate set time of rapid-setting concrete may be required. If the rapid-setting concrete sets too slowly, the concrete may not cure within the 2-hr requirement to support aircraft traffic. Use aluminum sulfate additive to meet the curing time. This additive is not in the crater repair UTC and should be sourced, purchased, and stocked in locations where climates fall below 50 degrees F.

5.2.2.1. The aluminum sulfate in powder form should be added to approximately 5-gal of water to form slurry before being added to the volumetric mixer water tanks.

5.2.2.2. **Table 5.2** displays the recommended dosage rates for aluminum sulfate per super sack of dry concrete material based on the ambient temperature. If the ambient temperature is between the temperatures listed, the lower temperature should be used to maintain conservatism. Rapid-setting concrete materials are not recommended for use below 15 degrees F.

Table 5.2. Recommended Dosage Rates for Aluminum Sulfate.

Ambient Temperature (°F)	Dosage Rate (lb./100-gal water)
50 and above	None
40 to 49	22 to 17.5
20 to 39	43 to 34.5
10 to 19	85 to 68

5.2.2.3. Water vessels should be stored inside to keep the water from freezing until use. The Inclement Weather Kit in the 4FWCR UTC has an inline water heater that should be used to heat water while filling all the water vessels for cold weather repairs.

5.3. Nighttime Operations. Six light carts are included with each 4FWCR UTC.

5.4. Camouflet Repair. EOD should investigate and mitigate any UXO within the camouflet.

5.4.1. If EOD confirms there is no munition, the camouflet is repaired by cutting the pavement at the extents of the cavity and repairing as prescribed above.

5.4.2. If EOD cannot confirm an explosive hazard, they may detonate the camouflet, in which case it is repaired as a normal crater.

5.4.3. If EOD confirms there is no explosive hazards (i.e., the munition is very deep or proposed), the cavity can be filled with flowable fill.

Note: Research, development, testing, and evaluation for improved camouflet repair procedures are underway; results to be added to this publication when finalized.

Chapter 6

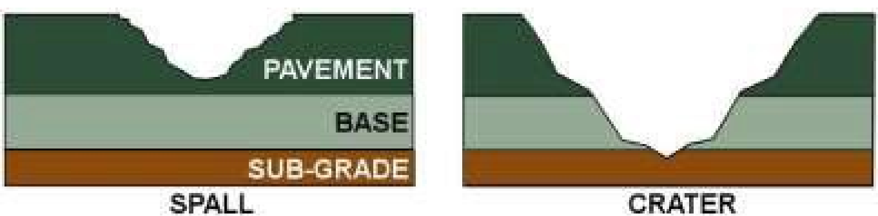
EXPEDIENT SPALL REPAIR

6.1. Introduction. Spalls are defined as pavement damage that does not penetrate the full pavement thickness to the underlying soil layers, is not larger than 5-ft in diameter, or has no upheaval in surrounding pavements (**Figure 6.1**). Spalls may be created as part of the original attack, from the Rapid Explosive Hazard Mitigation (REHM) process, or supplemental damage from the repair process**.**

6.1.1 During RDR operations, spalls are repaired utilizing expedient methods, different than performing full-depth spall repair. These expedient repairs are capable to support 500 passes of all mission aircraft.

6.1.2. The spall repair capabilities are delivered via the 4FWSR, Spall Repair UTC. This UTC is considered a supporting UTC to the 4FWCR, Crater Repair Vehicles. There is no direct correlation between the capabilities; however, the most common employment method is one 4FWSR per one 4FWCR.

Figure 6.1. Spall and Crater Profiles.



6.2. Resources. Table 6.1 identifies the Expedient Spall Repair resources (UTC 4FWSR) and required crew personnel. Supporting UTCs

Table 6.1. Spall Crew Required Resources per Small Capability.

Position	Suitable AFSCs	Vehicle/Equipment /Tools	Vehicle and Equipment Subs
Crew Lead	3E1X1, 3E2X1	6-pax pickup truck w/utility trailer	1-ton stake bed truck or equivalent
Laborer	3E1X1, 3E3X1, 3E2X1	N/A	N/A
Laborer	3E1X1, 3E3X1, 3E2X1	N/A	N/A

6.2.1. Crew Size Recommendations. The scope of spall damage will likely govern crew size. Experimentation has shown a 4-person spall repair crew is the optimal crew size for spall repair operations. However, there are instances when a 3-person and/or 5-person crew may be more appropriate; fatigue plays a large roll when determining crew sizes. **Note:** Crew performance may differ from the following examples due to personnel experience, personnel skills, equipment condition, etc.

6.2.1.1. The 3-person crew can repair an average of 40 spalls per hour. Therefore, this crew can theoretically repair up to 164 spalls within the 6.5-hour recovery time if they had enough repair material; however, this would only be the case in ideal conditions without factoring in personnel fatigue and cure time.

6.2.1.2. A 4-person crew can repair an average of 40 spalls per hour. Therefore, it appears this crew could repair up to 202 spalls within the 6.5-hr recovery time if they had enough repair material; however, this would only be the case in ideal conditions without factoring in personnel fatigue and cure time.

6.2.1.3. A 5-person crew can repair an average of 50 spalls per hour. Therefore, it appears this crew could repair up to 277 spalls within the 6.5-hr recovery time if they had enough repair material; however, this would only be the case in ideal conditions without factoring in personnel fatigue and cure time.

6.2.1.4. Factoring in fatigue, environmental conditions (e.g., extreme heat), and threat conditions requiring personal protective gear (e.g., battle rattle, chemical ensembles), it is a given the crews' production rate is going to decrease over time. In addition, cure time for the last spall repair before aircraft trafficking is 2-hr.

6.2.1.5. As mentioned earlier, a medium capability is going to have a total of nine spall repair personnel. This provides the flexibility of having multiple crew sizes to meet the scope of damage. The Repair Chief may choose to have three 3-person crews; two 4-person crews; one 4-person crew and one 5-person crew; one 3-person crew and one 4-person crew; one 3-person crew and one 5-person crew; or only one of either of the three crews. If the spall repair personnel are left over after selecting crew sizes, the extra people may be used for resupplying the spall repair crews (see **paragraph 6.4**).

6.2.1.6. The Repair Chief has even more flexibility with Large (15 spall repair personnel) and Very Large Capabilities (21 spall repair personnel). The possible crew sizes and numbers increase exponentially. **Table 6.2** provides a simplified example of determining numbers of spall repair crews related to workload. For example: if there were 45 spalls and the installation had a medium capability, assemble one 4-person crew and one 5-person crew.

Table 6.2. Examples of Spall Repair Crews to Assemble for Workload.

Minimum Crew Configurations to Complete Spall Repairs within 6.5 hrs*												
Work Load (no. of Spalls)	Very Large Capability (21 persons)			Large Capability (15 persons)			Medium Capability (9 persons)			Small Capability (3 persons)		
	Crew Sizes			Crew Sizes			Crew Sizes			Crew Sizes		
	3	4	5	3	4	5	3	4	5	3	4	5
150	1			1			1			1		
200		1			1			1		1		
250			1			1			1			
300	2			2			2					
350	1	1		1	1		1	1				
400		2			2			2				
450		1	1		1	1		1	1			
500	2	1		2	1		3					
550			2			2	3					
600		3			3		3					
650		2	1		2	1						
700	1		2	1		2						
750		1	2		1	2						
800			3	2	1	1						
850	2		2			3						
900	1	1	2			3						
950		2	2			3						

Minimum Crew Configurations to Complete Spall Repairs within 6.5 hrs*												
Work Load (no. of Spalls)	Very Large Capability (21 persons)			Large Capability (15 persons)			Medium Capability (9 persons)			Small Capability (3 persons)		
	Crew Sizes			Crew Sizes			Crew Sizes			Crew Sizes		
	3	4	5	3	4	5	3	4	5	3	4	5
1000		5				3						
1050	2	1	2									
1100			4									
1150	2		3									
1200	2		3									
1250	2		3									
1300	2		3									
1350	2		3									
1400	2		3									

6.2.2. Equipment, Materials and Tools. The 4FWSR UTC inventory is found in **Table 6.3**. The 4FWSR UTC is a supporting UTC to 4FWCR.

Table 6.3. Expedient Spall Repair Equipment Inventory (4FWSR).

Item	Qty	Item	Qty
3-lb Sledge Hammer	1	Knee Pads (Jell Filled Neoprene)	3
9-lb Sledge Hammer	1	Lamp, Head	3
Bags, Trash, 50-Gal (25-count)	1	Light, Wobble	2
Bar, Digging/Pry	2	Mask, Dust Box (20-count)	1

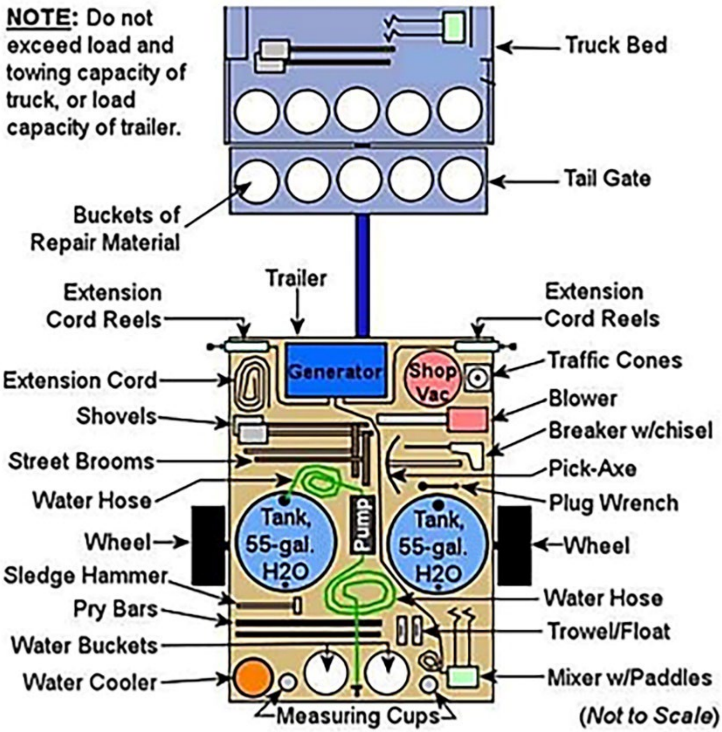
Item	Qty	Item	Qty
Belt, Reflective, Safety	3	Mixer, Dual Paddle	2
Blades, Utility Knife, Package	4	Nozzle, Hose	2
Blower, handheld	2	Paddle Set, Mixer	3
Broom, Finishing, Concrete, 30-in	2	Pick Axe	1
Broom, Hand, Concrete	2	Plastic Sheeting, Roll (20-ft x100-ft)	1
Broom, Push	2	Pliers	2
Bucket, 5-gal, w/lid	2	Plugs, Ear, Box (100-count)	1
Cable, 12.5-ft Ext. with 2-pin connector	2	Pump, Water, 12-v, On-demand	2
Cable, w/battery clips, 2-pin	2	Quad-con Containers	3
Cable, w/power-port connector, 2-pin	2	Repair Material, Buckets	192
Connector, brass, double male	4	Rotary Hammer Drill w/Chisel Bit	1
Cooler, Water, 5-gal	1	Shield, Face	3
Cord, Extension, 50-ft	2	Shop Towels (box)	2
Cord, Extension, Spring Return, 50-ft	2	Shovel, Round	2
Cup, Measuring, 1-qt	4	Shovel, Square	4
Cup, Measuring, 2-qt	4	Spout, Flex, 16-in	2
Cup, Measuring, 4-qt	4	Tin Snips	2
Drum, Poly, 55-gal	2	Tool, Bucket Lid Opening	2
First Aid Kit	1	Traffic Cones, White, 18-in	20

Item	Qty	Item	Qty
Float, Hand, Magnesium, 16-in	4	Trouble/Extension Light, 25-ft	2
Fuel, Cans 5-gal	2	Trowel, Finishing, Steel, 14-in	2
Generator, diesel	1	Utility Knife	4
Glasses, Safety	3	Vacuum, Shop, wet & dry	1
Glow Sticks, Box (10-count)	3	Wrench, drum bung	2
Hose, Water, 25-ft	4		

6.2.3. Vehicle Configuration Recommendations. The vehicle configuration should be capable of carrying all consumables and equipment necessary to complete repairs for assigned spall field(s) without having to restock. However, spall repair vehicles used for airfield recovery are shop and/or Base Expeditionary Airfield Resources (BEAR) vehicles and there is no way of knowing what vehicles should be available. When work is expected during darkness, ensure wobble lights, head-mounted lamps, and trouble-lights are loaded on vehicles. Whatever configuration is used, the vehicle load and towing capacities should not be exceeded. Recommended vehicle configurations follow:

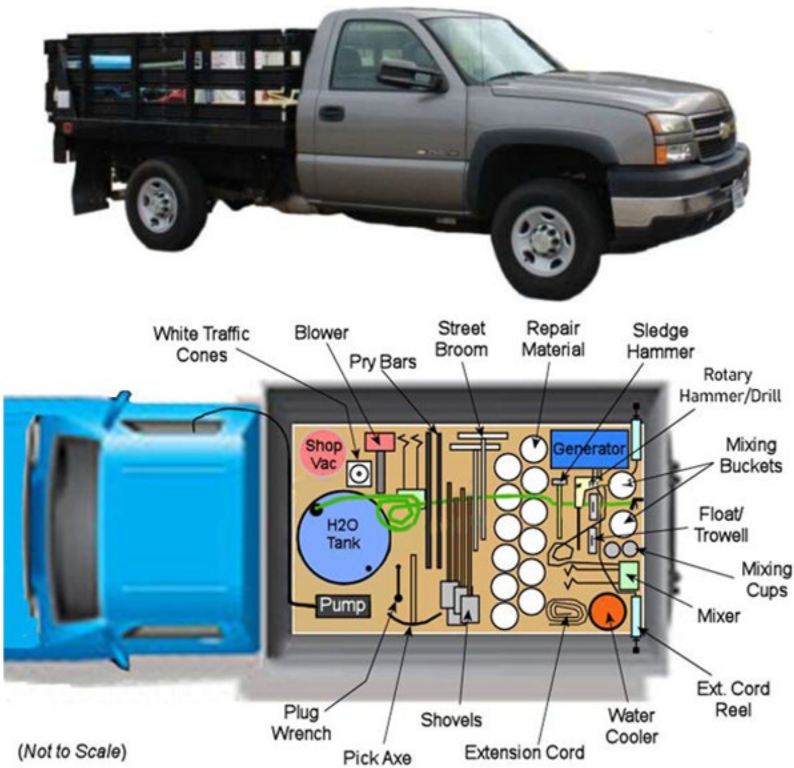
6.2.3.1. Six-Pax (3/4-ton) Pickup with Utility Trailer. The pick-up with trailer configuration is illustrated in **Figure 6.2**. The trailer eliminates the need to unload mixing material/equipment at each stop; thereby, increasing speed of repairs and lessening fatigue of crew members. Without the trailer, this vehicle does not have enough capacity or cargo space to be useful for the spall repair mission. The trailer provides load capacity to complete large numbers of repairs without continuously restocking consumables (e.g., water and repair material). The truck requires an appropriate hitch for the trailer connection. **Figure 6.2** also provides stocking recommendation for the truck and trailer.

Figure 6.2. Recommended Spall Repair Pickup and Trailer Stocking Configuration.



6.2.3.2. 1-Ton Stake-bed Truck. The 1-ton stake-bed truck configuration is illustrated in **Figure 6.3**. If available, an electric lift-gate would ease the process by keeping the lift-gate 12- to 18-in above the pavement surface and use it as the mixing station surface. This eliminates the need to unload and load the mixing buckets, cups, and mixer at every stop. Removing the side rails may improve access to cargo. **Figure 6.3** also illustrates the recommended load configuration for the equipment and materials.

Figure 6.3. One-ton Stake-bed Truck and Recommended Load Configuration.



6.2.4. Repair Material. The spall repair materials in the UTC are selected from the Approved Spall Repair Products List located on the Tri-Service Transportation website at: **https://transportation.erdc.dren.mil/cacsites/TriService/pavement_repair.aspx**. The kit has material to repair approximately 300 spalls with an average size of 16-in in diameter and 2-in deep. When replenishing the kit, ensure only items on the approved list are ordered. Follow manufacturers' instructions for mixing and placing material. **Note:** See **Attachment 2** for a listing of other useful resources and links.

6.2.5. Water Supply Set Up. Arrange water supply assets as shown in **Figure 6.4** and listed in **Table 6.4**. Use a spare 12-volt battery (or generator's battery) and item 8 when setting up water system for the 6-pax and trailer configuration. Use item 7 when a power-port is available inside the cab; otherwise, use item 8 to connect the pump to the vehicle battery for the 1-ton stake bed truck configuration. The on-demand pump starts and stops automatically as the spray nozzle is opened and closed.

Figure 6.4. Water Supply Set Up.

Table 6.4. Water Supply Assets.

Item #	Description
1	Drum, poly, open head, 55-gal
2	Wrench, drum bung, 10-in lg
3	Hose, garden, 50-ft
4	Connector, brass, double male
5	Pump, 12-v, on-demand
6	Cable, 12.5-ft power ext., 2-pin
7	Adapter, power port, 2-pin
8	Adapter, battery clips, 2-pin
9	Nozzle, garden hose
10	Bucket, 5-gal w/lids

6.3. Repair Process. After vehicles/trailers have been loaded, perform expedient spall repairs as follows and listed in **Table 6.5**.

6.3.1. Step 1: Identify Repair Zone. The repair zone is the area of a spall field where repairs occur each time the vehicle stops. The recommended repair zone is 50-ft wide by 25-ft long (**Figure 6.5**). If the MAOS is wider than 50-ft, consider making additional passes with the same crew or additional crews.

6.3.1.1. When using one crew for a full width runway, first repair spalls down the center of the MOS at the width of the aircraft wheel path so they cure within the established deadline. Then, while going in the opposite direction, repair spalls down one side of the runway. Finally, reverse direction and complete the spalls on the opposite/final side of the runway. Otherwise, three crews may work to cover the full MOS width simultaneously.

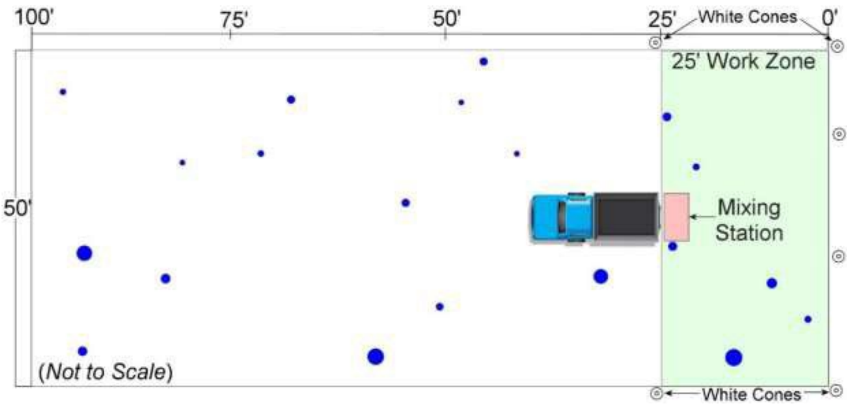
6.3.1.2. Mark spall fields with white cones (located within the spall repair kit) to prevent vehicle traffic over repairs while curing. Repairs may be trafficked by vehicles after 45-min of curing time and aircraft after 2-hr of curing time.

Table 6.5. Three-Person Crew Process at Each Repair Zone.

Task	Minutes						
	2	4	6	8	10	12	14
1. Sweep debris 12-18-in from spalls							
2. Clean debris, dust, & moisture from spalls							
3. Unload/flip buckets							
4. Remove repair material bucket lids							
5. Fill 2 empty buckets with water for mixing & rinsing							
6. Dry mix repair material							
7. Add water during wet mixing							
8. Wet mix repair material							
9. Fill spalls with wet mix							
10. Load material and equipment on truck							

Member 1: **Member 2:** **Member 3:**

Figure 6.5. Repair Zone.



6.3.2. Step 2: Repair Preparation. To help ensure a suitable bond, the spall should be cleaned and standing water removed before placing repair material in the spall.

6.3.2.1. Using a push broom, one crew member sweeps large debris at least 1-ft around the entire perimeter of the spall.

6.3.2.2. Another crew member starts the generator and using the electric blower or shop vacuum completely removes large chunks of debris, dust, and standing water from the spall. Keep the 1-ft clean space around the spall. If loose pieces of debris cannot be removed by hand, remove them with a pickaxe, pry bar, sledgehammer, or impact hammer/breaker. **Figure 6.6** shows a properly prepped spall ready for repair. If upheaval is apparent, or damage has penetrated completely through the pavement to underlying soil structures (**Figure 6.6**), mark the spall with double white cones, inform the Repair Team Lead of the situation and move on to the next repair.

Figure 6.6. Spall Prepared for Expeditious Repair.

6.3.3. Step 3: Repair Material Preparation. A third crew member estimates amount of spall repair materials required to perform repairs in the repair zone and unloads this amount from the truck and places buckets at the mixing station. **Note:** One bucket on average can repair two 16-in diameter spalls that are 2-in deep.

6.3.3.1. The repair material consolidates during storage; therefore, tumble the buckets end-over-end six to eight times in order to break apart the solid chunks of condensed dry mix into smaller, more manageable pieces when dry mixing with the power mixer. **Note:** This step may be conducted during pre-attack actions to save time during recovery.

6.3.3.2. By this time the first member should be finished clearing debris from the spalls. He/she removes bucket lids and fills two 5-gal buckets with water from the water tank and places them at the mixing location. **Note:** The water buckets require constant filling for mixing as well as for cleaning the mixer paddles and floats/trowels to prevent repair material buildup.

6.3.3.3. Plug the power mixer (**Figure 6.7**) into the generator and plunge the paddles into the dry-mix with a continuous and rapid rotation of the mixer head until all material is disturbed and has a "fluffy" appearance (approximately 30-sec). **Note:** This step may be conducted during pre-attack actions to save time during recovery.

Figure 6.7. Power Mixer.

6.3.3.4. Once material has been thoroughly dry-mixed and spalls within the repair zone have been prepared (i.e., debris, dust, and water removed) follow the manufacturers recommended mixing instructions (**Figure 6.8**). **Note:** Rinse paddles in water bucket after mixing each bucket.

Figure 6.8. Adding Water While Mixing Repair Material.

Note: All rapid setting concretes react differently in various environmental/ climatic conditions. Therefore, the mixer operator should pay particular attention to how quickly the material appears to be setting. The mixer operator determines how long each mix is mixed and when the mix is considered unsuitable for repairs and should be discarded.

6.3.4. Step 4: Placing Repair Material. Once a uniform wet-mix has been achieved, the member finished cleaning the spalls now quickly carries and places wet mixed material in the clean spalls.

6.3.4.1. Depending upon the type of repair material and environmental conditions, it may readily flow (**Figure 6.9**) into all exposed voids/cracks until reaching the surrounding pavement surface, or may require floating and/or troweling (**Figure 6.10**) to ensure material fills all exposed voids/cracks and to achieve a smooth and flush finish. Avoid feathering material beyond the perimeter of the repair; material on the parent surface may become a FOD potential. **Note:** When troweling is required, do not spend excessive time attempting to achieve a perfectly smooth and flush surface.

Figure 6.9. Self-Leveling Mix.

Figure 6.10. Mix Requiring Finish Work.

6.3.4.2. Slightly overfill the repair, not greater than 0.25-in (**Figure 6.11**), to compensate for settlement during hydration. **Note:** A magnesium float or steel trowel should be readily available in the event of overspill or when the material sets up too quickly leaving a rough surface texture that may cause aircraft tire damage if not smoothed (**Figure 6.12**). Excess material should quickly be removed before it sets and placed back in the bucket to prevent a FOD potential.

Figure 6.11. Correctly Filled Repair.

Figure 6.12. Smoothing Repair with Trowel.

6.3.5. Transport to Next Repair Zone. Once repairs in the repair zone have been accomplished, all tools, materials and trash are placed in the transport vehicle and the team moves to the next 25-ft x 50-ft repair zone (see **Figure 6.5**).

6.4. Restocking Vehicle(s) with Consumables. Vehicle configuration is going to determine how often consumables (e.g., water and repair material) are restocked. When comparing **Figure 6.2** and **Figure 6.3** it is readily apparent more consumables can be loaded on the truck and utility trailer configuration; therefore, this configuration does not require restocking as often as the 1-ton vehicle configuration. Likewise, 1.5- and 2-ton cargo trucks require less restocking than the 1-ton truck. **Note:** The more spall repair crews, the more personnel required to help keep the crews supplied with consumables. Therefore, any spall repair personnel not tasked may help the warehouse keep the crews stocked.

6.4.1. Using the spall baseline (16-in diameter by 2-in deep), the amount of repair material and water (about 1-gal of water per bucket) the vehicle can carry, and the number of spalls a crew can repair per-hour, it can be estimated how often each vehicle configuration is going to need to be restocked prior to resources being depleted. See **Table 6.6** for restocking requirements.

Table 6.6. Spall Repair Consumables Restocking Requirements (min).

Vehicle Configuration	Restock Repair Material Every:	Replenish Water Every:
1-Ton Stake Bed Truck	20-min	1-hr, 20-min
6-Pax Truck w/trailer	30-min	2-hr, 40-min
1.5-Ton Stake Bed Truck	60-min	2-hr, 40-min
2-Ton Stake Bed Truck	1-hr, 20-min	2-hr, 40-min

6.4.1.1. Six-Pax Truck and Utility Trailer Configuration. A significant advantage with this configuration is 110-gal (approximately 8-lb per gal) of water can be stocked on the trailer along with tools and equipment and the half-ton truck's cargo capacity can be reserved for buckets of repair material, which equates to 20 buckets (approximately 50-lb per bucket). This configuration can repair approximately 20 spalls before repair material runs out and approximately 110 spalls before the water runs out. It takes approximately 30-min for a 3-person crew to repair 20 spalls. Therefore, the warehouse team is going to restock the truck with repair material every 30-min and the water should be restocked every 2-hr and 40-min with a water truck from the backfill or capping crew. Restocking intervals are adjusted as fatigue affects production rates.

6.4.1.2. 1-Ton Stake Bed Truck. A significant disadvantage with this configuration is the load capacity of the truck limits the water load to only 55-gal and the repair material to 15 buckets. This configuration requires restocking repair material approximately every 20-min and the water tank refilled approximately every 80-min initially.

6.4.1.3. 1.5-Ton Stake Bed Truck. This vehicle increases the time between restocking requirements compared to the 1-ton truck. Two 55-gal water tanks can be loaded on this truck along with 36 buckets of repair material. This configuration requires restocking repair material approximately every 60-min and the water tank refilled approximately every 160-min.

6.4.1.4. 2-Ton Stake Bed Truck. This vehicle may be loaded with 110-gal of water and 56 buckets of repair material. This configuration provides the greatest intervals between restocking. Water should be restocked every 160-min and repair material is restocked every 80-min.

6.5. Asphalt Spall Repairs. Perform expedient asphalt spall repairs in the same manner as described for expedient concrete spall repairs in **paragraph 6.3.2**. These repairs are not likely to last 100 passes; therefore, they should be constantly monitored and should be repaired immediately as soon as signs of failure start to appear. Replace the expedient repairs with a permanent repair as soon as repair crews are granted time on the MAOS. **Note:** The Repair Team should attempt to roll the asphalt upheaval if it appears it can be rolled into place. If unable to roll the upheaval back in place, remove upheaval with a jackhammer, saw, or CTL with a planer attachment (all available on the ADR tool trailer). After airfield recovery, replace the repair with an asphalt patch when time permits.

6.6. Spall Repair in Rain. A roll of plastic sheeting is included in the Spall Repair UTC. Load this roll on the vehicle when loading equipment and material. During pre-attack actions, fill several buckets with sand to use for damming around repairs to keep rain from flowing in repairs. Load buckets of sand on the vehicle when rain is expected during repair operations.

6.6.1. Follow procedures from **paragraphs 6.3.2.1** thru **6.3.2.4**.

6.6.2. If pavement is sloped towards repairs causing water intrusion, use sand to dam around the high side of the repairs to keep water out.

6.6.3. With a wet-mixed bucket of repair material ready, vacuum or blow standing water out of the spall and immediately pour repair material in the spall.

6.6.4. As material is placed in the spall, cut a piece of plastic large enough to overlap the surrounding parent pavement by at least 4-in. Immediately after repair material is placed, cover the repair with plastic and anchor plastic sheet edges with debris to resist wind from blowing plastic off the repair. **Note:** This action slows repair set time.

6.6.5. After all spalls have been repaired, return to original starting point and remove plastic covers from repairs and place plastic in an empty bucket to be discarded later.

6.7. Spall Repair Complete. The Spall Crew informs the Repair Team Lead when spall repair is complete to receive their next assignment.

6.8. Permanent Spall Repair. Because expedient spall repairs are only approved for 500 passes when conditions return to normal operations, upgrade the expedient repairs with permanent repairs as described in UFC 3-270-01, *Asphalt and Concrete Pavement Maintenance and Repair.*

Chapter 7

RECONSTITUTION OF FOD AND REPAIR TEAMS

7.1. Overview. This phase begins when an appropriate authority directs the return to normal operations. During this phase, begin implementing plans to reconstitute the FOD and Repair Teams equipment, materials, and vehicles and then resume normal operations. Supervise an orderly return to the normal operating facilities, or movement to a temporary or permanent facility. Maintain communication with C2 agencies during transition and report mission manpower and capability.

7.2. Reconstitution. When directed, begin the following reconstitution actions:

7.2.1. FOD Removal Team.

- Perform vehicle post operational inspections and take appropriate action for any discrepancies found.
- Refuel vehicles.
- Return vehicles to their duty locations or staging areas.

7.2.2. Repair Team(s).

- Perform vehicle post operational inspections and take appropriate action for any discrepancies found.
- Refuel all vehicles and fuel operated equipment.
- Inspect wheel saw bits and saw wearing shoes and replace as necessary.
- Inspect, repair, and reload vehicle attachments and tools on their respective trailers and return to the staging location.
- Wash out and clean volumetric mixers and return to staging location.
- Return vehicles to their duty locations or staging areas.
- Restock ADR Tool Trailer expendables.
- Refill all water skids, tanks, trucks, and trailers.
- Restock Spall Repair kit expendables.

- Restock Inclement Weather kit expendables.

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Attachment 1

GLOSSARY OF REFERENCES AND SUPPORTING INFORMATION

References

AFI 10-210, *Prime Base Engineer Emergency Force (BEEF) Program*, 7 July 2019

AFI 48-127, *Occupational Noise and Hearing Conservation Program,* 26 February 2016

AFI 48-137, *Respiratory Protection Program*, 10 September 2018

DAFMAN 91-203, *Air Force Occupational Safety, Fire, and Health Standards,* 23 March 2022

AFPAM 10-219V4, *Airfield Damage Repair Operations*, 28 May 2008

AFTTP 3-32.10, *Introduction to Rapid Airfield Damage Recovery (RADR)*, 15 October 2019

AFTTP 3-32.18, *Rapid Airfield Damage Repair-Warehouse Operations,* 20 September 2018

T.O. 35E2-2-7, *Installation, Maintenance, Repackaging and IPB—AM-2 Airfield Landing Mat and Accessories (NASC),* 6 September 1985

T.O. 35E2-5-1, *Crushed Stone Crater Repair and Line-of-Sight Profile Measurement for Rapid Runway Repair*, 27 August 2007

UFC 3-250-08 FA, *Standard Practice for Sealing Joints and Cracks in Rigid and Flexible Pavements,* 16 January 2004

UFC 3-270-01, *Asphalt and Concrete Pavement Maintenance and Repair,* 21 February 2018

TSPWGM 3-270-01.3-270-07, *Airfield Damage Repair,* 21 May 2020

29 CFR 1910.133, *Eye and Face Protection,* 17 February 2021

29 CFR 1910.134, *Respiratory Protection,* 17 February 2021

Adopted Forms

DAF Form 847, *Recommendation for Change of Publication*

Abbreviations and Acronyms

ADAT—Airfield Damage Assessment Team

ADR—Airfield Damage Repair

AFCEC—Air Force Civil Engineer Center

AFSC—Air Force Specialty Code

AFTTP—Air Force Tactics, Techniques, and Procedures

AM-2—Aluminum Mat-2

ATO—Air Tasking Order

C2—Command and Control

CE—Civil Engineer

CE-UCC—CE Unit Control Center

CPM—Crater Profile Measurement

CTL—Compact Track Loader

CY—Cubic Yard

EOC—Emergency Operations Center

EOD—Explosive Ordnance Disposal

FOD—Foreign Object Debris

IPE—Individual Protective Equipment

lbs—Pounds

MAOS—Minimum Airfield Operating Surface

MOS—Minimum Operating Strip

OIC—Officer in Charge

PAR—Post-Attack Reconnaissance

RADR—Rapid Airfield Damage Recovery

RDR—Rapid Damage Repair

RPM—Revolutions Per Minute

RQC—Repair Quality Criteria

SDS—Safety Data Sheet

T.O.—Technical Order

TTP—Tactics, Techniques, and Procedures

UCC—Unit Control Center

UTC—Unit Type Code

UXO—Unexploded Explosive Ordnance

Terms

Airfield—An area prepared for the accommodation (including any buildings, installations, and equipment), of landing, and take off of aircraft.

Air Tasking Order (ATO)—A method used to task and disseminate to components, subordinate units, and command and control agencies projected sorties, capabilities and/or forces to targets and specific missions. Normally provides specific instructions to include call signs, targets, controlling agencies, etc., as well as general instructions. Source: JP 3-30.

Airfield Damage Assessment—Locating, classifying, and measuring the damage (camouflet, crater, spall, and UXO) on the airfield operating surfaces.

Airfield Damage Assessment Team (ADAT)—An airfield recovery team, used to identify and locate airfield damage and UXO following an attack. They are controlled by ESF-3, but they should posture directly adjacent to the airfield to shorten the assessment time. Their initial efforts are normally targeted towards the airfield proper; but can also be employed elsewhere as deemed necessary. The ADAT usually consists of one engineering technician and two EOD technicians. A CE member trained as an EOD assistant may replace one of the EOD technicians when two are unavailable for ADAT. The ADAT should be equipped with an armored vehicle and communications enabling them to report their observations to the MAOS Selection Cell. The ADAT damage reports should be accurate as this information is used in MAOS selection.

Apparent Crater Diameter—The visible diameter of the crater, inside edge to inside edge, at the original surface level prior to debris being removed. In actual practice, this can be measured from pavement edge to pavement edge. Apparent diameter is the information forwarded to the MAOS Selection Cell by the ADATs.

Apron—A defined area on an airfield intended to accommodate aircraft for the purposes of loading or unloading passengers or cargo, refueling, parking, or maintenance.

Camouflet—Craters with relatively small apparent diameters, but deep penetration and subsurface voids created by the munition puncturing through the pavement surface and exploding in the base material. **Note:** Munitions that penetrate the surface but do not explode are also treated as a camouflets.

Command and Control (C2)—The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. C2 functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission.

Contingency—An emergency involving military forces caused by natural disasters, terrorists, subversives, or by required military operations. Due to the uncertainty of the situation, contingencies require plans, rapid response and special procedures to ensure the safety and readiness of personnel, installations, and equipment.

Crater—The pit, depression, or cavity formed in the surface of the earth by an explosion. It may range from saucer-shaped to conical, depending largely on the depth of burst.

Crater Field—A cluster of small craters (less than two feet apart) where their upheaval joins the neighboring crater within a defined area.

Damage Assessment—1. The determination of the effects that attacks have on targets. 2. (DoD only) A determination of the effect of a compromise of classified information on national security. 3. (AF/CE) The process of identifying and locating damage and unexploded ordnance following an attack. Damage assessment activities generally are separated into two categories: airfield pavements and facility/utility.

Emergency Operations Center (EOC)—A temporary or permanent facility where the coordination of information and resources to support domestic incident management activities normally takes place.

Explosive Hazard—Any hazard containing an explosive component to include unexploded explosive ordnance (including land mines), booby traps (some booby traps are nonexplosive), improvised explosive devices (which are an improvised type of booby trap), captured enemy ammunition, and bulk explosives.

Explosive Ordnance—All munitions containing explosives, nuclear fission or fusion materials, and biological and chemical agents.

Explosive Ordnance Disposal (EOD)—The detection, identification, on-site evaluation, rendering safe, recovery, and final disposal of unexploded explosive ordnance. It may also include explosive ordnance which has become hazardous by damage or deterioration.

Facility—A real property entity consisting of one or more of the following: a building, a structure, a utility system, pavement, and underlying land.

MAOS Selection—The process of plotting damage and UXO locations on an airbase runway map and using this information to select a portion of the damaged runway which can be repaired most quickly to support aircraft operations.

Minimum Airfield Operating Surface (MAOS)—The combined requirement for airfield surfaces for both runway and access routes. The MOS is part of the MAOS.

Minimum Airfield Operating Surface Marking System (MAOSMS)—The MAOSMS is a visual marking system that provides material and equipment to mark a MOS between 50- and 150 –ft wide and between 5,000- and 10,000-ft. long. In addition, the system can mark 25- to 50-ft. wide taxiways.

Minimum Operating Strip (MOS)—1. A runway which meets the minimum requirements for operating assigned and/or allocated aircraft types on a particular airfield at maximum or combat gross weight. 2. The MOS is the smallest amount of area to be repaired to launch and/or recover aircraft after an attack. Selection of this MOS is going to depend upon mission requirements, taxi access, resources available, and estimated time to repair. For fighter aircraft, the typically accepted dimensions are 5,000-ft. long x 50-ft. wide.

Mitigation—Activities designed to reduce or eliminate risks to persons or property or to lessen the actual or potential effects or consequences of an incident. Mitigation measures may be implemented prior to, during, or after an incident. Mitigation measures are often developed in accordance with lessons learned from prior incidents. Mitigation involves ongoing actions to reduce exposure to, probability of, or potential loss from hazards. Measures may include zoning and building codes, flood plain buyouts, and analysis of hazard-related data to determine where it is safe to build or locate temporary facilities. Mitigation can include efforts to educate governments, businesses, and the public on measures they can take to reduce loss and injury.

Ordnance—Explosives, chemicals, pyrotechnics, and similar stores, e.g., bombs, guns and ammunition, flares, smoke, or napalm.

Pavement Upheaval—The vertical displacement of the airfield pavement around the edge of an explosion-produced crater. The pavement upheaval is within the crater damage diameter but is outside the apparent crater diameter. In other words, it is that part of the pavement out of "flush" tolerance which is elevated above the adjacent undamaged surface.

Personnel—Those individuals required in either a military or civilian capacity to accomplish the assigned mission.

Procedures—Standard, detailed steps that prescribe how to perform specific tasks.

Reconnaissance—A mission undertaken to obtain, by visual observation or other detection methods, information about the activities and resources of an enemy or adversary, or to secure data concerning the meteorological, hydrographic, or geographic characteristics of a particular area.

Recovery—The development, coordination, and execution of service- and site-restoration plans for impacted communities and the reconstitution of government operations and services through individual, private-sector, nongovernmental, and public assistance programs. This helps identify needs and define resources; provide housing and promote restoration; address long-term care and treatment of affected persons; implement additional measures for community restoration; incorporate mitigation measures and techniques, as feasible; evaluate the incident to identify lessons learned; and develop initiatives to mitigate the effects of future incidents.

Repair—The restoration of airfield damage.

Response—Activities that address the short-term, direct effects of an incident. Response includes immediate actions to save lives, protect property, and meet basic human needs. Response also includes the execution of emergency operations plans and of incident mitigation activities designed to limit the loss of life, personal injury, property damage, and other unfavorable outcomes. As indicated by the situation, response activities include: applying intelligence and other information to lessen the effects or consequences of an incident; increased security operations; continuing investigations into the nature and source of the threat; ongoing public health and agricultural surveillance and testing processes; immunizations, isolation or quarantine; and specific law enforcement operations aimed at preempting, interdicting or disrupting illegal activity and apprehending actual perpetrators and bringing them to justice.

Runway—A defined rectangular area of an airfield, prepared for the landing and takeoff run of aircraft along its length. A runway is measured from the outer edge of the thresholds from one end of the runway to the others. The width of the runway is typically measured from the outer edge of the load-bearing pavement on one side to the outer edge of the load-bearing pavement on the other side. In some cases the runway may be measured from the outside edge of the runway marking line on one side to the outside edge of the marking line on the other side and any remaining load bearing pavement is considered shoulder.

Senior Airfield Authority (SAA)—An individual designated/appointed by the component responsible for airfield operations at direction of the Joint Force Commander. The SAA is responsible for control, priorities, operation and maintenance of an airfield to include runways, associated taxiways, parking ramps, land, and facilities whose proximity affect airfield operations.

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 meters (5-ft.) in diameter.

Spall Field—A cluster of spalls within a defined area.

Taxiway—A specially-prepared or designated path on an airfield or heliport, other than apron areas, on which aircraft move under their own power to and from landing, takeoff, service, and parking areas.

Techniques—Non-prescriptive ways or methods use to perform missions, functions, or tasks.

Threat—An indication of possible violence, harm, or danger.

Unexploded Explosive Ordnance (UXO)—Explosive ordnance which has been primed, fused, armed, or otherwise prepared for action, and which has been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material, and remains unexploded either by malfunction or design.

Attachment 2

ENGINEER REACHBACK AND OTHER USEFUL LINKS

Table A2.1. Useful Organizational and Product Links.

Organization and Products Links
Air Force Civil Engineer Center (AFCEC): **https://www.afcec.af.mil/**
CE DASH (AFCEC Technical Support Portal): **https://usaf.dps.mil/teams/CEDASH/scripts/homepage/home.aspx**
CE Playbooks: **https://www.ceplaybooks.com.**
AFCEC Expeditionary Engineering SharePoint: **https://usaf.dps.mil/sites/13072/SitePages/Homepage.aspx**
AF Publications and Forms: **https://www.e-publishing.af.mil/**
AF Design Guides (AFDG): **https://www.wbdg.org/ffc/af-afcec**
Tri-Service Transportation, Pavements-Transportation-Community of Practice: **https://transportation.erdc.dren.mil/cacsites/TriService/pavement_repair.aspx**
US Army Corp of Engineers Official Publications, **http://www.publications.usace.army.mil/Home.aspx**
Unified Facilities Criteria (UFC): **https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc**
USACE Reachback Operations Center (UROC): **https://uroc.usace.army.mil**
USACE Protective Design Center: **https://intelshare.intelink.gov/sites/pdc/SitePages/Home.aspx**
Army Publications and Forms: **https://armypubs.army.mil/**
Navy Doctrine Library System: **https://doctrine.navy.mil/default.aspx**
DOD Issuances: **https://www.esd.whs.mil/DD/DoD-Issuances/**
Joint Publications: **https://jdeis.js.mil/my.policy**

Attachment 3

COMPONENT LISTING

Table A3.1. Vehicle Attachments Utilization and Storage Plan.

CTL Attachments (5 CTLs per capability)	Per Capability	Stored on Trailers	Attached to Vehicles	Storage Area
Broom, angle, BA18	3	3	0	0
Bucket-MP, 78-in, .52-cy	5	4	1	0
Cold planer, 205B	1	1	0	0
Compactor, vibratory CV18B	1	1	0	0
Impactor H65D (w/chisel & moil)	2	2	0	0
Forks, 48-in pallet with carriage	2	2	0	0
SW360 wheel saw	5	5*	4*	0
SW345 wheel saw	4			0
Excavator Attachments (2 Excavators per capability)	**Per Capability**	**Stored on Trailers**	**Attached to Vehicles**	**Storage Area**
Bucket, 24-in	2	0	0	0
Bucket, 48-in	2	1	1	0
Impactor	2	1	1	0
Plate compactor	2	2	0	0
Front-End Loader Attachments (4 Front-end loaders per capability)	**Per Capability**	**Stored on Trailers**	**Attached to Vehicles**	**Storage Area**
Boom with hook	4	0	0	4
Bucket, MP	4	0	4	0
Forks	4	0	0	4

*Pavement thickness, determined from pre-attack airfield survey, is going to determine wheel-saw size attached to CTLs

Figure A3.1. Work Tool Attachment #1 Pre-Attack Survivability Load Plan.

Figure A3.2. Work Tool Attachment #2 Pre-Attack Survivability Load Plan.

Note: Divide like items and attachments between trailers for survivability (dimensions may change without notice).

Table A3.2. RADR Tool/Component Trailer.

Description	Qty
Axe, pick	4
Bag, stake, 24-in	1
Bag, tool, canvas 24-in	1
Bar, pinch, digging	4
Bit, drill, ¾-in x 21-in	2
Bit, spade	1
Blade, cut-off saw, K-12, 12-in	6
Blade, saw, walk behind, 24-in	6
Blade, saw, walk behind, 36-in	3
Blade, saw, walk behind, 42in	3
Board, screed, MBW 12-ft	2
Broom, concrete, hand 12-in	4
Broom, street	6
Bucket, 5-gal w/lid	6
Cap, plastic, for form board 1/2-in (linear ft)	180
Chisel point	1
Chisel, hammer, demolition	2
Chisel, pointed 19-in	2
Chocks, wheel (standard)	2
Come-a-long, concrete	10

Description	Qty
Compactor, plate, 4-stroke	1
Compactor, rammer, 4-stroke	1
Compressor, portable	1
Cones, traffic, orange, all-weather 18-in	50
Cutter, asphalt, cross-cut	1
DCP Kit, K-100 airfield deluxe	1
Drill, hammer, electric, SDS max	2
First aid kit, large	1
Float, magnesium bull w/mount bracket	2
Form board, expansion joint, 1/2-in x –in x 10-ft (linear ft)	180
Form board, expansion joint, 1/2-in x 4-in x 10-ft (linear ft)	180
Form, concrete, 2-in x 4-in x 12-ft (plastic, 10 pk)	1
Form, concrete, 2-in x 6-in x12-ft (plastic, 10 pk)	1
Generator, diesel, 6,000-w	1
Geotextile, non-woven (12.5-ft W x 360-ft L roll)	1
Hammer, demolition, electric 40-lb	2
Hammer, sledge, 10-lb	4
Hammer, sledge, 3-lb	4
Handle, broom, street, wood 54-in	6
Handle, bull float	6
Hoe, mortar	2
Hose, suction 3-in x 20-ft	1
Jerrican, diesel, 5-gal	2
Level 4-in	1

Description	Qty
Light, wobble	3
Lute, asphalt, telescoping handle	6
Maddox	4
Measuring wheel	2
Moil (conical) point	1
Moil, hammer, demolition	2
Plastic, sheeting, roll, 20-ft x 100-ft (10Mil)	2
Pocket, slide (15 per bucket)	2
Pocket, stacking (5 per bucket)	3
Power unit, MBW, screed, honda engine	1
Puller, stake	2
Pump, water (mud hog)	1
Rake, asphalt	6
Rakes, garden/bow	6
Release agent, all purpose (asphalt)	2
Release agent, all purpose (concrete) 5-gal	2
Saw, cut-off, K-12 (K760)	1
Saw, reciprocating	1
Saw, walk behind, 4-in (Model: FS 7000 D 3-SP)	1
Shield, reflector, wobble light	3
Shovel, asphalt (scoop type)	4
Shovel, round head	10
Shovel, square head	12
Spout, jerrican, flex 16-in	4

Description	Qty
Sprayer, liquid, 2-gal hand pump	2
Stakes, nail 24-in x 3 /4-in	120
Teeth, wheel saw, concrete (50 per box)	12
Towels, shop (box of 200)	2
Vibrator, concrete, electric	2
Wheel barrow	1
Cabinet 1 Contents:	
Funnel	1
Gun, caulk	2
Liquid nails	5
Mixer, dual paddle, concrete	1
Shield, face	4
Cabinet 2 Contents:	
Hose, discharge, 3-in x 25-ft	1
Hose, fire, 2-in x 50-ft	2
Meter, flow	4
Cabinet 3 Contents:	
2-in camlock fog nozzle or fire nozzle, pistol grip, 1-1/2-in	2
Aluminum 2-in female camlock to 1-1/2-in male	2
Aluminum 2-in female camlock to 1-1/2-in female	2
Aluminum 2-in male camlock x 2-in female NPT	2
Aluminum 2-in NPT to 1-1/2-in NH double female	2
Aluminum 2-in male camlock to 1-1/2-in female NPT fitting	2
Aluminum 3-in Female camlock to 2-in male camlock fitting	2

Description	Qty
Aluminum 3-in male camlock x 3-in female NPT	2
Aluminum 3-ni female camlock to 3-in male NPT	2
Blade, circular saw	6
Drill, electric, 1/2-in chuck	1
Grinder, angle	1
Saw, circular 7-1/4-in	1
Wheels, grinder, cut-off	10
Wrench, impact, electric, 1/2-in	1
Cabinet 4 Contents:	
Hose, garden, 50-ft	4
Hose, rubber, red, 3/8-in x 50-ft	2
Wand, air compressor	2
Cabinet 5 Contents:	
Cord, extension, 30-amp twist lock, 50-ft	6
Level, 2-ft	1
Square, speed, combination	2
Cabinet 6 Contents:	
Glow stick, chem-light, green, 6-in	200
Measure set, liquid, nesting	4
Cabinet 7 Contents:	
Binder, load (5/16-in – 3/8-in 7,300-lb)	4
Binder, ratchet, chain (5/16-in – 3/8-in 7,300-lb)	10
Cables, jumper, 20-ft	1
Chain, grade 100 w/twist, 3/8-in link; 20-ft length	10

Description	Qty
Cabinet 8 Contents:	
Bag, tool, large	2
Bag, trash, 50-gal	2
Bar, crow, wrecking, 3/4-in x 30-ft	4
Box, tool, mechanics	1
Chain, grade 70 w/twistlock, (1/4-in link; 20-ft length)	2
Cutter, bolt, 3 in 1, 24-in	1
Hammer, claw	2
Pliers, wire twist, 12-in	2
Pliers, wire twist, 9-in	2
Strap, tow, 20-ft	2
Wrench, pipe, 18-in	2
Wrench, pipe, 36-in	2
Drawer 1 Contents:	
Glasses, safety	30
Respirator, face-piece, N95	120
Drawer 2 Contents:	
Brush, utility, nylon, 8-in OAL	6
Crayon, florescent red	96
Gloves, disposable, (box 100)	2
Plug, ear, pair	200
Drawer 3 Contents:	
Blade, knife, utility	100
Knife, utility	20

Description	Qty
Level, line	8
Opener, bucket	4
Scrapers, hand, 4-in	12
Set, drill bit and driver	1
Thermometer, infrared/IR-100	6
Drawer 4 Contents:	
Nozzle, hose, garden	4
String, nylon, 500-ft roll	4
Tape, measure, 25-ft	20
Tape, measure, 100-ft	2
Wire, bailing, 25-ft	2
Drawer 5 Contents:	
Edger, concrete, brass	4
Float, hand, magnesium, 18-in	6
Jointer, concrete, brass	4
Trowel, finishing, steel, 16-in	6

Table A3.3. Inclement Weather Kit Components.

Description	Qty
Container 1 Contents:	
Backpack blower	3
Bucket, 5-gal	36
Discharge hose, 50-ft	1
Inline water heater	1
Line marker	1
Ramp, 36-in Wide x 18-in Long	1
Suction hose, 20-ft	1
Tote, 50-gal	1
Vacuum	1
Water pump	1
Container 1, Tote 1 Contents:	
Automatic heat cable, electric, 18-ft	2
Blower extension	1
Bucket lid	36
Paint crayon, red, 12-ct	5
Pipe heater cable, 30-ft	2
Shop vac accessories kit	1
Shop vac hose	1
Shovel, charcoal/ash	1
Suction hose strainer, metal	1
Container 2 Contents:	

Description	Qty
Wire basket, 48-in x 40-in x 36-in	1
Wire basket, 48-in x 40-in x 42-in	2
Container 2, basket 1 contents	
Containment dike, 10-ft	36
Plastic sheeting, 20-ft x 100-ft	2
Tarpaulin	10
Tent anchor bags	44
Tie down, cargo, aircraft	5
Container 2, Basket 2 Contents:	
Fire hose, custom, 30-ft	18
2-1/2-in dust cap	18
2-1/2-in dust plug	18
No. 10 sieve	4
Tarpaulin	14
Container 2, Basket 3 Content:	
Pop-up tent	10

Attachment 4

RADR PRE-CONVOY BRIEF TEMPLATE

ADR PRE-CONVOY BRIEF																					
1. Briefing Location:																					
2. Threat																					
a. FPCON	Alpha	Bravo	Charlie	Delta																	
b. Threat Level	Low	Moderate	Significant	High																	
c. Work Party Security	Yes	No																			
3. Environmental conditions																					
a. Expected Weather	Fair	Rain	Snow																		
b. Heat Category	1	2	3	4	5																
c. (Heavy) Work/Rest Cycle	40/20	30/30	30/30	20/40	10/50																
d. Water intake (quart/hour)	3/4	1/1	1/1	1/1	1/1																
e. Chemicals present	Yes	No																			
f. MOPP level	MOPP 0	MOPP 1	MOPP 2	MOPP 3	MOPP 4	Variations:															
g. Performance Period	Day	Night																			
4. UXOs Present	Yes	No	Required Clear zone around UXO (feet):																		
Camouflets Present	Yes	No	Required Clear zone around camouflet (feet):																		
5. MAOS details																					
a. MOS coordinates	Coord string:	T/H:	Departure:	Width:	Length:	C/L offset:															
b. MOS configuration	Unidirectional	Bidirectional	Runway ID:																		
c. Taxiway(s) reqd. to repair																					
d. Taxiway pavement depth	inches																				
e. Arresting system(s)	1. Coordinates:	Conc.	Asph.	Soil	2. Coordinates:	Conc.	Asph.	Soil													
Set-back installation(s)	No	Yes	Setback distance from centerline:																		
f. Lighting	PAPIs	DTG	Approach	AAS Markers	Edge	Taxiway															
g. Striping	Approach	Departure	Centerline	Taxiway	Blackout																
h. MOS pavement depth	Approach:	Departure:	Center:																		
i. Dowels Present	Yes	No																			
6. Crater Repair Teams	1			2			3			4			5			6			7		
a. Number of craters																					
b. Repair zone coordinates																					
c. Capping Material	RS	A	FC	RS	A	FC	RS	A	FC	RS	A	FC	RS	A	FC	RS	A	FC	RS	A	FC
d. Admixtures	Yes	No		Yes	No		Yes	No		Yes	No		Yes	No		Yes	No		Yes	No	
e. Camouflets	Yes	No		Yes	No		Yes	No		Yes	No		Yes	No		Yes	No		Yes	No	
f. Push debris	Left	Right																			
g. Place repair material	Left	Right																			
7. Spall Field Coordinates																					
8. Warehouse Teams	1		2		3		4		5		6		7								
Material to Haul	RS	FF	RS	FF	RS	FF	RS	FF	RS	FF	RS	FF	RS	FF							
9. Asphalt Batch Plants	1	2	3	4																	
Supports Repair Team(s)	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7																	
10. Utility Locations	Fuel:	Water:	Electric:	Drains:	Comm:																
Required Utility Repairs	Fuel:	Water:	Electric:	Drains:	Comm:																
11. Convoy Route(s)	Primary:	Alternate:																			
Special Instructions																					
12. Status/DIME Reporting	Authentication required:	Yes	No																		

Attachment 5

EMERGENCY AUGER SWAP OUT PROCEDURES

A5.1. ProAll Mixer:

- Swap-out is performed by a 3-man team
- Member 1 removes tie-down straps and lifting clamps (fork pockets) from spare auger (**Figure A5.1**) stored on a single pivoting tube

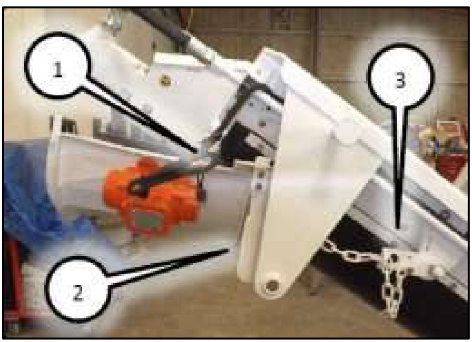
Figure A5.1. Spare Auger Tie-Down Straps and Fork Pockets.

- Members 2 and 3 lower auger chute to a horizontal position and disconnects hydraulic lines and electrical connectors from the hydraulic control system (**Figure A5.2**)
- Members 2 and 3 remove transition chute, by (1) disconnecting the electrical connector from the chute vibrator, (2) pulling release pin, (3)

removing the adjusting chains on both sides of the auger, and then rotating the transition chute off its mount (**Figure A5.3**)

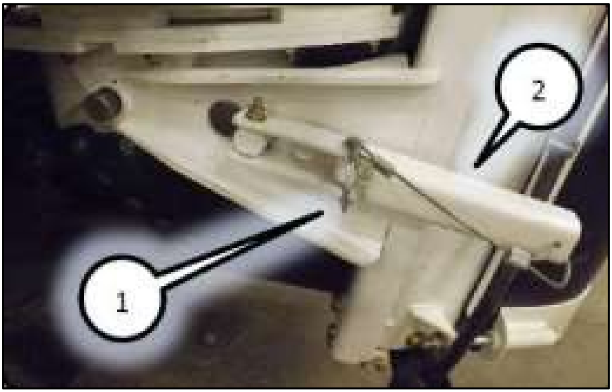
Figure A5.2. Hydraulic Line Quick Disconnects and Electrical Connector.

Figure A5.3. Transition Chute.



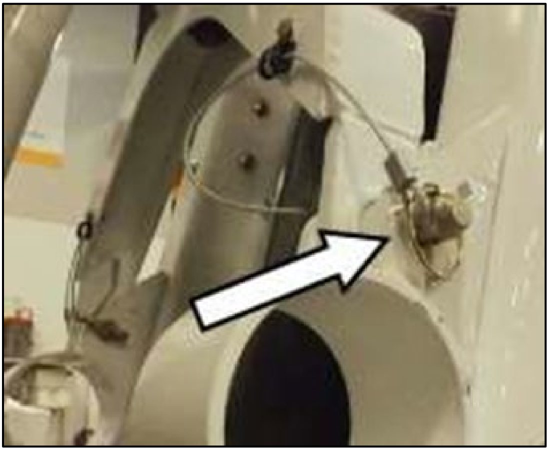
- Members 2 and 3 disconnect water hoses and removes the rapid release ears near mixing well by removing the pin and rotating the cam lever up and off of the ear (**Figure A5.4**). A hammer and tapered punch, located in the ADR Tool Trailer, is recommended to remove and install auger attachment pins.

Figure A5.4. Mix Auger Ears. (1) Pin, (2) Cam Lever.



- Member 1 installs lifting clamps on the damaged auger and then positions the forklift to assist in removal of damaged auger.
- When Members 2 and 3 release the auger chute from the mixing well and hoses are disconnected, they swing the auger chute 90 degrees.
- Member 1 inserts the forks into the lifting clamps to support the auger.
- Members 2 and 3 remove pins connecting auger chute to the link arm (**Figure A5.5**).

Figure A5.5. Link Arm Pin Location.



- Member 1 sets damaged auger aside to be repaired
- Members 2 and 3 reinstall the lifting clamps on spare auger and Member 1, using the forklift, removes spare auger from the stowage location with assistance from other two members.
  - Pull the auger out from the machine until the pin clears the rear holding bracket (**Figure A5.6**).

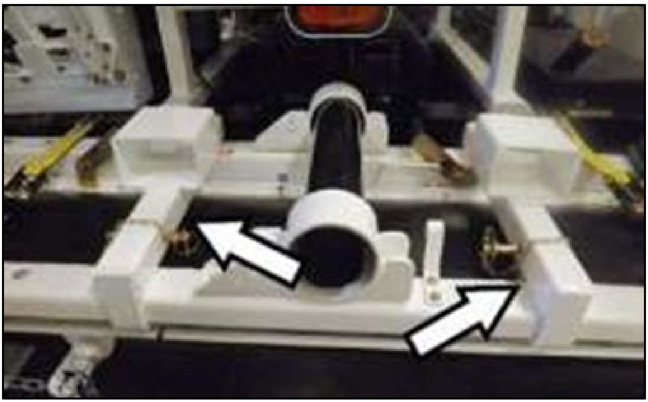
Figure A5.6. Rear Auger Holding Bracket.

- Rotate the auger on the pivot tube so the motor lowers towards the ground and the lock pin on the auger clears the front holding bracket (**Figure A5.7**).

Figure A5.7. Front Auger Holding Bracket.

- Attach the lifting clamps from the toolbox onto the auxiliary auger in the slots on the auger as shown in **Figure A5.8**.
- Lift the auger with a forklift to clear the lip on the pivot tube.
- Remove the auger straight from the machine to clear the pivot tube.
- Member 1 positions the spare auger for installation in reverse order of removal.

Figure A5.8. Auger with Lifting Clamps Installed.



A5.2. CemenTech Mixer:

Figure A5.9. Lifting Mixer to Relieve Pressure on Cylinder.

- Remove pins that hold the cylinder and first chute from the mixer assembly. Make sure to uncouple the chute vibrator wiring harness connector (**Figure A5.10**).

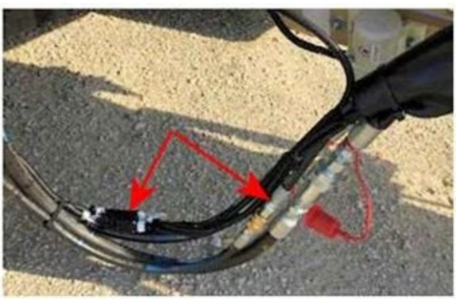
Figure A5.10. Pins Holding Cylinder and First Chute from Mixer Assembly.

- Completely retract the cylinder and gently lower it until it rests on the conveyor cover.
- Remove the cotter pin and washer from the hanger pins on both sides of the hopper (**Figure A5.11**).

Figure A5.11. Cotter Pins and Washers Location.

- Uncouple mixer hydraulic hoses and wire loom connectors (**Figure A5.12**).

Figure A5.12. Mixer Hydraulic Hoses and Wire Loom Connectors.



- Knock the retaining wedges out the right mixer arm (**Figure A5.13**). Pull the hanger bracket off the hanger pin and three arm studs and push the mixer assembly to the left. Be cautious and have situational awareness! Even though the mixer assembly is balanced it can drop on one end or swing without warning.

Figure A5.13. Retaining Wedges and Arm Studs.

- Carefully maneuver the mixer away from the unit and set it in a safe location where it can be stored without damage until it is worked on or stowed back on the trailer.
- Remove the lifting strap from the mixer assembly and install it on the spare mixer located on the front right side of unit. Carefully place the forklift in the proper position to lift the spare mixer off the frame (**Figure A5.14**). Do not hit the Oil Cooler with the forklift tines!

Figure A5.14. Lifting Spare Mixer Assembly from Storage Location.

- Drive the locking wedges out of the retaining pins (**Figure A5.15**).

Figure A5.15. Locking Wedge and Retaining Pin.

- Raise the forklift boom to put a little tension on the lifting strap and remove the pins from the chute hanger brackets (**Figure A5.16**).

Figure A5.16. Chute Hanger Bracket Pins.

- Slowly lift the spare mixer off the unit and maneuver it to the rear of the unit to be mounted.
- Remove the right side hanger ear from the mix auger.
- Slide the left hanger ear onto the pin and install the flat washer and the cotter pin (see **Figure A5.11**).
- Align the three pin holes in the right hanger ear and slide the ear over the mixer pins and hanger pin at the same time. It may be necessary to wiggle the discharge end or the mixer assembly to assist the hanger ear going onto the pins.
- Once the ear is in place, install the flat washer, cotter pin, and the three wedges (see **Figure A5.13**).

- Raise the mixer assembly with the forklift so the mixer is at 10 degrees. Extend the hoist cylinder, align the mounting holes, and install the pin (**Figure A5.17**). Use the hoist lever to make adjusts to slide the pin in.

Figure A5.17. Hoist Cylinder Pinned to Mounting Holes.

- Install the first chute.
- Connect the hydraulic lines and wire looms (see **Figure A5.12**).
- Grease the lower seal system on the mix auger with the grease gun mounted on the fender. Place the grease gun on the grease zerk located on the bottom end of the mixer (**Figure A5.18**). Pump the gun until grease is coming out between the hub on the mixer shaft and the outer ring (**Figure A5.19**).

Figure A5.18. Grease Zerk Location.

Figure A5.19. Area Where Grease Should Exit the Seal.