ERDC/GSL TR-20-27

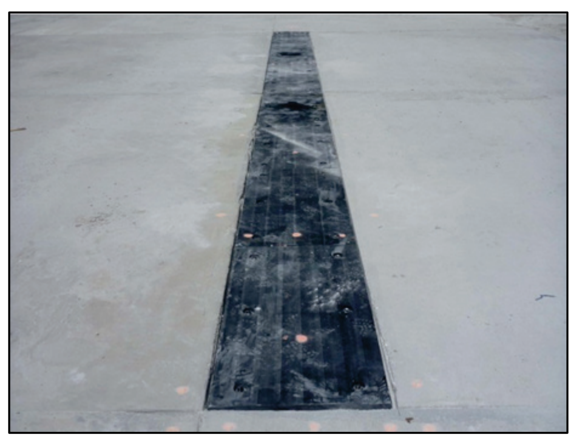
Geotechnical and Structures Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Development of Expedient Ultra-High Molecular Weight Aircraft Arresting System Panel Installation Procedures

Peter G. Bly

July 2020



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Final report

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Abstract

The US Army Engineer Research and Development Center conducted an evaluation of different procedures to install ultra-high molecular weight polyethylene panels beneath pendant-based aircraft arresting systems (AAS). Currently employed techniques were modified or new techniques were developed to increase productivity and installation accuracy, aid in system constructability, and reduce logistical concerns when compared to AAS requirements and pavement repair guidance. Procedures for both asphalt concrete and portland cement concrete surfaced runway pavement were evaluated.

The field evaluation was conducted from July to August 2013 at the Silver Flag Training Site, Tyndall Air Force Base, FL. The evaluation consisted of timing various procedures using a six- to eight-man installation crew. Equipment and supplies currently in Air Force inventories were preferred, but outside items were not prohibited if performance gains could be achieved and the new items were deployable using typical military cargo aircraft. Required work tasks were organized and grouped together to efficiently complete the panel installation work within multiple short-term runway closure windows without any long-term closures greater than 12 hours to allow for aircraft operations during the installation process.

This report summarizes the timed field trials and the pertinent conclusions based on the results. Recommendations for implementation including additional equipment, supplies, and personnel needs are provided.

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Preface

The study was conducted for the Air Force Civil Engineer Center (AFCEC) at Tyndall AFB, FL, under MIPR F4ATA42223J003. Mr. Jeb S. Tingle of the US Army Engineer Research and Development Center (ERDC) was the Airfield Damage Repair program manager at the time of this study. The technical manager for this study was Dr. Craig Rutland of the AFCEC.

The work was performed by the Airfield and Pavements Branch (GMA) of the Engineering Systems and Materials Division (GM), ERDC, Geotechnical and Structures Laboratory (GSL). At the time of publication of this report, Dr. Tim W. Rushing was Chief, GMA; Mr. Justin S. Strickler was Chief, GM; Mr. R. Nicholas Boone was the Technical Director for the Force Projection and Maneuver Support. The Deputy Director of ERDC-GSL was Mr. Charles W. Ertle, and the Director was Mr. Bartley P. Durst.

COL Teresa A. Schlosser was the Commander of EDRC, and the Director was Dr. David W. Pittman.

1 Introduction

1.1 Background

Arresting systems are needed to rapidly decelerate aircraft during landings. They are typically used to slow aircraft if runway lengths cannot accommodate the speed or weight of incoming aircraft or used in emergency situations. Mechanical systems are typically composed of a pendant (cable) or net that spans the width of the runway connected to a braking unit that absorbs the kinetic energy of the aircraft. Pendant systems require the aircraft to use a tail hook protruding from the aircraft fuselage to engage the system (Figure 1). Personnel in charge of operating and maintaining aircraft arresting system (AAS) must ensure the pendant is at least 1-1/2 in.[1] above a uniform pavement surface to ensure an aircraft catch (Department of the Air Force 2012). Other mechanical systems utilizing nets, strips of fabric, or placement of engineered construction materials as a pavement surface are also available.

Figure 1. Operation of a pendant-based AAS (Aerospaceweb.org 2020).

[1] For a full list of the spelled-out forms of the units of measure used in this document, please refer *to US Government Publishing Office Style Manual,* 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf

Arresting system pendants can cause considerable deterioration to the pavement surface layer, both asphalt concrete (AC) and portland cement concrete (PCC) surfacing. Figure 2 shows the surface abrasion resulting from steel pendant cables rubbing on the pavement surface over time. Removal of material from the surface of the pavement creates a reservoir capable of collecting foreign object damage (FOD), but more importantly increases the risk of an aircraft tail hook failing to engage the pendant (hook skip). Failure of the aircraft hook to engage results from the pendant's and supporting disks' sitting in the eroded groove, providing less clearance between the underside of the pendant and the original pavement surface (effective pendant height). Requirements for the effective pendant height are $2\frac{3}{8}$ in. and $2\frac{1}{2}$ in. for $1\frac{1}{4}$ in. and 1 in. diameter pendant cables, respectively (Headquarters, Department of the Air Force 2012).

Figure 2. Damage to pavement surface over time from AAS pendant[1].

Planning for pavement repairs at AASs begins once the effective pavement height is less than $1\frac{3}{4}$ in. and should be made before the height is $1\frac{1}{2}$ in. and requires an emergency repair (Headquarters, Department of the Air Force 2012). Repairs of pavement beneath the pendant using typical pavement repair materials are difficult to maintain, and reported repair performance varies between 14 days to several years. Figure 3 details typical repairs made to airfield pavement resulting from pendant abrasion.

[1] Rutland, C. 2013. Personal correspondence. Powerpoint presentation. AFCEC.

Figure 3. Typical pavement repairs made to correct pendant damage[1] (Rutland 2013).

1.2 Current arresting system requirements and guidance

Arresting system placement and pavement criteria are provided in Unified Facilities Criteria (UFC) 3-260-01, *Airfield and Heliport Planning and Design* (Headquarters, Departments of the Army, the Navy, and the Air Force 2008). Runway pavement requirements for a US Air Force (USAF) installation include the following:

- No changes in pavement type or interfaces between rigid and flexible pavement are allowed within the center 75 ft of the runway for 200 ft in both directions from the system pendant.
    - Sacrificial panels installed following Air Force Instruction (AFI) 32-1043 are not considered a change in pavement type or an interface between rigid and flexible pavements.
    - Emergency AASs in overruns do not apply to this requirement.
    - For BAK-14 systems stationed on 150 ft wide runways, the center 60 ft of the runway may not have any changes in pavement type (Department of the Air Force 2012).
- No protruding objects or undulating surfaces that are detrimental to tail hook engagements are allowed.
- The maximum allowed longitudinal surface deviation (roughness) is ± $^1/_8$ in. within any 12 ft length (measured by straightedge).

[1] Rutland, C. 2013. Personal correspondence. Powerpoint presentation. AFCEC.

- Saw cut grooves made to the pavement surface for surface drainage or improved surface friction (following UFC 3-260-02) are not acceptable within 10 ft in both directions from the system pendant. Grooving outside of this range is allowed within the 400 ft range where no pavement changes are allowed.
- PCC foundations are required for placing pendant anchoring and not considered a change in pavement type within the vicinity of the pendant when constructed in accordance with the USAF Typical Installation Drawings, 67F2011A or 67F2012A. Foundations used for AAS tie-down anchoring are exempt from the change in pavement type criteria.
- No rigid pavement inlays are allowed as a wearing surface beneath an arresting pendant in asphalt pavement runway sections. Concrete must be used for the foundation of sacrificial panels.
- Navy and Marine Corps AAS pavement protection design is provided in Naval Facilities Standard Design Drawing numbers 10-400-179 through 181. There are special requirements for the longitudinal and transverse slope of the pavement surface.

Planning, installation, operation, and maintenance practices for AASs are given in US AFI 32-1043 (Department of the Air Force 2012). Additional requirements and items to note for AASs include the following:

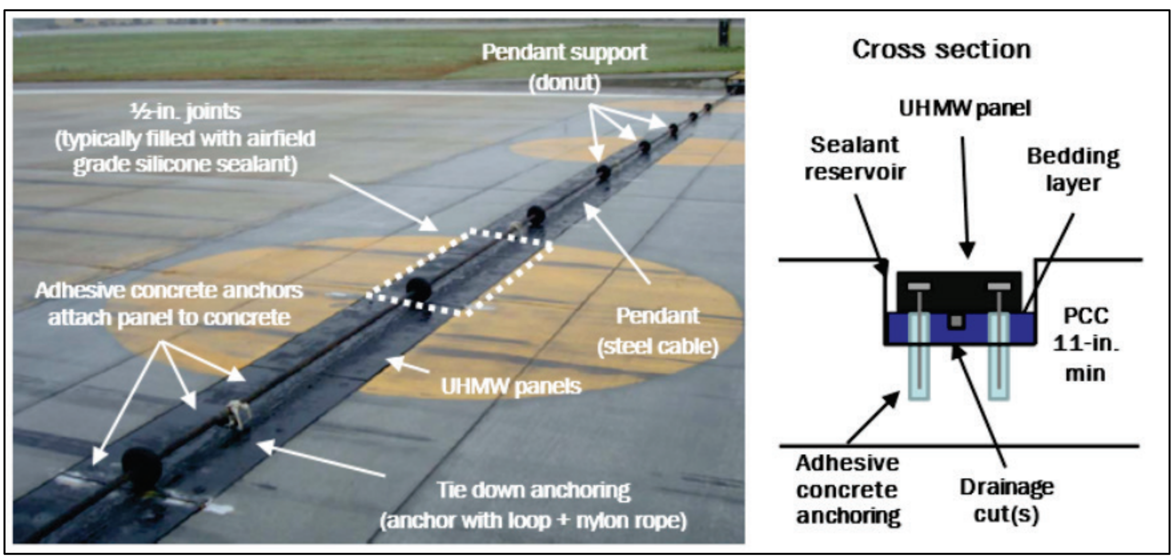
- The number of tie-down anchoring points used at AASs located between runway thresholds to limit aircraft damage from bouncing pendants depends on the type of aircraft operating at the installation.
  - For F-16, C-17, and C-130 operating bases: 8 anchors.
  - For all other aircraft operating: 4 anchors.
  - See document for spacing, location, and anchor design requirements.
- The anchoring block design given for flexible pavement use was “specially designed.”
- Attachment 8 of AFI 32-1043 covers the material requirements, installation, and design of sacrificial panels. A list of equipment, materials, and a typical installation schedule is provided.

1.3 Sacrificial panel systems

In the mid-1990s, the USAF began investigating the use of sacrificial panels installed beneath arresting system pendants after observing good performance with panels installed at several European air bases. Panels with good performance were made from ultra-high molecular weight (UHMW) polyethylene. Other paneling materials have been tested, but the majority warp significantly from thermal incompatibility with the underlying pavement and extend above the pavement surface, causing hook skip potential (AFCESA 1995). A 2009 US Army Engineer Research and Development Center (ERDC) study of various sites visits to locations utilizing UHMW sacrificial panels at arresting systems showed the panels could provide over 15 years of performance, even with multiple deficiencies observed at the places visited. The study provided best practices and construction guidance to mitigate damage and installation errors observed (Brown 2009).

Figure 4 details the major components of a sacrificial panel system. A system consists of a series of thin UHMW polyethelene plastic panels anchored to a concrete foundation. When placed on a PCC pavement, the panels are installed into a slot cut and chiseled into the pavement surface and placed on top of a smooth bedding layer. Holes for threaded rod anchoring points are drilled into the concrete, and the threaded rods are bonded into place by using a structural epoxy adhesive. Once the epoxy cures and the anchor can be loaded, nuts are placed on the thread bars and torqued to the correct installation torque to fix the panels to the pavement. The joints are sealed to minimize water intrusion and prevent FOD buildup.

Figure 4. Components of a sacrificial UHMW panel system (Brown 2009).



AC pavement installation is fairly similar to that completed for PCC pavements, except that a concrete foundation must be constructed to provide the required anchoring structure. To provide an anchoring structure, a 3 ft deep by approximately 25 in. wide trench is made across the runway. One foot of compacted aggregate base backfill is placed, followed by an approximately 22½ in. lift of concrete. Once the concrete cures to a minimum strength for drilling, the anchors are installed as described with PCC pavements and paneling installed.

1.4 Problem

A serious aircraft incident resulting from a hook skip at a BAK-12 arrester system with UHMW paneling occurred at an overseas AC-surfaced runway in 2009. The standard AC system design was modified to include a series of 10 ft square jointed PCC slabs placed across the runway. The UHMW panels were installed at a later time following the traditional procedure used for PCC installation. The ultimate goal of the design was to assist with keeping the runway operational by breaking the work required into multiple smaller closure windows. An investigation of the incident concluded the aircraft hook skipped over the pendant due to the expedient installation design used. The PCC slabs placed in the runway were a change in pavement type and were within the 200 ft on either side of the pendant where no change is allowed.

Review of investigation photos and AAS installation requirements showed that the true cause of the incident was the rigid inlay design used. Concrete must be used to provide a panel foundation, but the design used allowed the concrete to be the “top wearing surface” used by aircraft. AFI 32-1043 states this design practice is not allowed because cutting and trenching of the flexible pavement to place a PCC foundation loosens the soil along the construction joint and causes later consolidation of the soil layers. All gross voids created by the removal process are filled by backfill materials, but the smaller voids created when the soil is disturbed are not corrected in the construction process. As the soil consolidates over time, the AC surface elevation lowers as the underlying soil changes volume and exposes "the leading edge of the rigid pavement" placed (Department of the Air Force 2012). As arresting hooks attached to flexible cables are dragged across the pavement surface, like those depicted in Figure 1, the hook can skip over the pendant after impacting the exposed edge and fail to arrest the aircraft. Photos of the panel system show both the elevation difference between the PCC slabs and the existing AC pavement as well as impact damage at the PCC edge.

Installation of UHMW paneling at AASs is difficult work to complete expediently at forward operating locations. Current criteria are developed for main operating locations where long-term work closures can be scheduled; however, these criteria are still hard to apply at main locations due to the accuracy tolerances specified. Development of installation procedures that accurately and efficiently install UHMW paneling using a wide range of personnel must be determined for safe airfield operations.

1.5 Objective

The overall objective of this research was to determine the construction supplies, equipment, procedures, and scheduling required to install UHMW paneling at USAF AASs on AC- and PCC-surfaced runway pavements to minimize the risk of future hook skip incidents.

The Air Force Civil Engineer Center (AFCEC) has placed the following requirements on the procedures, equipment, and supplies used:

- The total runway width that must be completed is 150 ft.
- Work can be completed in multiple phases.
  - It is preferred each phase be fewer than 6 hr in duration.
  - Each phase must be fewer than 12 hr in duration.
  - The runway must return to operational status at the end of each phase.
  - There is no limit to the number of work days used.
- AFCEC prefers all supplies and equipment to be readily available in current USAF inventories.
- Use of items in current or new Airfield Damage Repair (ADR) kits is preferred.
- Other outside items are acceptable for performance gains as long as they are transportable in C-130 or C-17 aircraft.

1.6 Approach and Scope

This project consisted of evaluating different expedient construction methods for the installation of UHMW paneling at AASs. A field evaluation was conducted at the Silver Flag Training Site, Tyndall AFB, FL. The evaluation consisted of timing the various procedures considered, using a six- to eight-man installation crew. Timing data collected were analyzed to determine the adequacy of the supplies, equipment, personnel roles, and overall procedures used to meet USAF mission requirements.

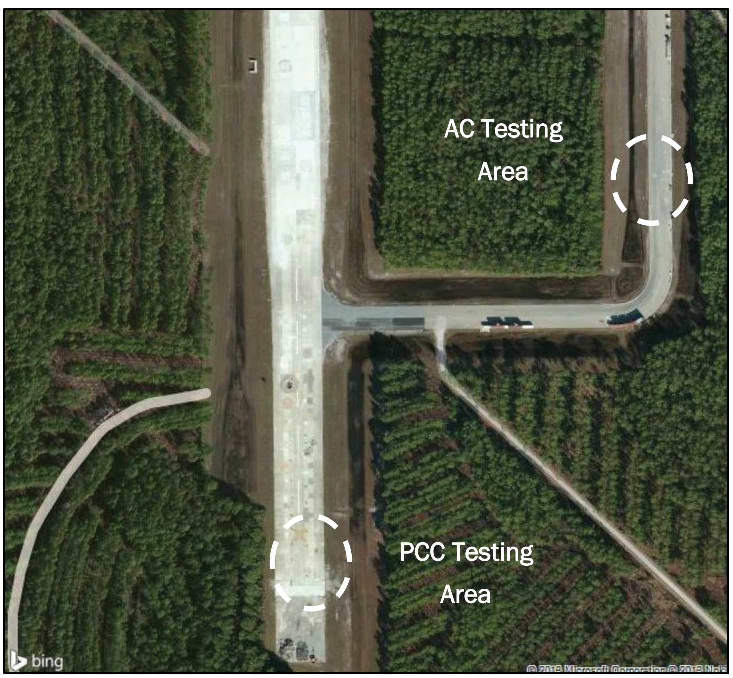
Chapter 2 describes the test site and experimental program used for this study. Chapters 3 and 4 present the results and analysis of the study conducted, respectively. Chapter 5 discusses the pertinent conclusions and recommendations for additional process optimization and design changes. A listing of the recommended supplies, equipment, and detailed installation procedures is provided in Appendices A through E. Additional component improvement recommendations and drawings are given in Appendices F and G.

2 Description of Test Site and Testing Efforts

2.1 Test site

The Silver Flag Training Site is located approximately 10 miles from the main gate of Tyndall AFB, FL. The training airfield on the installation consists of a 6,000 ft long by 150 ft wide PCC runway and three AC taxiways. Testing was limited to a 32-slab area in the southeast corner of the runway and a 40 ft wide by 120 ft long portion of the southern AC taxiway (Figure 5).

Figure 5. Testing locations used at Silver Flag Training Site (Microsoft 2013).



The pavement cross section for the runway pavement varied from 9 to 13 in. of PCC over a crushed limestone base over the natural dark brown sand subgrade. Both the longitudinal and transverse joints were cut at approximately 15 ft intervals and contained 1 in. diameter steel dowels spaced at 12 in. on center. The concrete mix design used was a 5,000 psi minimum compressive strength mixture at 28 days with a 1 in. maximum nominal-sized limestone coarse aggregate from a local ready mix supplier. Silver Flag personnel reported the concrete placed was part of their unit training classes and the surface roughness may be greater than expected on an operational airfield. The surface condition of the pavement was satisfactory to good in the testing area and contained only minor spalls and high-severity joint sealant damage where no sealant was present (Figure 6).

Figure 6. Pretest conditions of PCC pavement.

The pavement cross section for the taxiway pavement was $2^1/_2$ in. of a locally available AC highway mixture on 6 in. of $1^1/_2$ in. maximum sized limestone base above the dark brown sand subgrade. The overall surface condition was poor and contained medium-severity weathering and block cracking (Figure 7).

Figure 7. Pretest conditions of AC pavement.

2.2 Candidate installation procedures considered

AFCEC requested expedient installation methods be determined for three different runway pavement configurations to cover a wide range of possibilities the USAF might encounter, as listed below. A fourth option that considered a PCC keel and an AC exterior pavement was also asked for but not tested since information concerning this configuration could be generated from the other options.

- 150 ft wide runway surfaced with 12 to 18 in. of PCC
- 150 ft wide runway surfaced with 4 in. of AC
- Retrofit of an arresting system installed over a 10 ft wide PCC slab in a full-width AC pavement runway.

A list of candidate construction methods was developed by AFCEC and the ERDC to accomplish each surfacing scenario along with a general sequence of events and material requirements. Further details on each method are described later in this report.

2.2.1 PCC methods

2.2.1.1 Traditional partial-depth method

This approach follows the traditional procedure given in AFI 32-1043 (Department of the Air Force 2012) where a partial-depth repair is performed to create the recessed slot for the UHMW panels. The panel slot has been relocated to a transverse slab joint rather than the center of the slab to minimize future slab damage. The repair must be demolished to at least 3⅝ in. in depth to follow UFC minimum repair dimension requirements. Final screeding of the bedding layer leaves a smooth surface for the panel to bear on and allows for recessing just below the panel's surface. Equipment and supply modifications are required for increased installation speed and constructability. The following construction tasks are required:

1. Saw cut the panel area.
2. Remove material to form the panel recess.
3. Place the bedding layer.
   a. Screed the surface of the repair to provide 1⅝ in. depth for panel installation and panel recessing.
   b. Allow concrete to cure to a compressive strength of 2,500 psi.
   c. Saw cut joints in the bedding layer where existing pavement's joints are located.
4. Cut water drain channels in the surface of the bedding layer.
5. Place and align UHMW panels.

6. Drill anchoring locations.
7. Install anchoring.
8. Finalize installation of UHMW panels after full cure of the anchor adhesive.
9. Seal joints.

2.2.1.2 Full-depth method

This approach uses a full-depth patch beneath the pendant, following UFC concrete repair guidance. The size of the patch made for this repair depends on the drilling equipment used to install load transfer devices at the sawn construction joints created. Tie bars are needed in the slab interior to promote aggregate interlock with the existing slab that remains. Dowels will be needed along the transverse joint between slabs to either replace cut original dowels or provide load transfer between slabs where sawing has smoothed the vertical face of the joint. Since the length-to-width ratio for the repair made will most likely be less than ¾, reinforcement is required to control contraction cracking. Placing concrete around removable formwork fabricated to the shape of the final slot dimensions removes the need for cutting a panel slot and installing a bedding layer. Once the repair is cast, the anchor installation tasks required are similar to that of the traditional saw-cut and chisel method. The following construction tasks are required:

1. Saw cut the panel area to full depth.
2. Remove pavement within marked perimeter.
3. Drill holes for tie bars and dowels into existing pavement.
4. Install accessory hardware.
5. Place concrete.
6. Allow concrete to cure to a compressive strength of 2,500 psi.
7. Cut water drain channels into the surface of the bedding layer.
8. Place and align UHMW panels.
9. Drill anchoring locations.
10. Install anchoring.
11. Finalize installation of UHMW panels after full cure of the anchor adhesive.
12. Seal joints.

2.2.1.3 Partial-depth repair with cold planer

This approach is similar to the traditional partial-depth method except that a cold planer tool is used to demolish the pavement. Multiple shallow passes are made with the cold planer to form the panel void. An airfield vacuum sweeper truck is used to capture the small sized millings to minimize FOD and cleanup efforts. A bedding layer or drainage cuts may not be needed, depending on the cutting action of the cold planer and the resulting surface. After the panel void is cut to the required depth, installation tasks are similar to those given in the traditional partial-depth method.

2.2.2 AC methods

2.2.2.1 Traditional foundation approach

This approach follows the traditional procedure given in AFI 32-1043 in which a trench is excavated to prepare a concrete foundation used to affix the UHMW panels. The instructions discuss backfilling the trench with a layer of compacted aggregate base material and capping with a thick layer of concrete; however, the rapid-setting flowable fill and concrete packages currently used in the USAF ADR procedures will be exchanged for these elements to increase the speed of construction required to keep the runway operational at the conclusion of the work day. The final elevation of the concrete cap accommodates the required recessing of the panel, and no bedding layer is required. Reinforcement is added to the mid-depth of the slab cast to control any concrete contraction cracking. The following construction tasks are required:

1. Saw cut the panel area.
2. Excavate a 3 ft deep trench.
3. Compact the trench depth.
4. Backfill the trench with 1 ft rapid-setting flowable fill.
5. Install reinforcement.
6. Place rapid setting concrete.
7. Allow concrete to cure to a compressive strength of 2,500 psi.
8. Cut water drain channels into the concrete surface.
9. Place and align UHMW panels.
10. Drill anchoring locations.
11. Install anchoring.
12. Finalize installation of UHMW panels after full cure of the anchor adhesive.
13. Seal joints.

2.2.2.2 Soil anchoring

This approach uses a different type of anchoring foundation to fasten the UHMW panels to the pavement. Instead of excavating, backfilling, and placing a large concrete foundation for the anchoring points, individual friction piles (micropiles) with threaded connection points are created in the pavement system to resist pulling out of the soil. A panel slot is cut into the surface of the AC. Piles are constructed at each panel anchor location by excavating a void with an auger, installing the pile's steel skeleton, and backfilling the remaining void with concrete. Separate tie-down anchorage is required for this method, since there is no shared foundation element available between the individual piles as with the traditional method. AFI 32-1043 provides drawings for constructing tie-down anchorage for AC runway pavements where UHMW panels are not used. The following construction tasks are required:

1. Saw cut the panel area.
2. Remove the material in the panel slot.
3. Place and align UHMW panels to mark pile locations.
4. Auger pile holes.
5. Install pile hardware.
6. Backfill piles.
7. Place and align UHMW panels.
8. Install UHMW panels.
9. Construct tie-down anchorage.
10. Seal joints.

2.2.3 Pavement retrofit

The retrofit option is used in a different situation than the other methods previously discussed. Here elements of an in-service, defective, or out-of-specification panel system must be recycled in its current location. The scenario will focus on a pavement constructed similarly to that described in the 2009 aircraft incident mentioned earlier in the problem statement, since it is believed having both PCC and AC pavements across the width of the runway makes this scenario the most difficult system to repair. The surface of the concrete inlay must be demolished and the area restored to an asphalt-surfaced pavement by using a large patch to be in compliance with AFI 32-1043. Partial demolition of the concrete surface to allow for a 2 in. minimum thick overlay allows for recycling the in-place concrete for the foundation material needed. Milling the surface directly under the pendant for the panel slot and placing a bedding layer restores the area to receive UHMW panels. The following construction tasks are required:

1. Saw cut the outlying asphalt patch area.
2. Remove panels and demolish any existing anchorage items.
3. Remove the surface material within the patch area.
4. Resurface concrete with AC overlay.
5. Allow AC overlay to cool.
6. Remove material to form the panel area.
7. Place bedding layer.
8. Cut water drain channels into the surface of the bedding layer.
9. Place and align UHMW panels.
10. Drill anchoring locations.
11. Install anchoring.
12. Finalize installation of UHMW panels after full cure of the anchor adhesive.
13. Seal joints.

2.3 Timed trials testing process and measurements taken

A controlled installation crew conducted small-scale timed trials of each candidate installation method from mid-July to mid-August 2013 at the Silver Flag Training Site. One timed trial was completed for each candidate repair method, where the projected construction sequence was completed from start to finish using the estimated equipment and supplies. All timed trials were videotaped for analysis of the individual work task timing and effort required by personnel.

Trials covered 30 linear feet of pavement per installation method tested. Initial timing estimates suggested 30 ft was the most progress that could be made within the 12 hr AFCEC schedule threshold for most groupings of work tasks of the methods considered. This length of paneling also allowed for the completion of two full 15 ft wide slabs for PCC pavement testing and allowed half of the 60 ft AC taxiway to remain open to local traffic during the testing effort. Timing data were scaled up or down as needed for work tasks expected to be finished across different runway widths.

The installation crew consisted of six to nine people for the majority of the work completed. The crew that completed the majority of the work was made of two to three ERDC construction technicians and four USAF Rapid Expeditionary Deployable Heavy Operation Repair Squadron Engineers

(RED HORSE) airmen. The airmen's skill disciplines included two horizontal construction experts (dirt boys), one vertical construction expert (structures), and one power and propulsion expert (power/pro). The RED HORSE group represented typical personnel that might be tasked with runway arrester system paneling installation when deployed. Power/pro personnel are responsible for maintaining AAS. ERDC engineers assisted as needed when additional personnel were required for more laborious tasks.

The tasks required to complete each repair were broken down, and the critical path and appropriate work task sequencing of each method determined. Task rearrangement and modifications to equipment and supplies from those used in the trials, detailed in AFI 32-1043 or manufacturer recommendations, were made to make the installation process more efficient in terms of both overall timing and ease of installation.

3 Results

Small-scale timed trials of each candidate installation method were conducted using a controlled installation crew in July and early August 2013. One timed trial was completed from start to finish for each candidate repair method, using the projected equipment and supplies. Work series were not completed from beginning to end due to equipment availability at the beginning of trials and the overall length of the time required being greater than a standard work day. Timing for some tasks was taken from multiple similar operations completed on a single day or work for one installation method completed over multiple days. The initial work tasks developed by the ERDC were tested. Modifications were made to the listing to improve the process for time improvements and personnel or equipment efficiency. Projected task timing was developed for the updated and improved list of work tasks for comparison against project requirements. Timing information was entered into Microsoft Project project management software to assist with estimating timing where tasks could be overlapped.

3.1 Initial task considerations

The general plan of attack for all installation methods focused on packaging together work tasks that minimized significant damage to the pavement surfacing that would stop aircraft operations and maximized work completed within each phase to meet the preferred time requirements. If both items could be accomplished, minimizing the total number of work days was considered for overall plan optimization.

3.1.1 Demolition

Significant damage was deemed as an action that created a change in roughness greater than ⅛ and ¼ in. over a 12 ft length longitudinally and transversely along the runway, respectively. These criteria are similar to current construction specifications for new runway PCC pavement in Unified Facilities Guide Specifications (UFGS). For this work, any demolition efforts where pavement materials were removed or excavation occurred fall into this category; however, thin saw cuts were considered harmless to aircraft as long as smooth cuts were made with minimal spalling and a thorough cleaning of the area followed to remove any FOD generated. Accessory items preinstalled to the pavement surface to prepare for future work tasks also follow these same criteria, but the accessories installed must also not pose a risk for tire damage. With this in mind, demolition efforts could be broken up into separate phased events where all work up to removing the pavement surface is completed across a portion to the full width of the runway. Surfacing removal and replacement in shortened segments transversely with panel installation could be accomplished within reduced time frames. Since saw cutting was not projected to take more than 6 hr to complete per each 30 ft of installation section, combining all saw-cutting efforts into 1 or 2 days for the entire 150 ft runway width made the best use of time on the runway for a work event and minimized time lost to multiple mobilization and cleaning events over multiple days.

3.1.2 Joint sealing

Joint sealing of the panels was believed to be best accomplished after all paneling was installed so all sealant could be placed monolithically with a single thorough cleaning of the sealant surfaces. This task was expected to take much fewer than 6 hr to complete per each 30 ft of installation section; therefore, all sealing was combined into a single work day for the entire 150 ft width of the runway.

Joint sealing work tasks at this time were considered to be cleaning joints, installing backer rod, placing of typical self-leveling airfield-grade silicone sealant, and allowing the surface of the sealant to cure before reopening the runway. UHMW paneling dimensions considered were the standard configuration given in the AFI 32-1043. The ERDC is currently completing research to prevent debonding of sealant from the joint faces by increasing joint preparation tasks and grooving the perimeter of the panel. If ongoing ERDC work recommends changes to the UHMW paneling configuration or preparation efforts, the proposed work tasks and timing given in this document will need to be revisited to verify the runway closure timings are still met.

3.1.3 Progressive assembly of select tasks

Progressive assembly (assembly line) is the manufacturing process of constructing a component in multiple pieces by a group of workers with specific assigned tasks. The goal of progressive assembly is to minimize time lost to individual workers conducting all tasks required to construct components individually by collectively completing a portion of work required in a specified sequence. Work tasks that contain multiple, similar actions are good candidates for this procedure to reduce the total effort needed if multiple personnel are available to assist. Work tasks like running multiple saws for demolition efforts or breaking down the adhesive anchor installation for completion by a team with individual, specific tasks fall into this category. Staggering out multiple tasks within the process also assists in mitigating congestion of working personnel.

3.1.4 Tie-down anchoring design

The pendant is restrained to the panel area by tying the cable to a series of anchoring points along the runway with 5,000 lb maximum-strength nylon ropes. AFI 32-1043 details the three anchoring systems for use with tie-down anchors; however, none were considered for this work due to projected difficulty when installing or inability to find the specified parts. The shepherd's hook and locally manufactured plate anchors described must be installed into plastic concrete. Installation of these anchors may be difficult since the anchoring location must be accurately located and molded into the plastic concrete before the panels are placed. Post-concreting installation makes for an easier alternative since prospective locations can be easily determined once the UHMW panels are installed and final positions fixed, but a utility cut and patch in the pavement will be required to provide the plastic concrete needed to embed and affix the anchor in the pavement for use. Both the shepherd's hook and the plate anchor shown in the AFI document will require a full-depth patch when installed, since both anchors are required to be embedded 10 in. into the pavement and most likely greater than half the slab thickness in most situations. A less invasive installation method may be available. The alternative cable tie-down anchor shown in AFI 32-1043 appears to be designed for an asphalt concrete overlaid pavement where the anchor can be removed, but the specified part numbers could not be found during an internet search.

One option available is installing an eyebolt designed for lifting applications as the tie-down fixture. An eyebolt with a shoulder will be required for this application since the loading applied to the eyebolt will be at an angle. A small amount of demolition will be required to construct the recessed void for the eye and the embedment hole for the bolt shank, but demolition needed is significantly less than the coring for a full-depth repair. The adhesive specified for the panel anchoring can be used for this application since it is load bearing and most of the installation equipment required is similar to what is already needed. Additional wire brushes for cleaning the hole perimeter may be needed, depending on the final eyebolt shank diameter selected.

A review of available eyebolts against the requirements given for the alternative cable tie-down anchor given in AFI 32-1043 showed that a 3,500 lb allowable vertical lifting load anchor was the best match to the dimensions given, but ultimately a 10,000 lb capacity anchor will be required since the loading applied to the anchor is a combined shear/axial loading and not just an axial load. A 5,000 lb capacity anchor was used for the timed trial testing to model the installation procedure since no performance testing of the anchor was completed, but the final design will include the 10,000 lb model (McMaster-Carr part number 3018T22 or equivalent).

To install the eyebolt, a two-step demolition procedure is needed. A shallow, larger diameter void is needed to house and recess the eye below the pavement surface. Once the final void depth is determined, a hole must be drilled deeper into the concrete for the shank of the eyebolt.

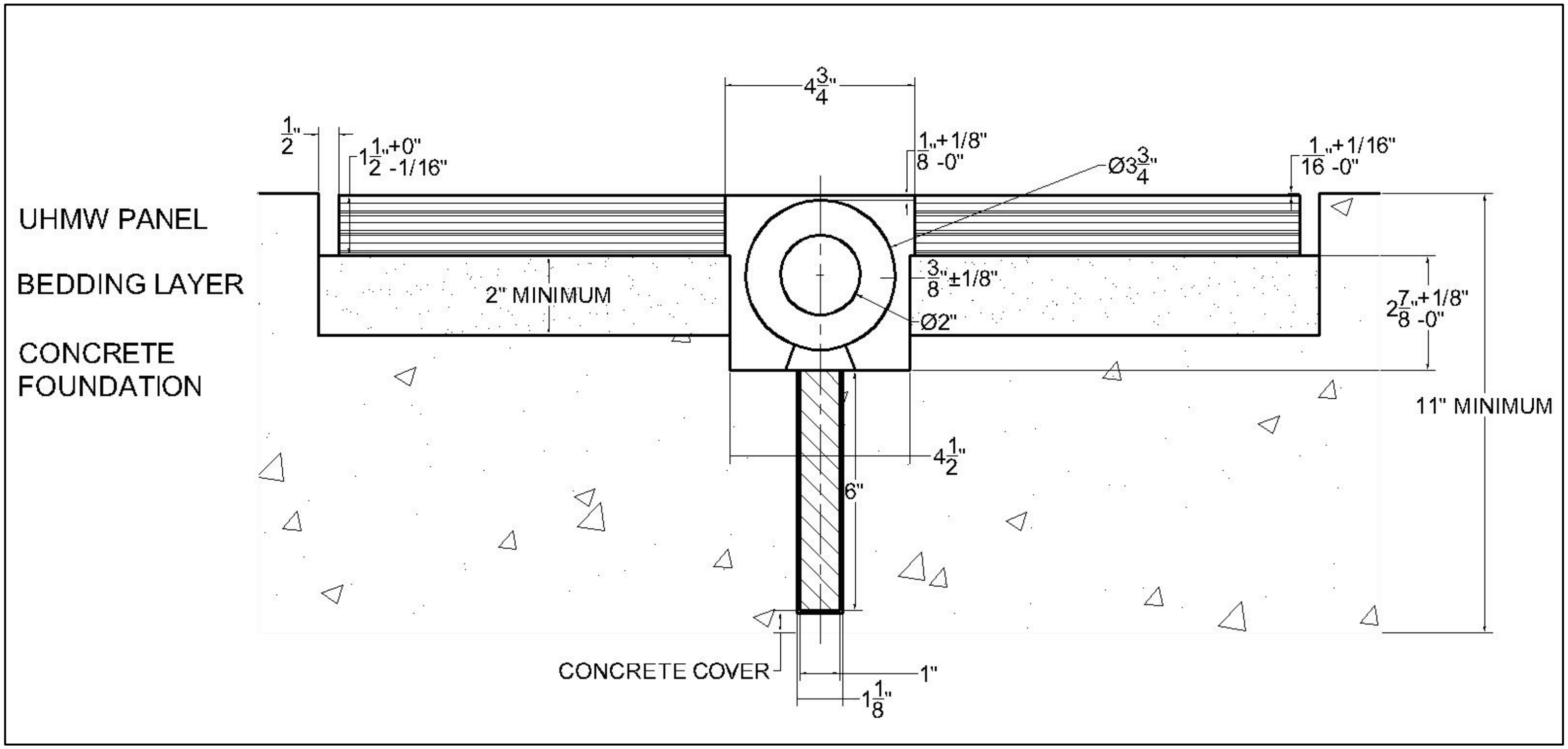
Partial-depth coring can be used to make a smooth void perimeter; however, the water used will moisten the concrete and can reduce the load capacity of the adhesive anchoring epoxy when installed. To remove water from the demolition procedure, a dry cutting masonry core barrel was selected, as shown in Figure 8. The model selected can be used with the rotary hammer drills currently used for the panel anchoring, provided the drill bit specified matches the chuck type of the hammer drill on hand. A model with a pilot drill bit is recommended to assist in accurately centering the void made and assist in locating the hole needed for the shank. The diameter of the core bit selected should be compatible with the outer diameter of the eyebolt selected. For the prospective anchor selected, a drill that produces an outer diameter of 4½ in. is needed. Use of this size core barrel will require a larger hole be cut in the UHMW panel for the tie-down anchoring to accommodate the core diameter. The diameter of the tie-down anchoring hole in the UHMW panel should be no less than 4¾ in.

Figure 8. Dry cutting core barrel.

Figure 9 details the anchor installation and cutting depths required to mimic that currently given in AFI 32-1043 that can be used for any scenario where concrete is available to install the anchor, provided no reinforcement is in the vicinity of the installation area. The carbide-tipped masonry drill bits are not able to cut through steel. Additional drill bits are commercially available to cut through steel reinforcement but were not considered for this work. One modification to the stock eyebolt anchor recommended is to fully thread the shank of the eyebolt to provide additional adhesion to the concrete.

After the perimeter is cut, the concrete within the cut area can be leveled with a demolition hammer with chisel and bushing bit to construct the eye void and cleaned with compressed air and a vacuum to remove loose material. An additional hole must be drilled to embed the shank of the bolt into the concrete with the adhesive epoxy. Installation of the eyebolt will be similar to that of the threaded rods used for the panel anchoring. Drill bit sizing will be ⅛ in. larger in diameter than the diameter of the bolt shank, as typically specified for adhesive anchoring. The anchor selected has a 1 in. nominal diameter; therefore, a 1⅛ in. drill bit will be required.

Figure 9. Tie-down anchor installation.



3.1.1 Daily pendant replacement

Replacing the pendant at the end of the construction day for any retrofitting effort will not be considered for this work. Partially tying down the pendant as new anchorage points are installed for new installations will also not be considered. It is projected that the pendant will be removed from the runway before demolition work begins and will not be operational until all required construction tasks are completed to be in full compliance with AFI 32-1043. Making the arrestor not operational also saves significant time at the beginning and at the end of the construction day lost to dismantling and reassembling the pendant. Pendant reassembly could begin towards the end of the panel installation work or after any joint-sealing activities at a minimum.

3.2 Results for PCC pavement installations

Three methods were investigated for the expedient installation of UHMW panels in PCC pavements. The traditional method used a partial-depth repair to create a smooth, recessed void in which to anchor the panels. A full-depth repair method was also considered to reduce the time needed for demolition efforts and to correct the uneven surface produced before installing panels. A second partial-depth repair method was also considered in which different demolition equipment than that used for the traditional method was used.

3.2.1 Traditional partial-depth method

The first option considered for concrete-surfaced installations was the traditional partial-depth repair. AFI 32-1043 details the construction events used for installing a UHMW panel from a timed study. A total of 21.5 hr over three construction days was reported to install eight panels. No details on the panel or slab dimensions used are given, but eight panels approximately correspond to a two-slab-wide installation for the multiple panel arrangements shown in AFI-32-1043. From the scheduling described, the installation methods given did not allow for the runway to remain operational at the conclusion of the second and third work days since only the panel void was prepared by the end of day 2.

To better accomplish the construction tasks, equipment and supply modifications to the listing given were made to increase the installation speed and best tailor items to those currently in USAF inventories. With increased speed on major construction tasks, the scheduling of work tasks or daily project extents was modified to best comply with USAF airfield mission requirements.

All saw cutting videotaped was reviewed to determine average timing to complete operations with the saws available. The SuPR kit has three pavement cutting saws available: a large, self-propelled concrete floor saw; a medium-sized, operator-pushed walk-behind saw; and a hand-held cutoff saw. A hand-held concrete chainsaw is also in the SuPR kit but was not considered for this work. All saws are shown for reference in Figure 10. Saw timing was broken down into three separate tasks for timing review to determine the time required to make individual cuts: mobilization, alignment, and cutting. Table 1 details the cutting-task timing and cutting rates for the larger saws considered for this work used to estimate sawing work-task durations for asphalt and concrete pavements. Timing is based on multiple cuts from all the cutting completed. Cut lengths focused on 2, 5, and 30 ft long cuts. Two-person teams of an operator and a spotter to assist and monitor saw alignment were used with all sawing except for the cutoff saw, for which only the operator was used. Cutoff-saw timing was not collected since it was not used on a major scale. The cutoff saw was mainly used for minor trimming of surface pavement or short cuts for joint restoration. Timing information is expected to be similar to that of the walk-behind saw since the equipment is as mobile and easy to operate. Table 1 shows the floor saw can cut faster than the walk-behind saw but takes longer to mobilize and significantly more time to align due to its weight. The self-propelled movement of the floor saw helped minimize binding of the saw from cutting more than the saw was capable and allowed for more continuous operation.

Figure 10. Pavement sawing capabilities in the SuPR kit.

Floor saw

Walk-behind saw

Cutoff saw

Chain saw

Table 1. Saw-cut timing information.

Saw type	Mobilization (sec)	Alignment (sec)	Cutting Speed (ft/min)
Floor saw	30	320	5.8
Walk-behind saw	15	30	3.6

Table 2 details the required sequence of work tasks initially needed before the trial began. Table 3 details the timing recorded for each task, scaled up to the appropriate runway width completed per work day. Process improvements and new projected timings are given.

Table 2. Initial sequencing of required work tasks for PCC traditional method.

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Daily Runway Closure Time (hr)
1	1	Demolition	Mark longitudinal sawcuts.	150	5:30
2			Saw cut shallow longitudinal relief cuts.		
3			Wash saw slurry.		
4			Clean work zone.		
5	2 Repeat five times		Remove material with light jackhammers.	30	11:55
6			Remove debris and clean area.		
7			Final slot inspection.		
8			Water blast slot.		
9		Panel Installation	Place bedding layer.		
10			Allow concrete to gain strength; clean site.		
11			Cut joints in bedding layer and clean perimeter.		
12			Conduct final slot inspection.		
13			Cut water drain holes.		
14			Water blast completed slot.		
15			Air blast completed slot.		
16			Place and arrange panels.		
17			Shim panels.		
18			Drill anchoring holes.		
19			Clean anchoring holes.		
20			Install anchors.		
21			Allow adhesive to cure; begin clean up.		
22			Install hardware on panel anchors.		
23			Remove shims and finish cleanup.		
24		Tie-Down Anchorage Installation (as required)	Drill anchoring holes with core bit.		
25			Clean hole made.		
26			Drill anchor embedding hole.		
27			Clean hole made.		
28			Install anchors.		
29			Tie-down pendant to anchoring.		
30	3	Joint Sealing	Air blast joints and anchor holes.	150	6:30
31			Install backer rod.		
32			Install sealant.		
33			Allow sealant to cure; clean site.		

Table 3. Installation timing information for PCC traditional partial-depth method.

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended Major Process Improvement	Projected Timing (h:m)	Personnel Used	Major Equipment Changes or Additions
1	—[a]	5	Tape measure, chalk line	Break up into two teams: marking and chalking.	1:00	4	Same as before
2	0:32	2	Walk-behind saw	Make multiple longitudinal cuts using only floor saw.	2:45	3	Floor saw
3	0:07	1	Pressure washer	Add second pressure washer as team works toward crown to assist with additional cleaning area that will require cleaning.	1:00	2	Same as before
4	—	—	—	Add airfield sweeper cleaning for final debris removal.	0:30	1	Airfield sweeper truck
-	—	—	—	Add shallow relief cutting to transverse direction.	5:15	3	Those used in tasks 1-4
5	0:52	6	Jackhammers, air compressor, hand tools	Ensure operators angle jackhammer correctly.	1:00	6	Same as before
-	—	—	—	Add milling slot depth to level surface.	0:15	2	CTL with cold milling attachment
6	—	—	—	Add airfield sweeper truck vacuuming to clean fine millings.	0:05	1	Airfield sweeper truck
7	0:15	2	—	Inspect demolished slot depth elevation, correct as needed. Additional time needs to be provided in case excessive fine tuning is needed, but milling the high spots should mitigate a significant amount of risk.	0:30	3	Demolition tools
-	—	—	—	Add airfield sweeper truck vacuuming to clean fine millings.	0:05	1	Airfield sweeper truck
8	—	—	—	Water blast the slot to remove any latent material.	0:15	1	Pressure washer
-	—	—	—	Add air blast to remove standing water and dry surface.	0:03	1	Air compressor with air lance
-	—	—	—	Caulk joints and allow material to set.	0:30[b]	2	Caulk and application gun

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended Major Process Improvement	Projected Timing (h:m)	Personnel Used	Major Equipment Changes or Additions
-	—	—	—	Apply bonding agent to dry surface if required. Begin applying just before caulk set time ends.	0:15	2	As directed by concrete manufacturer
9	0:40	7	CTL, concrete mixer attachment, water truck	Add washout water collection equipment. Additional time needed in case an additional batch of concrete is needed due to the potential for a rough surface after demolition.	1:00	8	Same as before, dump hopper
10	2:00	0	—	Monitor strength gain with non-destructive testing (NDT) equipment.	2:00	1	Schmitt hammer or equivalent
11	—[a]	—	—	Move cleaning/grinding perimeter to separate task.	0:15	2	Walk-behind saw
-	0:08	2	Angle grinder	Make cleaning separate task after concrete placement.	0:10	2	Same as before
12	1:12	2	—	Inspect bedding later elevation, correct as needed.	0:45	3	Demolition tools
13	0:15	2	Walk-behind saw	Add steel track piece along panel anchoring points.	0:15	2	Same as before
14	—	—	—	Water blast the slot to remove saw slurry.	0:10	1	Pressure washer
-	—	—	—	Add airfield sweeper truck vacuuming to clean fine millings.	0:05	1	Airfield sweeper truck
15	0:05	1	—	Add air blast to remove standing water and to dry surface.	0:05	1	Air compressor with air lance
16	0:05	4	—	Have panels pre-positioned and laid out close to site.	0:05	2	—
17	0:34	4	Shims, hammers, pry bars, stringline	Add additional shims for secure placement.	1:00	4	—
18-20	1:30	4	Hammer drill, air compressor, electric drill, adhesive gun, portable band saw	Add additional personnel to begin installation after cleaning Set out hardware in advance, modify anchor lengths as needed.	1:15	6	Same as before

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended Major Process Improvement	Projected Timing (h:m)	Personnel Used	Major Equipment Changes or Additions
24-28	0:36		Hammer drill, air compressor, electric drill, adhesive gun	Only one installed for timing; time doubled assuming two installed when needed.	0:30		Same as before
21	—[a]	—	—	Time varies depending on product used. Select product that meets set time requirement at concrete slab temperature.	1:00[b]	—	—
22	1:00	6	1-¼ in. socket	Use teams of people to remove/collect setting hardware or place/tighten nut, remove setting hardware with impact wrench, grossly tighten nut with impact wrench, stagger personnel and tasks to allow for more room to work.	0:45	6	Impact wrench, torque wrench
-	—[a]	1	Angle grinder	Modify setting hardware for more consistent anchor embedding; modify anchor length as needed before installing.	0:30	2	Same as before
23	0:15	2	Pressure washer, air compressor	Maintain a clean site over course of project; begin major cleaning of site after adhesive is placed; begin sweeping site after all work is complete.	1:00	2	Airfield sweeper truck
29	—[a]	2	—	Do not reinstall pendant until after joint sealant is installed.	—	—	—
30	1:00[a,b]	1	Air compressor	—	1:00	1	Same as before
31	3:00[a,b]	2	—	Use insertion tool to place at correct depth instead of by hand; use precut short longitudinal pieces.	1:30	2	Backer rod insertion tool
32	3:00[a,b]	2	Air compressor, sealant gun	—	3:00	2	Same as before
33	—[a]	—	—	Time varies depending on product used and environmental conditions. Allow surface to harden before trafficking.	1:00[b]	—	—

a) No timing data collected
b) Estimated

Notable installation issues observed and applicable modifications made to specific work tasks are described below.

1. Saw cutting relief cuts would be extended to both the longitudinal and transverse directions to assist with the surface removal and reduce cleanup efforts (Figure 11). Previously, cuts spaced approximately 6 in. apart transversely were believed to be enough to help the demolition team gage the correct removal depth. However, when chiseling, personnel were making multiple small pieces that required extensive cleanup. Later testing for the retrofit option used a grid of relief cuts to assist the demolition crew by breaking the concrete off into larger, intact chunks. By angling the jackhammer more horizontally at the base of the small block, an intact prism of concrete popped off the surface, leading to a more plane and smoother surface. Disposal of the prism was much easier on personnel since fewer pieces were created, and they were light enough to easily lift and move by hand.

Figure 11. Additional relief cut construction and removal of smaller concrete pieces.

Additional relief cutting required additional work days to prepare for demolition. Separating the sawing work by cut lengths was recommended rather than making all cuts on one day to help meet the preferred closure time and minimize work site congestion. Projected timing using the information in Table 1 shows the floor saw is more efficient at cutting long stretches rather than short segments where multiple realignments are required. Time lost before cutting is completed can be made up when the saw makes the cuts. The walk-behind saw can be moved and positioned easily but does not cut as fast as the floor saw. It is recommended to use the walk-behind saw for making multiple short cuts and the floor saw for fewer, longer cuts to tailor the tasks completed to the operation of the equipment available. Use of the different saws operating in different directions will add congestion to the site and may lead to accidental cutting of water hoses. Therefore, it is recommended to make sawcuts in each direction on separate days.

2. Multiple additions of cleaning the work area with an airfield sweeper truck were added to ensure a clean site.
3. Cold milling the demolished completed slot was added to provide a plane surface (Figure 12). Milling ⅛ to ¼ in. after removing the surface material by jackhammer will minimize high peaks within the slot depth when casting the bedding layer on the slot surface. Cold milling is also projected to minimize the need for additional leveling of the repair void. Only a quick inspection of the surface may be needed to verify the panel slot is ready for the next tasks; however, the lengthy duration of the inspection will remain in the work schedule as a precaution.

Figure 12. Compact track loader (CTL) milling concrete.

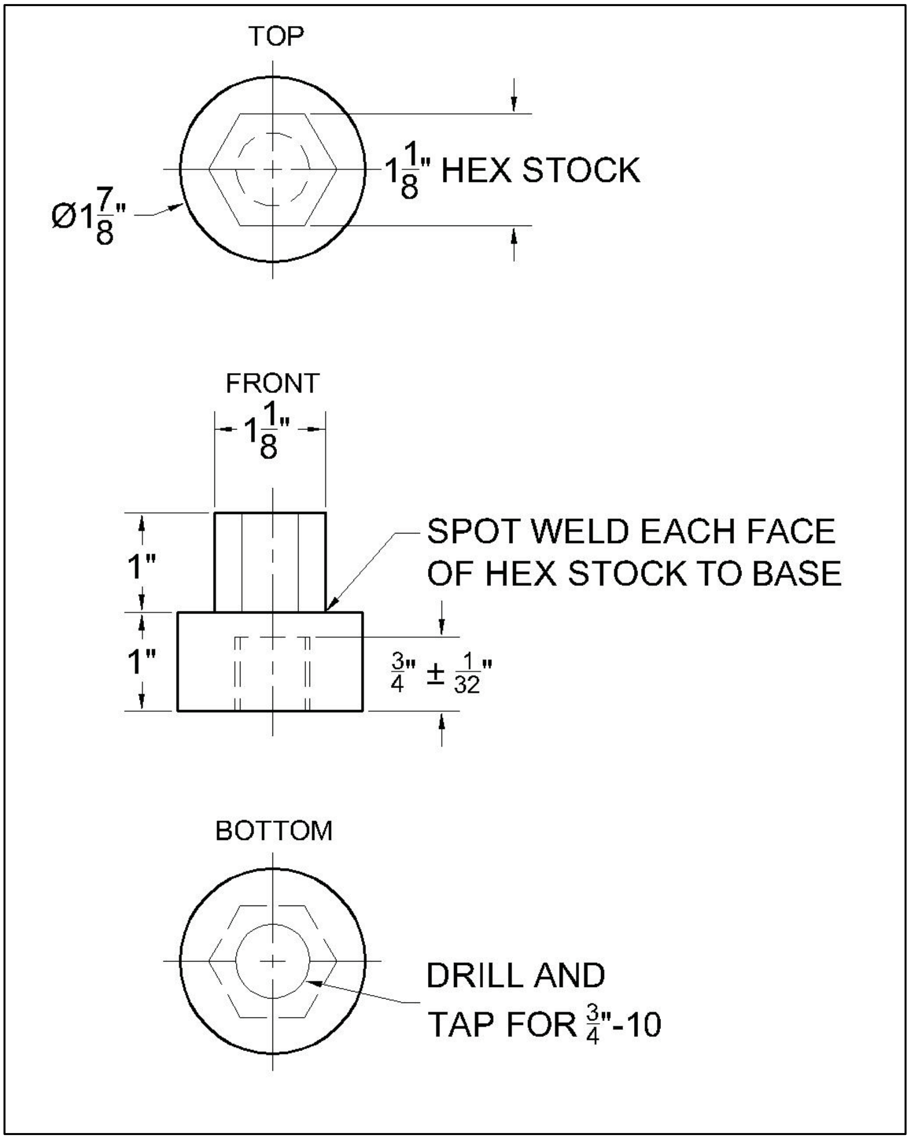
4. UFC concrete repair guidance (Headquarters, Department of the Army, Navy and Air Force 2001d; Headquarters, Department of the Army, Navy, and Air Force 2001e) and UFGS concrete pavement repair specifications (UFGS 2008) show placing a bead of caulk along joints to prevent repair material from entering and locking up the joint. It is not required for USAF partial-depth repairs. Adding the caulking task is recommended to ensure a good quality patch is made that mitigates any potential for poor repair performance.
5. Procurement of rapid-setting concrete materials for the bedding layer placement should focus on those that use water as a bonding agent. Using water as a bonding agent eliminates a task in the work sequence, since water blasting the slot area will saturate the surface. Any standing water will be removed by air blasting to make the panel slot ready to accept concrete.
6. The strength of the bedding layer should be monitored as it cures to verify when work can continue and the concrete is ready for drilling. Different materials and changes in temperature may cause the concrete to gain strength at rates different from those expected. If the strength gain is faster than expected, work may commence sooner and ultimately lead to additional time reductions on the runway. If strength gains are slower than expected, preparations can be made to gain additional time on the runway from airfield management to allow for additional curing in advance or abort additional construction tasks and begin filling the panel void with concrete to restore the pavement surface. Measurements made by nondestructive Schmidt hammer testing (ASTM 2018) to estimate in situ strength after placement is recommended since it is a small and easy-to-use tool. Correlations of the Schmidt rebound number to the measured strength of specific repair materials are also recommended for greater accuracy when estimating in situ strength and required cure times.
7. A washout container was added to the equipment listing to provide an environmentally friendly way to collect and dispose of concrete wash water. Washing out in the container also helps maintain a cleaner site. A dumping hopper capable of being moved with a forklift would make a suitable container. The hopper should be fully welded and have a lid to minimize loss of the waste water during transport.
8. Wire brushing the slot perimeter was made a separate work activity after concrete placement to enhance the cleanliness of the slot perimeter.

9. Moving the panel location to a transverse joint increases the risk that the anchor-drilling team may encounter embedded steel within the slab. Since the panel anchoring locations are fixed and the carbide-tipped hammer drills cannot cut through the dowels, the only option is to cut the excess length of the anchor. A bandsaw with a metal cutting blade is recommended to trim the individual anchors to quickly reduce their length as encountered (Figure 13).

Figure 13. Field modification of panel anchoring rods.

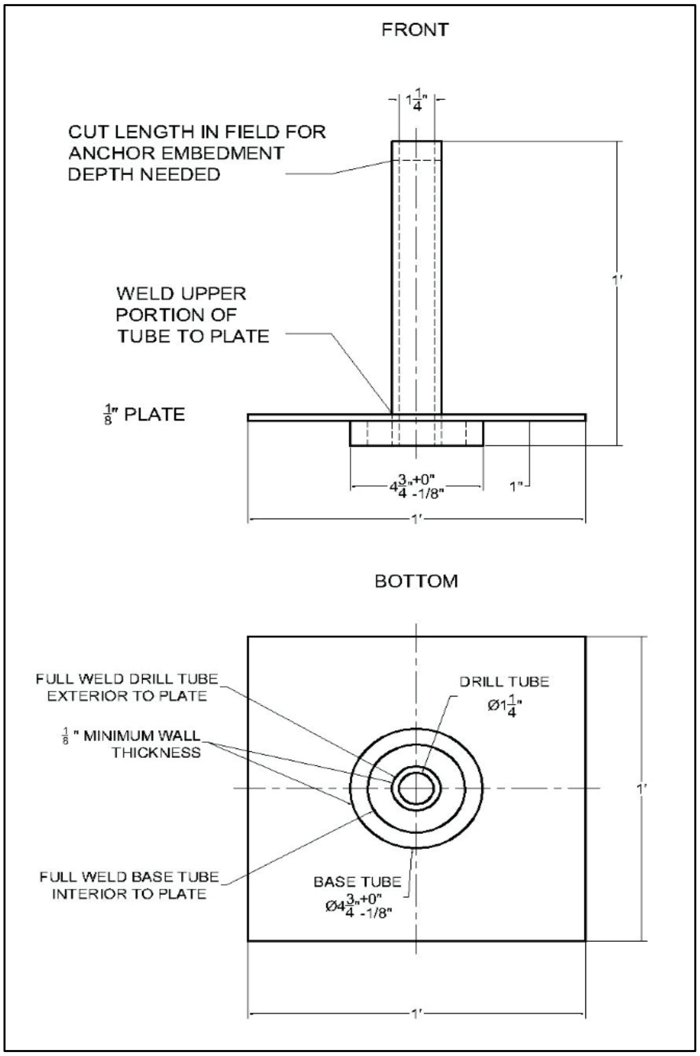
Setting the correct elevation for the panel anchoring was difficult. Some anchors required grinding to ensure the anchor rod was below the panel surface. The problem was attributed to the cap nuts used for temporary setting hardware. The top of the rod enters the dome of the cap nut when the nut is completely twisted onto the rod. Efforts to lower the elevation of the rod by rotating the nut 1½ to 2 full revolutions of the nut from fully twisted on the rod varied, and grinding was still needed in some cases. To reduce the need for grinding and have more consistent installations, future installations should use a custom installation nut to precisely set the elevation of the panel anchoring rod. A drawing of the temporary hardware is shown in Figure 14 and consists of a steel puck that has been bored and tapped to accept the threaded anchor rod to a tolerance that minimizes grinding of the panel anchoring rod head. The diameter of the puck is small enough to fit into the UHMW panel anchor recess. A piece of hex rod is welded to the top of the puck to allow for quick removal by an impact wrench after the epoxy has hardened.

Figure 14. Temporary setting hardware drawing.



10. An installation jig like that used for the panel anchoring should be used for drilling the hole for the tie-down anchor eyebolt to ensure proper drill bit alignment and cutting depth. The jig should be similar to construction as that used for the panel anchoring, sized to fit just inside the cored void and accept the drill bit diameter needed for the eyebolt shank. Figure 15 details a prospective jig for this work.

Figure 15. Tie-down anchor drilling jig.

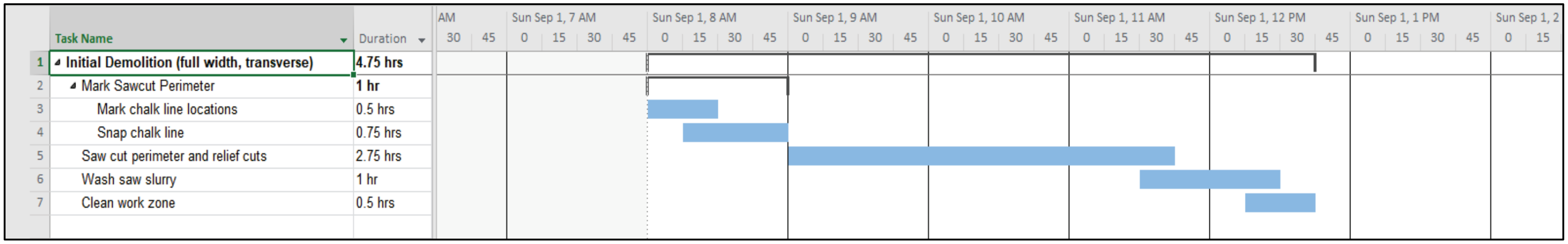


11. Significant changes to the installation of backer rod are needed. Use of an insertion tool is believed to expedite installation, automatically place the rod at the correct depth, and reduce personnel effort. The tool should have wheels to push along the pavement surface and an adjustable wheel that pushes the rod into the joint reservoir. A handle allows personnel to work upright. The transverse joints should be placed first as long pieces followed by the short longitudinal pieces to minimize installation work. Precut longitudinal segments are recommended to speed installation.

Figure 16 shows the prospective Gantt charts developed for the installation work days. Table 4 details the modified sequencing of work tasks with updated timing. Four separate phases are needed to complete all tasks.

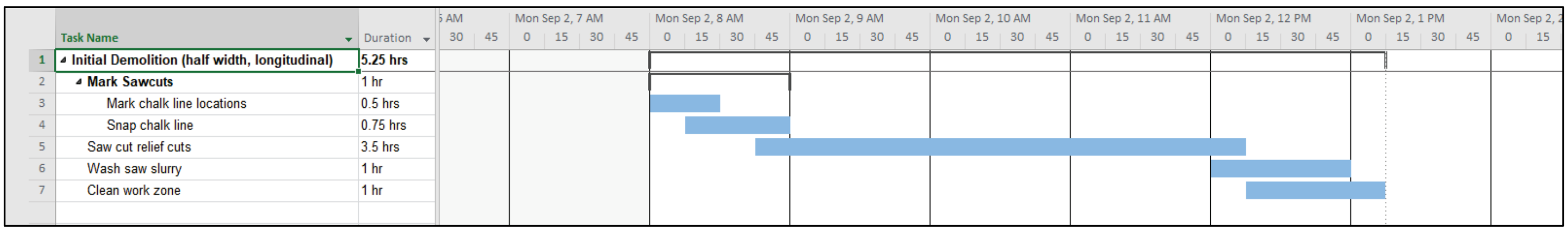
Figure 16. Gantt chart for traditional partial-depth repair installation method concrete surfaced pavements.

a. Initial demolition – Phase 1



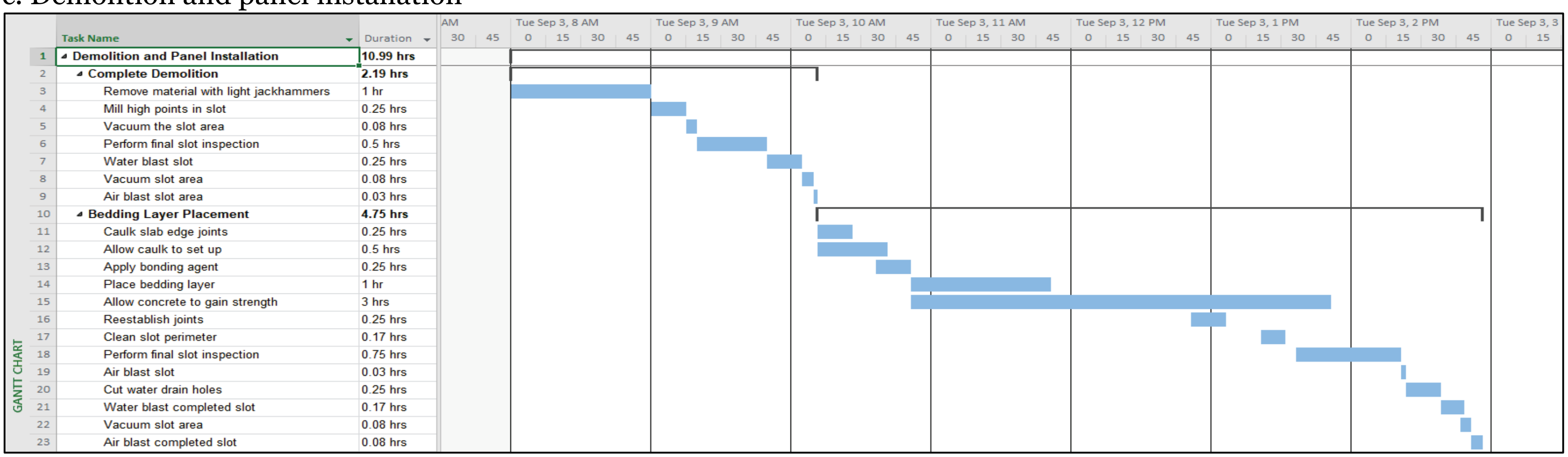
(Sheet 1 of 1)

b. Initial demolition – Phase 2



(Sheet 1 of 1)

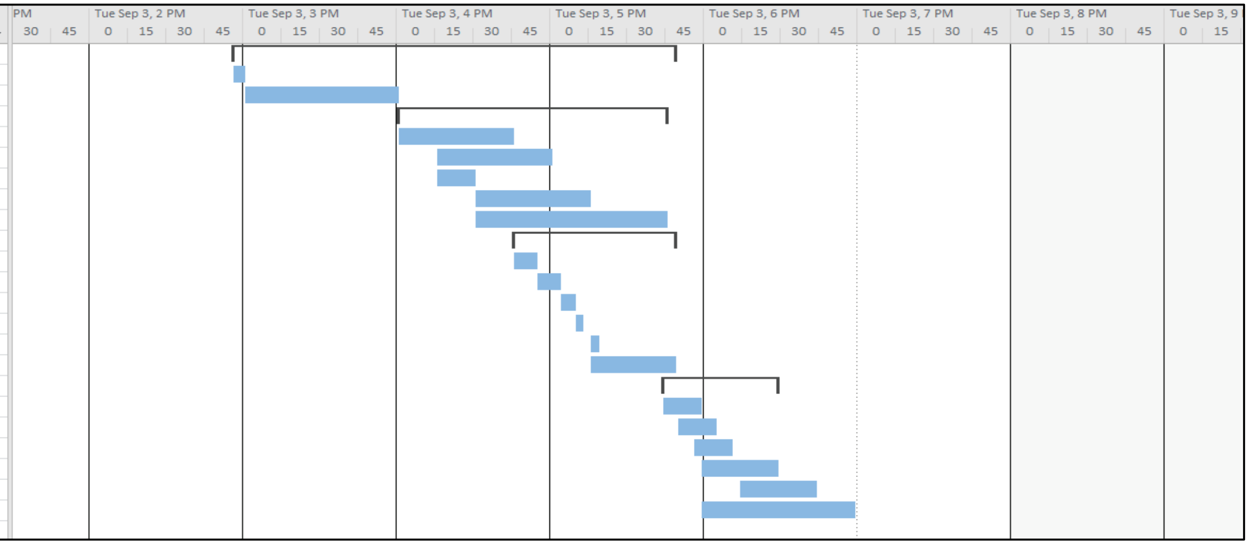
c. Demolition and panel installation



(Sheet 1 of 2)

GANTT CHART

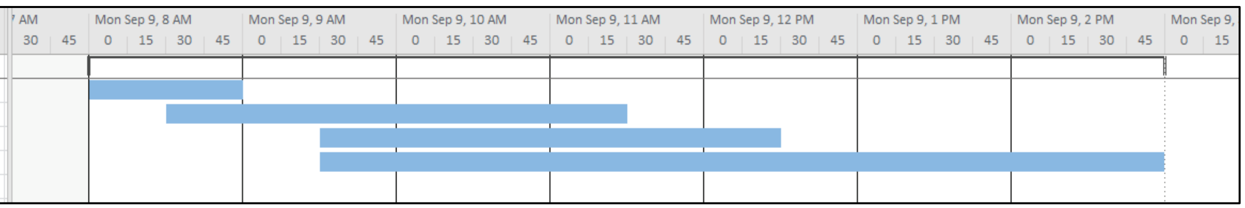
	Task Name	Duration
24	◢ **Place and Install Panels**	**2.88 hrs**
25	Place and arrange panels	0.08 hrs
26	Shim panels	1 hr
27	◢ **Panel Anchor Installation**	**1.75 hrs**
28	Drill anchoring holes	0.75 hrs
29	Clean anchoring holes	0.75 hrs
30	Set out anchors	0.25 hrs
31	Install anchors	0.75 hrs
32	Allow adhesive to cures	1.25 hrs
33	◢ **Install Tie Down Anchoring (As required)**	**1.05 hrs**
34	Dry core and remove interior	0.15 hrs
35	Clean hole made	0.15 hrs
36	Drill anchor embedding hole	0.1 hrs
37	Clean hole made	0.05 hrs
38	Anchor installation	0.05 hrs
39	Adhesive cures	0.55 hrs
40	◢ **Install Panel Anchor Hardware**	**0.75 hrs**
41	Remove setting hardware	0.25 hrs
42	Install hex nut	0.25 hrs
43	Gross torque hex nuts	0.25 hrs
44	Fine torque hex nuts	0.5 hrs
45	Verify final anchor elevations	0.5 hrs
46	Remove shims and clean up	1 hr



(Sheet 2 of 2)

d. Joint sealing

	Task Name	Duration
1	◢ **Joint Sealing (full width)**	**7 hrs**
2	Air blast joints	1 hr
3	Install backer rod	3 hrs
4	Install sealant	3 hrs
5	Sealant cures, begin clean up	5.5 hrs



(Sheet 1 of 1)

Table 4. Optimized sequencing of required work tasks for PCC traditional method.

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
1	1	Demolition	Mark transverse sawcuts.	150	4.8
2			Saw cut transverse relief cuts and perimeter.		
3			Wash saw slurry.		
4			Clean work zone.		
5	2 Repeat two times		Mark longitudinal sawcuts.	75	5.3
6			Saw cut longitudinal relief cuts.		
7			Wash saw slurry.		
8			Clean work zone.		
9	3 Repeat five times		Remove material with light jackhammers.	30	11.0
10			Mill slot depth.		
11			Vacuum demolished panel slot.		
12			Perform final slot inspection.		
13			Water blast slot.		
14			Vacuum slot.		
15			Air blast slot.		
16		Panel Installation	Caulk slab edge joints and allow material to set up.		
17			Apply bonding agent (as needed).		
18			Place bedding layer.		
19			Allow concrete to gain strength; clean site.		
20			Cut joints in bedding layer.		
21			Clean slot perimeter.		
22			Perform final slot inspection.		
23			Air blast slot.		
24			Cut water drain holes.		
25			Water blast completed slot.		
26			Vacuum slot area.		
27			Air blast completed slot.		
28			Place and arrange panels.		
29			Shim panels.		
30			Drill panel anchoring holes.		
31			Clean panel anchoring holes.		
32			Install panel anchor.		
33			Allow adhesive to cure; begin clean up.		

(Sheet 1 of 2)

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
34	3 Repeat five times		Install hardware on panel anchors.	30	11.0
35			Verify final anchor elevations.		
36			Remove shims and finish cleanup.		
37		Tie-Down Anchorage Installation (as required)	Core and demolish tie-down anchoring location.		
38			Drill tie-down anchoring holes.		
39			Clean tie-down anchoring holes.		
40			Tie-down anchor installation.		
41			Allow adhesive to cure.		
42	4	Joint Sealing	Air blast joints and anchor holes.	150	7.0
43			Install backer rod.		
44			Install sealant.		
45			Allow sealant to cure; clean site.		
(Sheet 2 of 2)					

Many of the required work tasks are sequential and little parallelization can be completed to reduce the total duration of the work. With the modified timing, two of the work phases are less than the preferred 6 hr time limit per work day. The additional two phases of work are less than the maximum 12 hr requirement. All phases of construction meet the maximum time allotted by the USAF. A total of nine work days is required to install a UHMW panel system across a 150 ft concrete surfaced runway with this option.

Many of the items and equipment are currently in USAF inventories, and all may be delivered to the site by C-130 aircraft. Items not included in a standard SuPR kit include water truck, airfield sweeper truck, air compressor lance, pneumatic adhesive dispensing gun, Schmidt hammer nondestructive testing device, torque wrench, caulk compound, steel cup brush, wooden shims, backer rod insertion tool, and a pneumatic sealant dispensing gun.

3.2.2 Full-depth method

The second option considered for concrete-surfaced installations was the full-depth repair option. The goal of the full-depth repair was to reduce the amount of time taken to demolish the concrete within the slot area by fully removing the concrete surface. A custom piece of formwork is used to shape the panel slot as the void is backfilled with plastic concrete, eliminating the bedding layer. After the formwork is removed, the panels can be arranged and installed like that described for the traditional method.

When planning for the dimensions of the repair made with this option, considerations for the operations of a concrete drill must be made. The dowel drill is required to make holes in the vertical face of the concrete slab to embed tie and dowel bars within the repair. Ties and dowels are highly recommended for this repair since sawing efforts will make a formed/construction joint where aggregate interlock is heavily reduced from smoothing the joint faces. Failure to provide aggregate interlock or provide a load transfer mechanism will increase the stress generated from aircraft loads and has the potential to accelerate fatigue damage to the slab. Typical construction procedures for embedding steel into concrete pavements involve drilling a hole and bonding the steel into the hole with an epoxy adhesive. The SuPR kit has a surface-mounted concrete drill in its inventory. Review of the equipment's technical information showed the drill required at least $4^1/_2$ ft in which to operate when the drilling arm rotates into position. Use of this equipment doubles the area of the repair made for the paneling system as compared to the traditional partial-depth repair option, but the speed and the accuracy of the equipment are a necessity for this work to construct a proper repair following UFC guidance. A cut 5 ft from the transverse joint was selected to ensure enough concrete was removed for the drill's use (Figure 17). Dowel and tie sizing and spacing will follow that provided in UFC airfield pavement design guidance 3-260-02 (Headquarters, Departments of the Army, Navy, and Air Force 2001a).

With the plan dimensions of the repair determined, all prospective combinations of transverse slab width to repair width yield a significantly rectangular area with a ratio outside the recommended range of 0.75 to 1.25 used for joint spacing determination of new slabs. Reinforcement was added to the full-depth repair to control cracking transversely and to keep any cracks tightly held together (Figure 18). Keeping the prospective cracks tight will be particularly important if cracks intersect drilled anchor holes to ensure maximum anchorage capacity when installed.

Figure 17. Concrete drill used in repair void.

Figure 18. Repair reinforcement.

American Concrete Institute (2005) Designation: 318 guidance for temperature and shrinkage steel design was used to select the reinforcement. A minimum reinforcement ratio of 0.18% was used when selecting the amount of steel to use. A 5/8 in. diameter steel bar was selected since UFC guidance recommends the same size bar used for tie bars to minimize using multiple bar sizes. Using this information, five bars spaced at a 12 in. center-to-center were selected for transverse steel. No cracking was expected in the longitudinal direction since the longitudinal repair width was much smaller than the minimum spacing; therefore, steel was not specified for crack control. Longitudinal bars were added at an approximately 30 in. spacing to help support the transverse bars and maintain their elevation while placing concrete. Material properties for the steel were similar to those required by UFGS (2015) concrete pavement specifications. Grids were assembled in advance of the work day on site from 20 ft stock lengths of reinforcement and a manual cutting/bending tool to minimize the time needed on the runway for this task. Assembled grids were light and rigid enough to be lifted and placed into the repair void by hand using two personnel.

The reinforcing steel would be supported just above the mid-height of the slab by the pre-installed dowels and ties on the exterior bars. A row of steel high chairs was added to the center of the reinforcement grid for additional support. Bars were cut to the transverse slab width of the existing pavement but cut short to provide a minimum bar cover of 3 in. for concrete exposed to earth to prevent corrosion. All bar intersections, both to other bars or accessory pieces, were tied using standard 16-gage tie wire to prevent movement after placement.

It was believed that full removal of the concrete surface would speed up demolition efforts, even though a larger repair is required. Portions of the slab would be removed by lifting the concrete out of the repair area and sending the concrete off site for further demolition and disposal. Anchorage and rigging for the lifting operations would be completed using a locally available forklift, the 5/16 in. steel tow chain in the SuPR kit, and concrete expansion anchors specified for a fiber-reinforced polymer (FRP) repair matting kit detailed by Rushing et al. (2016). The anchors chosen are in the USAF inventory and are reusable; however, no attempts to pre-install the anchors were made other than predrilling and cleaning the holes needed.

The anchor system's allowable tensile lifting capacity was verified against the prospective mass of concrete that would be removed. A pavement design in PCASE was conducted to estimate the thickest slab that might be encountered as a worst case scenario. Design assumptions include the following: the arrestor system is placed at the end of a runway (Traffic Area A), modified-heavy standard USAF design traffic, a standard 650 psi flexural strength concrete mixture (approximately 5,000 psi compressive strength), a slab on grade cross-section, and a modulus of subgrade reaction of 200 pci. PCASE determined a 20 in. slab would be needed for the assumed traffic section. Calculations for the minimum lifting force the anchor must be able to resist when removing square segments of the pavement are shown in Table 5 and show the maximum plan size of the concrete removed is 2½ ft square. Removing this sized small slab will require three long transverse cuts and multiple short longitudinal cuts when initial demolition tasks are made. A locally available standard warehouse forklift with a lifting capacity of 5,000 lb could be used at a minimum to remove the concrete slabs from the pavement, but multiple other pieces of equipment would be capable as well, provided the minimum lifting capacity is met (Figure 19).

Table 5. Lifting anchor design calculations.

Concrete Element Width (ft)	Max Volume Projected to Lift (ft^3)[a]	Maximum Weight Projected to Lift (lb)[b]	Maximum Force Anchor Resists (lb)[c]	Allowable Anchor Tensile Load by Concrete Strength (lb)[d]	
				4,000 psi	6,000 psi
5	41.7	6,250	9,375	2,490	3,275
2.5	10.4	1,563	2,344		

(a) Assumes 20 in. thick pavement maximum is removed.

(b) 150 lb/ft^3 used for assumed concrete unit weight.

(c) 50% more force to account for dynamic loading and segments of uncut concrete at corners.

(d) Manufacturer uses safety factor = 4; installation depth is greater than the minimum provided for strengths given.

Due to the prospective slab thicknesses that will be encountered in the field, saw-cutting efforts must rely on using the larger floor saw for cutting the concrete slabs to their full depth. The typical walk-behind saw in a SuPR Kit is capable of cutting with up to an 18 in. diameter blade, which can cut to a maximum depth of only 6 in. Most airfield slabs will be significantly deeper than this, so use of the walk-behind saw will be applicable only for partially completing the longitudinal cuts since they are shorter and it is less critical that these cuts be straight. Use of the floor saw will be recommended for all cuts with this work to minimize the different pieces of equipment needed.

Figure 19. Slab removal by forklift.

Additional considerations are needed in order to produce straight full-depth saw cuts. Multiple passes of the saw with different sized saw blades will be required to cut the full depth of the concrete present. Changing blades for multiple passes with one saw will be time consuming. Use of additional saws outfitted with a variety of blade diameters can reduce time lost to changing saw blades, but the work conducted by multiple saws will have to be staggered to minimize conflicts that will create downtime for the saws.

Once the concrete pavement is removed, rapid-setting concrete is placed to fill the void. To further reduce installation time, formwork can be placed in the void to cast the shape of the panel slot (Figure 20). The formwork should be easy to assemble and dismantle on site and accurately mold the panel slot. Once the concrete cures to a minimum compressive strength of 2,500 psi, the formwork can be removed, and the panel anchoring can be installed.

Figure 20. Wooden formwork used for the panel slot in new concrete placement.

Table 6 shows the initial sequence of tasks for the PCC full-depth method and the timing recorded for each phase of the work scaled up to the appropriate runway width to be completed per work day and the anticipated runway closure times. Process improvements and new projected timing are shown in Table 7 details of the modified sequencing of work tasks and updated timing.

Table 6. Initial identification, sequence, and estimated completion rate of tasks for different work phases involved in PCC full-depth method.

Task	Work phase	Phase	Task description	Runway width completed per work day (ft)	Projected daily runway closure (hr:min)
1	1	Demolition	Mark areas.	150	7:45
2			Make full-depth saw cuts.		
3			Drill anchor hole.		
4			Install lifting anchor.		
5			Dismantle surface extruding pieces of anchors.		
6			Wash saw slurry.		
7			Clean work zone.		
8	2 Repeat five times		Reassemble anchor with rigging hardware.	30	14:50
9			Lift out small concrete slabs.		
10		Install accessory items	Mark drilling locations.		
11			Drill tie bar locations.		
12			Drill dowel locations.		
13			Clean drilled holes.		
14			Install full-depth compressible insert.		
15	2 Repeat five times	Install accessory items	Install ties.	30	14:50
16			Install dowels.		
17			Allow adhesive to cure.		
18			Grease dowels and place expansion caps.		
19			Install reinforcement grid.		
20			Install slot formwork.		
21		Replace surfacing concrete	Place rapid-setting concrete.		
22			Allow concrete to cure.		
23			Dismantle formwork.		
24			Cut joints in bedding layer.		
25			Final slot inspection.		
26			Clean slot perimeter.		
27			Air blast slot area.		
28			Cut water drain holes.		
29			Water blast completed slot.		
30			Air blast completed slot.		
					Sheet 1 of 2

Task	Work phase	Phase	Task description	Runway width completed per work day (ft)	Projected daily runway closure (hr:min)
31	2 Repeat five times	Panel installation	Place and arrange panels.	30	14:50
32			Shim panels.		
33			Drill anchoring holes.		
34			Clean anchoring holes.		
35			Install anchors.		
36			Allow adhesive to cure; begin clean up.		
37			Install hardware on panel anchors.		
38			Remove shims and finish cleanup.		
39		Tie-down anchorage installation (as required)	Drill anchoring holes with core bit.		
40			Clean hole made.		
41			Drill anchor embedding hole.		
42			Clean hole made.		
43			Install anchors.		
44			Tie down pendant to anchoring.		
45	3	Joint sealing	Air blast joints.	150	6:30
46			Install backer rod.		
47			Install sealant.		
48			Allow sealant to cure; clean site.		
					(Sheet 2 of 2)

Table 7. Installation timing information for PCC full-depth method.

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended Major Process Improvement	Projected Timing (h:m)	Personnel Used	Major equipment changes or additions
1	—[a]	5	Tape measure, chalk line	Break up into two teams: marking and chalking.	0:30	5	Same as before
2	0:42	2	Walk-behind saw/floor saw	Make all cuts using an 18 in. diameter blade with floor saw.	3:00	2	Floor saw only
2	0:48[b]	2	Floor saw	Make all cuts using a 24 in. diameter blade with floor saw.	3:00	2	Same as before
-	—	—	—	Break sawing operations up into two work days and install lifting anchors on a third day to reduce time on runway. Use two saws each with different sized blades and stagger start of each saw.	—	—	—
6	0:07	1	Pressure washer	Add second pressure washer as team works toward crown to assist with additional cleaning of area.	1:00	2	Same as before
7	—	—	—	Add airfield sweeper cleaning for final debris removal.	0:30	1	Airfield sweeper truck
2	0:32	2	Floor saw	Make all cuts using a 36 in. diameter blade with floor saw.	3:00	2	Same as before
2	—[a,c]	2	Floor saw	Make all cuts using a 42 in. diameter blade with floor saw (if needed).	3:00	2	Same as before
6	0:07	1	Pressure washer	Use two machines to increase cleaning speed.	1:00	2	Same as before
7	—	—	—	Add airfield sweeper cleaning for final debris removal.	0:30	1	Same as before
-	—	—	—	Mark the center of each small slab before drilling.	1:00	2	Tape measure/guide, lumber crayon
3	2:00	3	Hammer drill	Add team members to distribute tasks better; do progressive assembly; add a plug to the portion of the anchor that remains after installation to prevent damage.	1:40	2	Hammer drill
4	0:30		Air compressor			1	Air compressor
7	—	—	—	Add airfield sweeper cleaning for final debris removal.	0:30	1	Airfield sweeper truck

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended Major Process Improvement	Projected Timing (h:m)	Personnel Used	Major equipment changes or additions
5/8		2	Impact wrench, rigging equipment	Have more rigging equipment on hand so forklifts can start removing earlier.	0:48	3	Same as before
9	0:52	2	Forklift, $^{5}/_{16}$ in. chain	Add another forklift and chair to increase removal. Use two operators and two riggers.	1:00	4	Web sling
10	0:07	1	Tape measure, spray paint	—	0:15	1	Lumber crayon
—	—	—	—	Compact the surface of the soil after slab removal.	0:33	1	Rammer compactor
11	0:20	3	Large air compressor, concrete drill	Test setting requirements for proper drill depth off-site before work. Start drilling dowels first so compressible insert installation starts after holes are drilled.	0:20	2	Same as before
12	0:52	3	Large air compressor, concrete drill	Test setting requirements for proper drill depth off-site before work begins. A second drill can be used that is pre-set to drill depth needed for ties and dowels to remove time lost to changing settings. If a second drill is available, two teams can be used by staggering the drill teams to reduce the overall time.	0:45	2	Same as before
13	0:52	2	Small air compressor, electric drill	Begin cleaning holes following manufacturer instructions when able, remain out of the way of the drilling team.	0:45	2	CTL with cold milling attachment
14	0:18	2	Knife	Locate holes to cut when able to install entire length of sheet without disturbing cleaning crew. Fill excess void areas around dowels with caulk.	0:40	3	Pneumatic adhesive gun, caulk
-	—	—	—	Attach insert to concrete.	0:20	3	Small air compressor and pneumatic nail gun or construction adhesive and adhesive dispenser
15	0:20	2	Small air compressor, pneumatic adhesive gun	Double team and equipment to increase installation speed.	0:20	4	Same as before
16	—						
17	—	—	—	Time varies depending on product used and environmental conditions. Meet manufacturers' projected cure time before completing additional work on embedded steel.	—	—	—

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended Major Process Improvement	Projected Timing (h:m)	Personnel Used	Major equipment changes or additions
18	0:07	2	Towel, dead blow/rubber hammer	Add personnel to increase installation speed.	0:10	3	Same as before
19	0:09	2	Rebar tying equipment	Add personnel to increase installation speed.	0:10	3	Same as before
20	—[a]	4	Wooden formwork, nails, hammers, sprayer	Redesigned steel formwork with bolted connections; anchor formwork into concrete with concrete wedge anchors.	1:00[d]	6	Steel formwork, ratchet, hammer drill, air compressor, torque wrench, sprayer
21	0:48	9	Volumetric mixer, forklift, spud vibrator, concrete hand tools	—	1:00	10	Same as before
22	—	—	—	Time varies depending on product used, admixture (retarder) dosage, and environmental conditions. Concrete cylinder testing showed concrete used had over 5,000 psi compressive strength at 4 hr. Any material must achieve 2,500 psi compressive strength before removing formwork and continuing with work tasks.	2:00	—	—
-	—	—	—	Monitor strength gain with NDT equipment.		1	Schmitt hammer or equivalent
23	—	4	Pry bar, walk-behind saw	Redesigned formwork will reduce dismantling effort, anchors need trimming /grinding to level/smooth. Begin disassembly (unfastening elements) near the end of the minimum cure period. Begin removing component from pavement after minimum strength is achieved.	0:30[d]	6	Ratchet, angle grinder
24	—[a]	2	Walk-behind saw	Add steel track piece along panel anchoring points.	0:15	2	Same as before
25	2:00	4	Depth guides, lumber crayons, demolition equipment	Redesigned formwork that resists buoyant forces will significantly reduce time needed.	0:30[d]	4	Same as before
26	0:09	2	Angle grinder, wire brush attachment	—	0:10	2	Same as before
—	—	—	—	Air blast slot area.	0:02	1	Air compressor
27	0:15	2	Walk-behind saw	—	0:15	2	Same as before

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended Major Process Improvement	Projected Timing (h:m)	Personnel Used	Major equipment changes or additions
28	0:05	1	Pressure washer	Ensure washing of slot area only, riding surface outside repair does not need through cleaning.	0:05	1	Same as before
29	0:05	1	Air compressor	—	0:05	1	Same as before
30	0:05	4	—	Have panels pre-positioned and laid out close to site.	0:05	2	—
31	0:34	4	Shims, hammers, pry bars, stringline	Add additional shims for secure placement.	1:00	4	—
32-37	1:30	4	Hammer drill, air compressor, electric drill, adhesive gun, portable band saw	Add additional personnel to begin installation after cleaning. Set out hardware in advance, modify anchor lengths as needed.	1:15	6	Same as before
38-42	1:10	4	Hammer drill, air compressor, electric drill adhesive gun	Only one panel installed for timing, additional tie downs may be added without significant additional time added. Phased construction using same personnel as with panel anchoring not used for these tasks, significant time saving projected if this is completed.	0:30	6	Same as before
43	—[a]	2	—	Do not reinstall pendant until after joint sealant is installed.	—	—	—
40	—[a]	—	—	Time varies depending on product used. Select product that meets set time requirement at concrete slab temperature.	1:00[d]	—	—
41	1:00	6	1-¼ in. socket	Use teams of personnel to remove/collect setting hardware or place/tighten nuts, remove setting hardware with impact wrench; grossly tighten nut with impact wrench, stagger personnel and tasks to allow for more room to work.	0:45	6	Impact wrench, torque wrench
-	—[a]	1	Angle grinder	Modify setting hardware for more consistent anchor embedding; modify anchor length as needed before installing.	0:30	2	Same as before
42	0:15	2	Pressure washer, air compressor	Maintain a clean site over course of project; begin major cleaning site after adhesive is placed; begin sweep site after all work is complete.	1:00	2	Airfield sweeper truck

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended Major Process Improvement	Projected Timing (h:m)	Personnel Used	Major equipment changes or additions
43	—[a]	2	—	Do not reinstall pendant until after joint sealant is installed.	—	—	—
44	1:00[a,c]	1	Air compressor	—	1:00	1	Same as before
45	3:00[a,c]	2	—	Use insertion tool to place at correct depth instead of by hand, use precut short longitudinal pieces.	1:30	2	Backer rod insertion tool
46	3:00[a,c]	2	Air compressor, sealant gun	—	3:00	2	Same as before
47	—[a]	—	—	Time varies depending on product used and environmental conditions. All surfaces need to harden before trafficking.	1:00[d]	—	—

(a) No timing data collected.

(b) 24 in. diameter blade not used in all sawing efforts, best estimated time reported.

(c) 42 in. diameter blade was not needed for the pavement used for testing. Additional time may be required for thicker pavements where saw blades larger than 36 in. diameter are required.

(d) Estimated.

Notable installation issues observed and applicable modifications made to specific work tasks are described in the following paragraphs:

1. Improved formwork is needed compared to that used in the time trial development (Figure 21). The formwork should be designed to produce a flat, smooth void where panels can be immediately installed after formwork removal. The formwork needs to be better designed to resist the buoyant uplift force created by the plastic concrete. Continued use of a pre-constructed form is recommended over a form placed into the plastic concrete to reduce the risk of excessive demolition from casting errors. The assembled formwork should be anchored into the pavement using concrete anchors to reduce the need for oversized weights to restrain the forms and provide a more unobstructed work area. Large air voids trapped under the horizontal plate need to be vented to provide a smooth surface. Consolidation by spud vibrators was not able to remove the air pockets due to the large surface area of the formwork. Additionally, the formwork should be reusable so it can be used over the width of the runway. An improved formwork package was designed to counteract the deficiencies described and is detailed in Chapter 4.

Figure 21. Various issues observed with the formwork used.

Formwork lifted from surface

Saw needed to free formwork

Air pockets present after removal

Form destroyed to remove

2. The compressible full-depth insert should be fixed to and remain in contact with the vertical surface of the concrete to prevent its movement during concrete placement (Figure 22). The cuts made to the concrete were not straight in the transverse direction, also contributing to the lack of contact of the insert to the concrete. The dowels alone are not sufficient to hold the insert in the proper position.

   Applying a construction adhesive is one available method to fully and continuously secure the insert along the concrete surface. The adhesive must have a quick setting (working or repositioning) time to ensure work can continue expeditiously after its placement. It is not critical for the adhesive to reach fully, cured strength before placing concrete, only that there is sufficient holding power to ensure the insert material stays in place. A review of commercially available adhesives showed limited products had set times of less than 15 min. Use of a pneumatic nail gun capable of shooting masonry nails or pins into the concrete could be used for rapid installation where no curing time would be needed. Little guidance as to the required spacing to secure expansion joint board or the minimum edge distance required to minimize spalling concrete edges was found. Additional information or testing is required to verify pinning the board as an installation technique.

Figure 22. Poor installation of compressible insert.

3. Improvements to the volumetric mixer chute are recommended for a cleaner placement. Significant splatter occurred when the material was placed (Figure 23). The volumetric mixer is typically used with large area openings, like craters, and the splatter material lands within the repair boundaries. A tremie should be used to help direct the concrete into the formwork void. The formwork should also be designed to

collect splattered or misplaced concrete, and the material should be directed into the repair.

Figure 23. Concrete splatter during volumetric mixer placement.

4. Future lifting of concrete from the pavement requires a more detailed rigging design with commercially available, generic components for safe and efficient slab removal. For the testing completed, a custom lifting attachment used by the ERDC for pavement anchor testing was used as the rigging attachment between the sling and the anchor head to remove the concrete. The demolition team planned to use the 5/16 in. chain from the SuPR kit using a single vertical hitch for the chain sling; however, the bolt of the lifting attachment was too large to fit through the center of the links. To complete the work, the chain was used in a basket hitch connection as shown in Figure 19. One end of the 100 ft chain, which has clevis hooks at each end, was wrapped around half the perimeter of the bolt on the lifting attachment and hooked to itself with the clevis hook to connect it with the shackle on the forklift. Use of the chain by this method is not recommended since hooking the chain onto itself reduces the lifting capacity of the chain by 25% (Garby 2005). The chain in the SuPR kit has a manufacturer's stated working capacity of 4,700 lb. Applying the load reduction brings the available capacity of the chain closer to the minimum required for lifting.

   To make a generic system with commercially available components for the expected maximum forces for the lifts completed, further consideration for an adequate sling, hoist ring, or equivalent piece of rigging equipment to provide a lifting point to the anchor head and a shackle to connect the sling to the ring hoist were required.

   In addition, to be sufficiently rated for the maximum vertical lifting capacity, multiple aspects of the hoist ring must be considered to accommodate the selected concrete anchor. Items to consider include the following:

- The center hole on the lifting hoist must be slightly oversized to freely let the anchor slide through when installing. The outer sleeve on the anchor has an outer diameter of 3/4 in.; therefore, the inner diameter of the of the lifting hoist should be 7/8 in. to accommodate or be sized to accept 7/8 in. bolts.
- The base of the hoist must be no more than 3 in. thick to ensure the minimum anchor embedment length is achieved to lift the estimated load using the 7 in. long anchor.
- Hoists with both fully swiveling (rotate around bolt) and pivoting (rotate about bolt) bases are recommended to compensate for any unbalance in the loading applied since loads on the rigging may be angular if the concrete is not cut to its full depth at corners.
- Hoists with preinstalled bolts included must have the bolt removed before use to accommodate the anchor, but all remaining hardware shall be used when operating the rigging.
- The minimum vertical capacity of the hoist should be 25% larger than the maximum force the anchor resists to fully accommodate any angular lifting. For the values shown in Table 5, the minimum working load capacity of the hoist ring should be 3,000 lb.

The shackle used should have a similar vertical lifting working load capacity requirement to that of the lifting hoist. The bolt should be small enough to fit through the hole of the chain links. The interior dimensions of the sling should be 1/8 in. larger than the hoist ring arm diameter to easily slide on and attach the shackle. Models with both a nut and a cotter pin used to secure the bolt should be used for safety. It is recommended to replace the cotter pin with a quick-connecting pin to reduce the effort required to install the cotter pin by the rigging personnel when attaching and removing the shackle (Figure 24).

Figure 24. Shackle with quick-connecting pin installed.

A shorter, separate piece of larger chain or other type of sling is highly recommended to complete this work to ensure safe lifting. Review of chain sizes showed a $^1/_2$ in. chain will provide the minimum required interior link dimensions needed for the prospective bolt shackle selected. A 3 ft long piece of chain should be a sufficient length to allow personnel to make the required connections and will be much more manageable that the 100 ft provided within a stock SuPR kit.

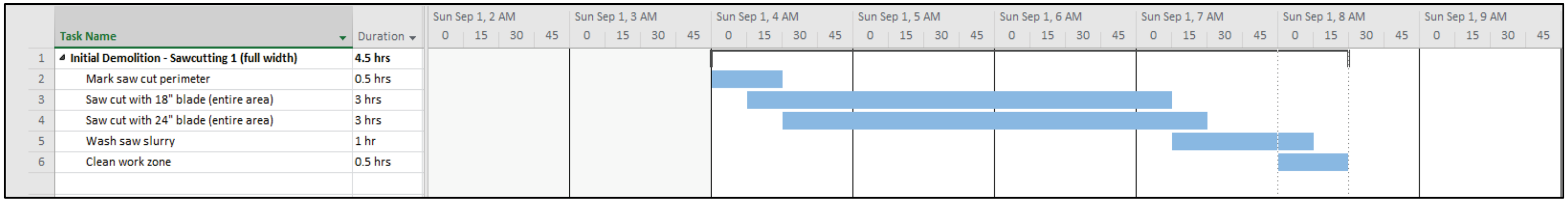
Use of chain slings may not be the most appropriate option for the prospective lifting conditions. Chain slings are not recommended for use with dynamic/impact loads (Garby 2005). A dynamic loading is expected when removing the small slabs if saw kerfs (overcuts) are not made to ensure the circular saw blade cuts the pavement full-depth the full length of the cuts made. Failing to overcut the pavement may leave the corners of the smaller slabs intact with the pavement that will remain. Lifting the pavement will cause the smaller slab to break free from the larger mass and may displace significantly once released. A synthetic web sling may be a more appropriate sling type to use for this application since a synthetic web sling is elastic (Garby 2005). The sling capacity specified should be greater than 3,000 lb for a choker hitch configuration. The choker hitch was selected as worst-case scenario in the event that the forklift used does not have a shackle installed on the fork attachment. Instead, the forks could be pushed together and the sling wrapped around the forks. A 4 ft long sling should be provided for use of a web sling to provide extra length lost to wrapping around the forks.

Timing shown will reflect that of individually lifted pieces of concrete. During field testing, a 10,000 lb capacity telehandler was used both to lift individual pieces by the anchors installed and to lift groups of slabs by wedging the forks beneath the slabs once enough were removed to allow the forks to fit into the void made. Lifting the smaller individual slabs with the anchors is preferred to prevent extensive damage to the underlying soil that would need time-consuming recompaction; to ensure a safe, controlled lift of the slabs without falling from the forks during transport; and to allow for a wider range of equipment possibilities to be used.

Figure 25 shows the prospective Gantt charts developed for the installation work days. Five different phases are needed to complete all work required. Many of the required work tasks are sequential, but some parallelization could be done to reduce the total duration of the work. With the modified timing, three of the work phases are less than the preferred 6 hr time limit per work day. The remaining two sets of work phases are less than the maximum 12 hr requirement. A total of nine work days is required to install a UHMW panel system across a 150 ft concrete-surfaced runway with this option.

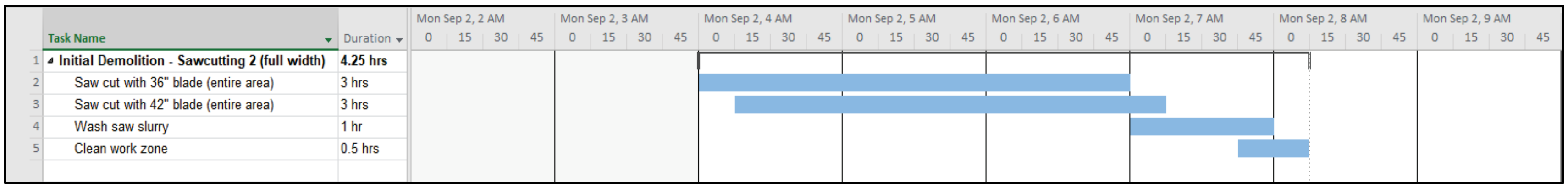
Figure 25. Gantt chart for PCC full-depth repair installation method.

a. Initial demolition – Phase 1



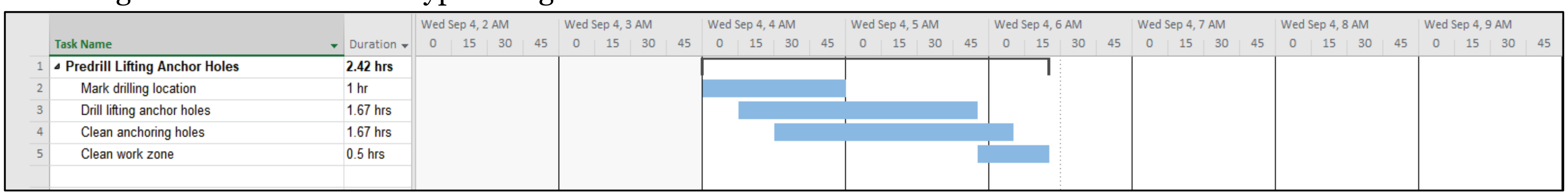
(Sheet 1 of 1)

b. Initial demolition – Phase 2



(Sheet 1 of 1)

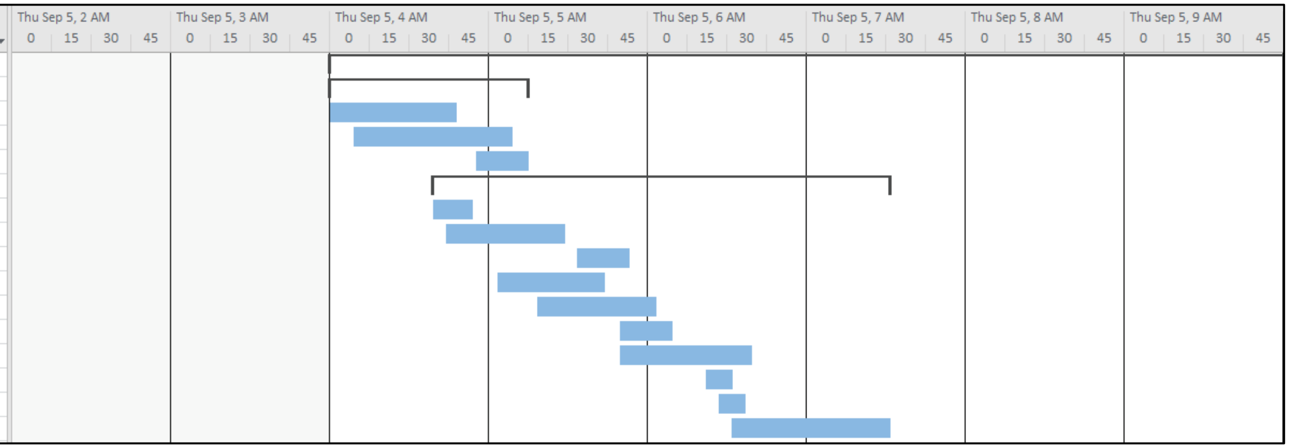
c. Drilling holes for mechanical type lifting anchors



(Sheet 1 of 1)

d. Finalize demolition and panel installation

	Task Name	Duration
1	**Demolition and Panel Installation**	**11.6 hrs**
2	**Complete Demolition**	**1.25 hrs**
3	Install anchors	0.8 hrs
4	Liftout/remove small slabs	1 hr
5	compact soil	0.33 hrs
6	**Install Accessory Items**	**2.88 hrs**
7	Mark tie and dowel locations	0.25 hrs
8	Drill dowel locations	0.75 hrs
9	Drill tie locations	0.33 hrs
10	Install compressible insert	0.67 hrs
11	Clean holes for ties and dowels	0.75 hrs
12	Install ties and dowels	0.33 hrs
13	Allow adhesive to cure	0.83 hrs
14	Grease and install caps on dowels	0.17 hrs
15	Install reinforcement grid	0.17 hrs
16	Install slot formwork	1 hr



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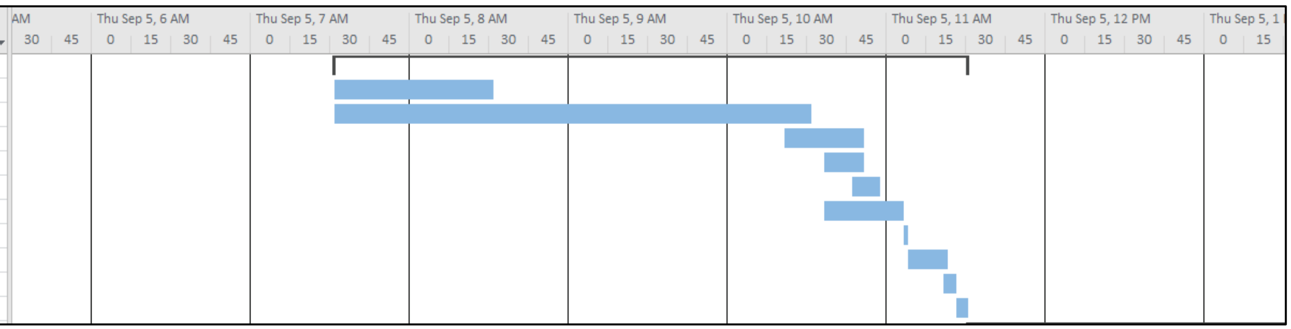
	Task Name	Duration
17	**Replace Surfacing Concrete**	**3.99 hrs**
18	Place rapid setting concrete	1 hr
19	Allow concrete to gain strength	3 hrs
20	Demolish slot formwork	0.5 hrs
21	Restablish joints	0.25 hrs
22	Clean slot perimeter	0.17 hrs
23	Final slot inspection	0.5 hrs
24	Air blast completed slot	0.03 hrs
25	Cut water drain holes	0.25 hrs
26	Water blast completed slot	0.08 hrs
27	Air blast completed slot	0.08 hrs



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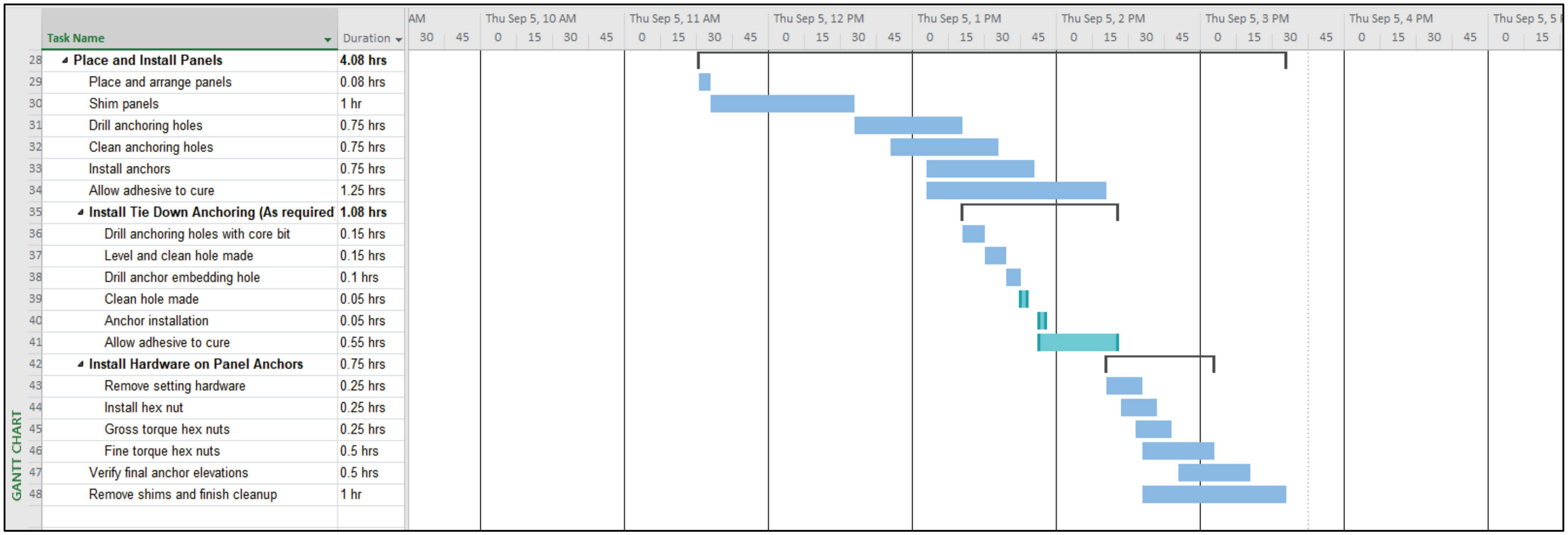

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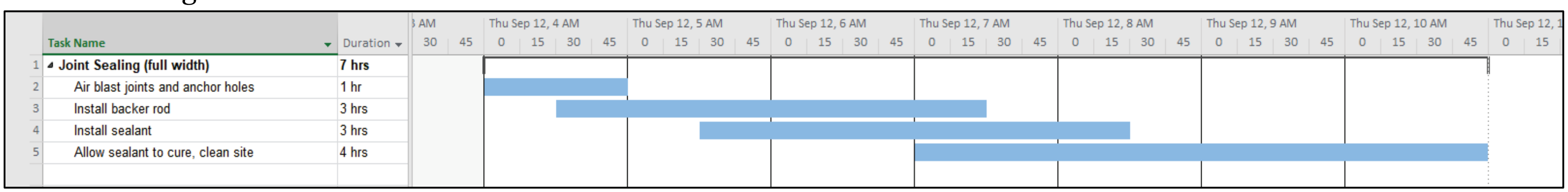
d. Joint sealing



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One item of potential concern is the proper timing to complete cutting of contraction joints to reestablish the existing joint pattern. Contraction joints are cut to mitigate uncontrolled cracking as concrete shrinks during curing from thermal differences and volume changes resulting from cement hydration. The proposed timing puts cutting of the contraction joints after the formwork is removed to allow the saw access to the pavement. Removal of the formwork is not recommended until the backfilled concrete reaches a minimum compressive strength of 2,500 psi to minimize potential damage at the sharp corners constructed at the panel void perimeter that would spall the pavement. Staging the work as shown follows similar practices used in Department of Defense (DoD) concrete pavement construction specification to prevent spalling when drilling dowel bars. However, not cutting the concrete soon enough before shrinkage occurs may lead to uncontrolled cracks forming away from the prospective jointing location. The cracking has the potential to form within the vicinity of the panel anchoring that is installed later in the work day and may reduce the ultimate strength of the anchor. Additional information concerning the shrinkage potential of the repair material used for backfilling is necessary to determine the best timing of this work. Since most rapid-setting materials produce significant amounts of heat when hydrating, it is assumed that the heat generated offsets the amount of shrinkage the backfilled concrete experiences and the concrete will not begin to significantly shrink until the slab begins to cool well after the formwork is removed and jointing is reestablished.

Table 8 details the modified sequencing of work tasks with updated timing. Many of the items and equipment are currently in USAF inventories, and all may be delivered to the site by C-130 aircraft. Items not included in a standard SuPR kit include those previously listed for the traditional partial-depth repair method along with the additional items detailed in the major modifications listed.

Table 8. Optimized sequencing of required work tasks for PCC full-depth method.

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Daily Runway Closure Time (hr)
1	1	Demolition	Mark transverse saw cuts.	150	4.5
2			Make saw cuts.		
3			Wash saw slurry.		
4			Clean work zone.		
5	2		Mark longitudinal saw cuts.	150	4.3
6			Make saw cuts.		
7			Wash saw slurry.		
8			Clean work zone.		
9	3		Mark drilling locations.	150	2.4
10			Drill anchor hole.		
13			Clean work zone.		
14	4 Repeat five times		Install anchors.	30	11.6
15			Lift out small concrete slabs.		
16			Compact soil.		
17		Panel installation	Mark drilling locations.		
18			Drill dowel locations.		
19			Install full-depth compressible insert.		
20			Drill tie bar locations.		
21			Clean drilled holes.		
22			Install ties and dowels.		
23			Allow adhesive to cure.		
24			Grease dowels and place expansion caps.		
25			Install reinforcement grid.		
26			Install slot formwork.		
27			Place rapid-setting concrete.		
28			Allow concrete to cure.		
29			Dismantle formwork.		
30			Cut joints in bedding layer.		
31			Perform final slot inspection.		
					(Sheet 1 of 2)

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Daily Runway Closure Time (hr)
32	4 Repeat five times	Panel installation	Cut water drain holes.	30	11.6
33			Water blast completed slot.		
34			Air blast completed slot.		
35			Place and arrange panels.		
36			Shim panels.		
37			Drill anchoring holes.		
38			Clean anchoring holes.		
39			Install anchors.		
40			Allow adhesive to cure; begin clean up.		
41			Install hardware on panel anchors.		
42			Remove shims and finish cleanup.		
43		Tie-down anchorage installation (as required)	Drill anchoring holes with core bit.		
44			Clean hole made.		
45			Drill anchor embedding hole.		
46			Clean hole made.		
47			Install anchors.		
48	5	Joint sealing	Air blast joints and anchor holes.	150	7.0
49			Install backer rod.		
50			Install sealant.		
51			Allow sealant to cure; clean site.		
					(Sheet 2 of 2)

3.2.3 Partial-depth repair with cold planer

A third option considered for concrete surface pavements was a variation of the traditional method described in AFI 42-1043. Instead of removing concrete for the slot void by chiseling, the panel slot was demolished by roto-milling using the CTL with cold planer milling attachment in the SuPR kit. The goal of this method is to reduce the manpower needed for slot demolition and increase the depth removal control when removing concrete. Multiple passes of the cold planer are made to remove the concrete in thin, controlled cuts until the minimum repair thickness is met. Two passes of the equipment are required for each cut increment, since the milling drum on the standard SuPR kit cold planar attachment is 18 in. wide and a 25 in. wide slot is required. The millings made are collected by sweeping and then disposed of off-site. Once the panel slot is cut to proper depth, construction tasks are the same as that used for the traditional partial-depth repair methods detailed earlier.

The key information collected for this repair method was the cutting rate of the equipment used. Timing data collected are not the best due to the tentativeness of equipment operators when using the machine, but the data can be used to gain insight into the demolition speed. Table 9 describes the last six passes made with the CTL for the single trial conducted. Previous timing information could not be determined because no video recording occurred, but passes 1 through 3 were made similarly at a 1/4 in. cutting depth with no issues. The timing results show that demolition efforts remove approximately four linear ft per minute for each pass made. To achieve the minimum required depth for installing the bedding layer, eight passes are required to remove 3 5/8 in. of concrete minimum and will require 2 hr to complete that portion of the slot construction. Demolition by roto-milling is equivalent to chiseling when comparing the two methods used.

Table 9. Roto-milling with CTL timing data.

CTL Pass Made	Cut Length, ft	Cut Depth, in.	Measured Timing, min						Average Cutting Rate, fpm	
			Backup	Adjust Cut Depth	Align Mill Head	Cut	Cleanup	Total	Cutting Only	All Work Tasks
4-R	30	0.5	-	-	2.2	2.4	3.4	8.0	12.5	3.8
4-L	30	0.5	0.4	1.1	1.0	1.3	2.2	5.8	24.0	5.1
5-R	30	0.5	0.5	0.0	1.2	3.9	2.5	8.1	7.7	3.7
5-L	30	0.5	0.5	0.0	0.9	3.5	2.3	7.1	8.7	4.2
6-R	30	0.5	0.3	1.8	0.7	2.3	3.7	8.9	13.0	3.4
6-L	30	0.5	0.3	0.3	0.7	2.0	1.9	5.2	15.1	5.8
End of Milling	-	-	0.2	0.9	-	-	-	-	-	-
Average			0.4	0.7	1.1	2.6	2.7	7.2	13.5	4.3
Standard Deviation			0.1	0.7	0.6	1.0	0.7	1.4	5.9	0.9

Table 10 details the overview of the required sequence of work tasks initially needed before the trial began. Table 11 details the timing recorded for each task, scaled up the appropriate runway width completed per work day. Process improvements and new projected timing are given.

Table 10. Initial sequencing of required work tasks for PCC partial-depth repair with demolition by milling.

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Daily Runway Closure Time (hr)
1	1	Demolition	Mark transverse sawcuts.	150	5:30
2			Saw cut slot perimeter.		
3			Wash saw slurry.		
4			Clean work zone.		
5	2 Repeat five times		Remove surface material.	30	11:55
7			Complete final slot inspection.		
8			Water blast slot.		
9		Bedding layer placement	Place bedding layer.		
10			Allow concrete to gain strength, clean site.		
11			Cut joints in bedding layer and clean perimeter.		
12			Perform final slot inspection.		
13			Cut water drain holes.		
14			Water blast completed slot.		
15			Air blast completed slot.		
16		Panel installation	Place and arrange panels.		
17			Shim panels.		
18			Drill anchoring holes.		
19			Clean anchoring holes.		
20			Install anchors.		
21			Drill tie-down anchoring holes.		
22			Clean tie-down anchoring holes.		
23			Remove shims and finish cleanup.		
24		Tie-down anchorage installation (as required)	Drill anchoring holes with core bit.		
25			Clean hole made.		
26			Drill anchor embedding hole.		
27			Clean hole made.		
28			Install anchors.		
29			Tie down pendant to anchoring.		
30	3	Joint sealing	Air blast joints and anchor holes.	150	6:30
31			Install backer rod.		
32			Install sealant.		
33			Allow sealant to cure, clean site.		
					(Sheet 1 of 1)

Table 11. Installation timing information for PCC partial-depth repair with cold planer method.

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended Major Process Improvement	Projected Timing (h:m)	Personnel Used	Major Equipment Changes or Additions
1	—[a]	5	Tape measure, chalk line	Break up into two teams: marking and chalking.	1:00	4	Same as before
2	0:32	2	Walk-behind saw	Make multiple transverse cuts using only floor saw.	2:45	3	Floor saw
3	0:07	1	Pressure washer	Add second pressure washer as team works toward crown to assist with additional cleaning area that will require cleaning.	1:00	2	Same as before
4	—	—	—	Add airfield sweeper cleaning for final debris removal.	0:30	1	Airfield sweeper truck
-	—	—	—	Add shallow relief cutting to longitudinal direction.	5:15	3	Those used in tasks 1-4
5	0:52	6	Jackhammers, air compressor, hand tools	Ensure operators angle jackhammer correctly.	1:00	6	Same as before
-	—	—	—	Add milling slot depth to level surface.	0:15	2	CTL with cold milling attachment
6	—	—	—	Add airfield sweeper truck vacuuming to clean fine millings.	0:05	1	Airfield sweeper truck
7	0:15	2	—	Inspect demolished slot depth elevation; correct as needed.	0:45	3	Demolition tools
-	—	—	—	Add airfield sweeper truck vacuuming to clean fine millings.	0:05	1	Airfield sweeper truck
8	—	—	—	Water blast the slot to remove any latent material.	0:15	1	Pressure washer
-	—	—	—	Add air blast to remove standing water and dry surface.	0:05	1	Air compressor with air lance
-	—	—	—	Caulk joints and allow material to set.	0:45	2	Caulk and application gun
-	—	—	—	Apply bonding agent to dry surface if required.	0:15	2	As directed by concrete manufacturer
9	0:40	7	Concrete mixer	Add washout water collection equipment.	1:00	8	Dump hopper, concrete mixer
10	2:00	0	—	Monitor strength gain with NDT equipment.	2:00	1	Schmitt Hammer or equivalent
11	—[a]	—	—	Move grinding perimeter to separate task.	0:30	2	Walk-behind saw
12	1:12	2	—	Inspect of bedding later elevation; correct as needed.	0:45	3	Demolition tools
13	0:15	2	Walk-behind saw	Add steel track piece along panel anchoring points.	0:15	2	Same as before
-	0:08	2	Angle grinder	Make cleaning separate task after concrete placement.	0:15	2	Same as before
14	—	—	—	Water blast the slot to remove any latent material.	0:10	1	Pressure washer

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended Major Process Improvement	Projected Timing (h:m)	Personnel Used	Major Equipment Changes or Additions
-	—	—	—	Add airfield sweeper truck vacuuming to clean fine millings.	0:05	1	Airfield sweeper truck
15	0:05	1	—	Add air blast to remove standing water and dry surface.	0:09	1	Air compressor with air lance
16	0:05	4	—	Have panels pre-positioned and laid out close to site.	0:05	2	—
17	0:34	4	Shims, hammers, pry bars, stringline	Add additional shims for secure placement.	1:00	4	—
18-20	1:30	4	Hammer drill, air compressor, electric drill, adhesive gun, portable band saw	Add additional personnel to begin installation after cleaning Set out hardware in advance; modify anchor lengths as needed.	1:15	6	Same as before
24-28	0:36		Hammer drill, air compressor, electric drill adhesive gun	Install only one tie-down anchor for timing data collected; projected time doubled assuming two tie-down anchors installed when needed.	0:30		Same as before
21	—[a]	—	—	Time varies depending on product used. Select product that meets set time requirement at concrete slab temperature.	1:00[b]	—	—
22	1:00	6	1¼ in. socket	Use teams of people to remove/collect setting hardware or place/tighten nut placement, remove setting hardware with impact wrench, grossly tighten nut with impact wrench, and stagger personnel and tasks to allow for more room to work.	0:45	6	Impact wrench, torque wrench
-	—[a]	1	Angle grinder	Modify setting hardware for more consistent anchor embedding, modify anchor length as needed before installing.	0:30	2	Same as before
23	0:15	2	Pressure washer, air compressor	Maintain a clean site over course of project; begin major cleaning site after adhesive is placed; begin to sweep site after all work is complete.	1:00	2	Airfield sweeper truck
29	—[a]	2	—	Do not reinstall pendant until after joint sealant is installed.	—	—	—
30	1:00[a,b]	1	Air compressor	—	1:00	1	Same as before
31	3:00[a,b]	2	—	Use insertion tool to place at correct depth instead of by hand; use precut short longitudinal pieces.	1:30	2	Backer rod inserter tool
32	3:00[a,b]	2	Air compressor, sealant gun	—	3:00	2	Same as before
33	—[a]	—	—	Time varies depending on product used and environmental conditions. Allow surface to harden before trafficking.	1:00[b]	—	—

a) No timing data collected

b) Estimated

Notable installation issues observed and applicable modifications made to specific work tasks are listed below.

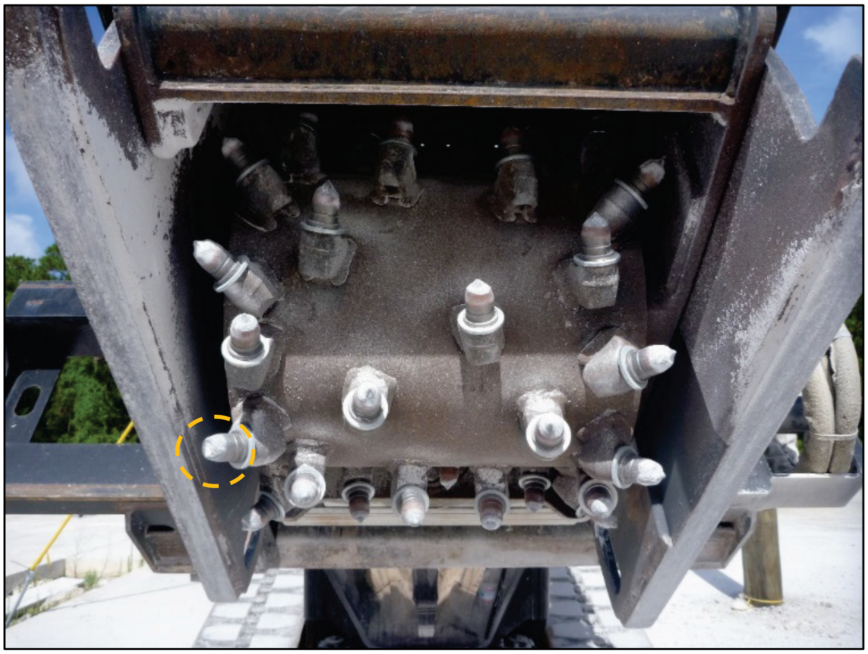
1. A large quantity of small millings were made using this demolition technique. The millings must be controlled and removed to minimize FOD and allow the CTL to have adequate traction when operating. Cleaning efforts revolved around hand brooms and a backpack leaf blower to direct and collect the millings since only one CTL was on site for this work. Additional testing conducted on site utilized the Silver Flag airfield sweeper truck to vacuum the millings for disposal. The sweeper truck was very effective at collecting the milled concrete. Alternating passes of the CTL with the cold planer attachment and airfield sweeper truck should be made. No differences in required cleaning time are expected.
2. When the milling head is used, the operator should focus on milling the central 23 in. of the panel slot area and not attempt to remove all material present between the saw cuts. Attempting to remove all the material within the slot area is difficult with the lack of fine yaw control with the CTL and can lead to overcutting. Overcutting the concrete may require additional partial-depth repairs be made. Cutting the central portion allows for a gross removal of the majority of the panel followed by the minor removal of the remaining material along the perimeter. The minor removal of remaining concrete can be conducted with a light jackhammer with scaling bit or a crowbar and a hammer (Figure 26).

Figure 26. Removal of unmilled portion of concrete with hand tools.

3. After 11 passes total, inspection of the milling head showed 2 of the 48 interchangeable teeth were damaged on the operator's right side (Figure 27). Tooth life of these specific teeth (Caterpillar model number 375-7681) for this application is not known. The teeth are distributed for cold planer applications, but the performance will ultimately vary depending on the operator using the equipment and the strength and aggregate type of the in situ concrete. Current ADR technologies using these teeth for wheel-saw testing require cutting teeth to cut a minimum of 340 linear feet (by approximately $3^1/_2$ in. wide by 18 in. deep) to complete all concrete crater cutting needed (Bell et al. 2015). This equates to approximately 150 ft^3 of concrete removed. Daily milling of the projected 30 ft long panel slot void (24 in. wide by $3^5/_8$ in. deep minimum) requires demolishing less than 20 ft^3 of concrete, significantly demolishing less volume than the wheel saw application. Therefore, tooth wear is not expected to be significant per work day.

Equipment spotters should monitor tooth wear during the milling process to provide the maximum cutting rates to ensure the projected timing is met and the work stays on schedule. Teeth should be checked while the airfield vacuum truck is cleaning the surface between milling passes and replaced when the tips are damaged. Teeth are relatively easy to replace. Approximately 15 min is needed to replace all 64 or 70 teeth on a typical CAT wheel saw used with current ADR technologies by hand with a mallet and punch tool.This corresponds to an individual replacement rate of 1 tooth every 15 sec. Spot replacement of a small portion of the 48 teeth on the cold planer attachment as needed is an achievable task during the short downtime the equipment has during surface cleaning.

Figure 27. Teeth wear after eight total passes of roto-milling.



4. Roto-milling of the pavement was stopped at the longitudinal joint to prevent overcutting and the need for conducting any spall repairs. Stopping short will lead to significant leveling of approximately the last 8 in. of each end of the panel slot area, since the round drum head does not remove the concrete to its full required depth (Figure 28). Additional considerations are needed to reduce hand labor and ultimately reduce the total time needed for demolition.

   UFC guidance for partial-depth repairs recommends full-depth overcutting across joints by 1 in. to ensure a full-depth cut is made; however, the width of the cut made by the saw blade is significantly less than the overall panel slot required. If the milling head is used and an overcut is made, a temporary medium- or high-severity spall will be created on the adjacent slab (approximately 25 in. wide by 9 in. long by 3 5/8 in. deep) where the overcutting from roto-milling is terminated. This is greater than the minimum edge spall repair dimensions (6 in. long by 3 in. wide by 2 in. deep).

Figure 28. Un-millable portion of panel slot.

Optimizing the overcut length is the best available option for reducing the amount of hand work needed to remove the concrete full-depth to prevent the need for a spall repair. A comparison of the different milling scenarios is shown in Figure 29. Reducing the overcutting length to less than 3 in. on the surface significantly reduces the volume of concrete that must be demolished by hand as compared to stopping at the joint.

Figure 29. Optimization of roto-milling of panel slot ends.

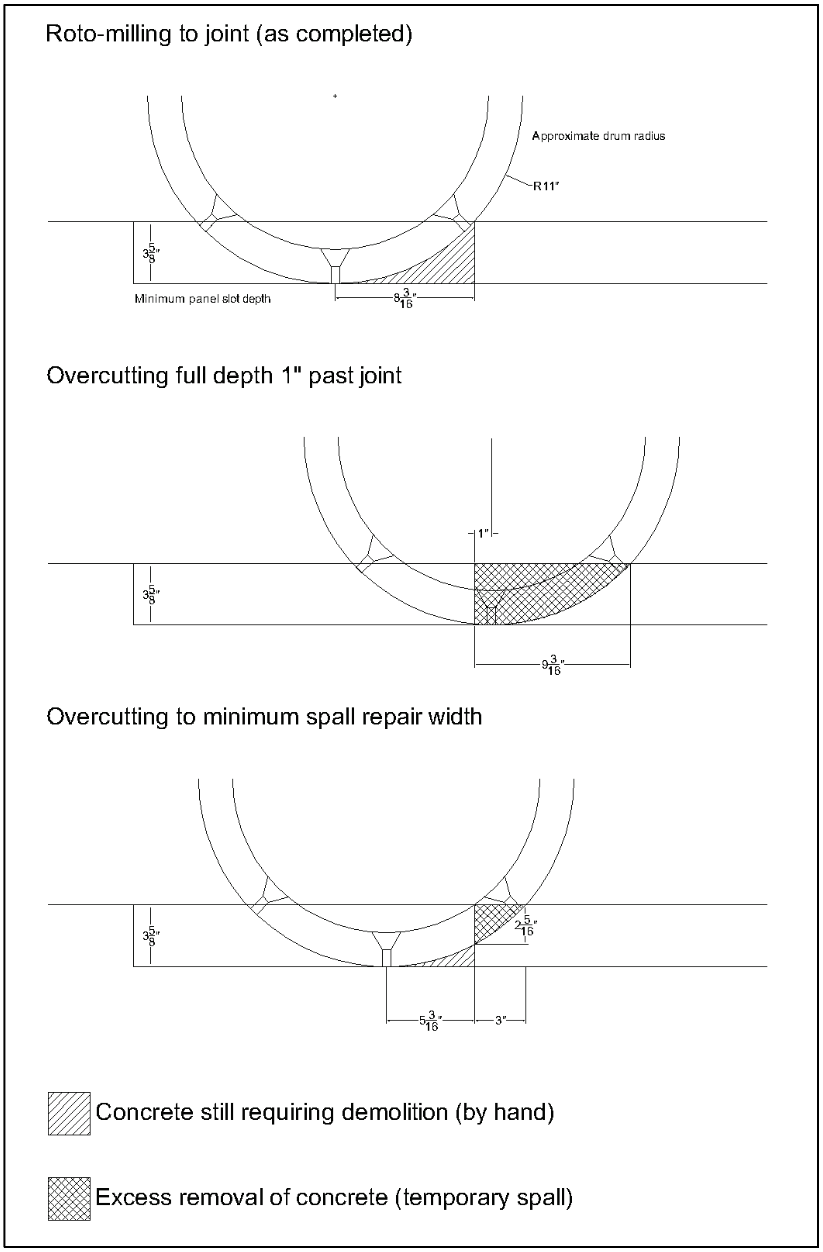
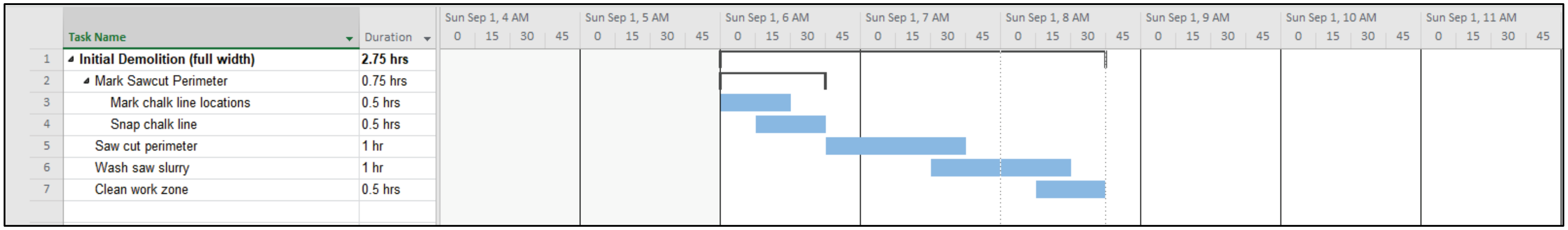


Figure 30 shows the prospective Gantt charts developed for the installation work days. Three different work phases are required. Many of the required work tasks are sequential, and little parallelization can be completed to reduce the total duration of the work. With the modified timing, one work phase is less than the preferred 6 hr time limit per work day, and one is less than the 12 hr maximum time requirement. One set of work phases is greater than the maximum 12 hr requirement. A total of 7 work days is required to install a UHMW panel system across a 150 ft concrete-surfaced runway with this option.

Figure 30. Gantt chart for PCC partial-depth repair method with demolition by milling.

a. Initial demolition



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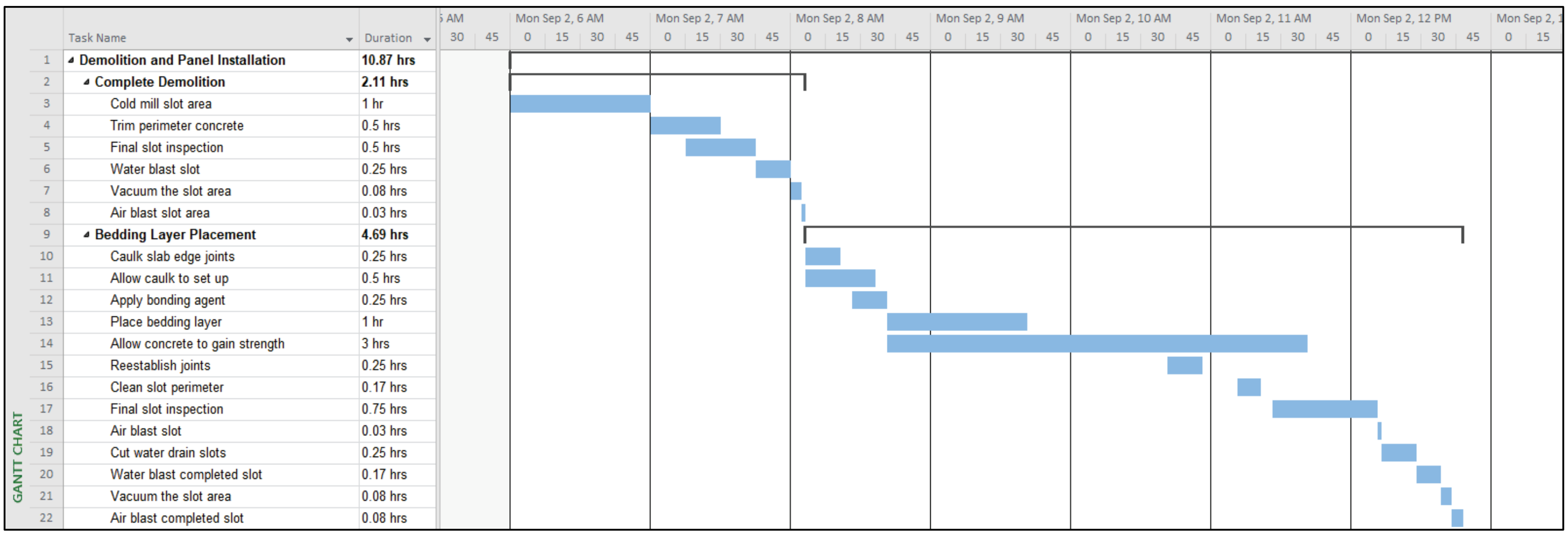
b. Demolition and panel installation



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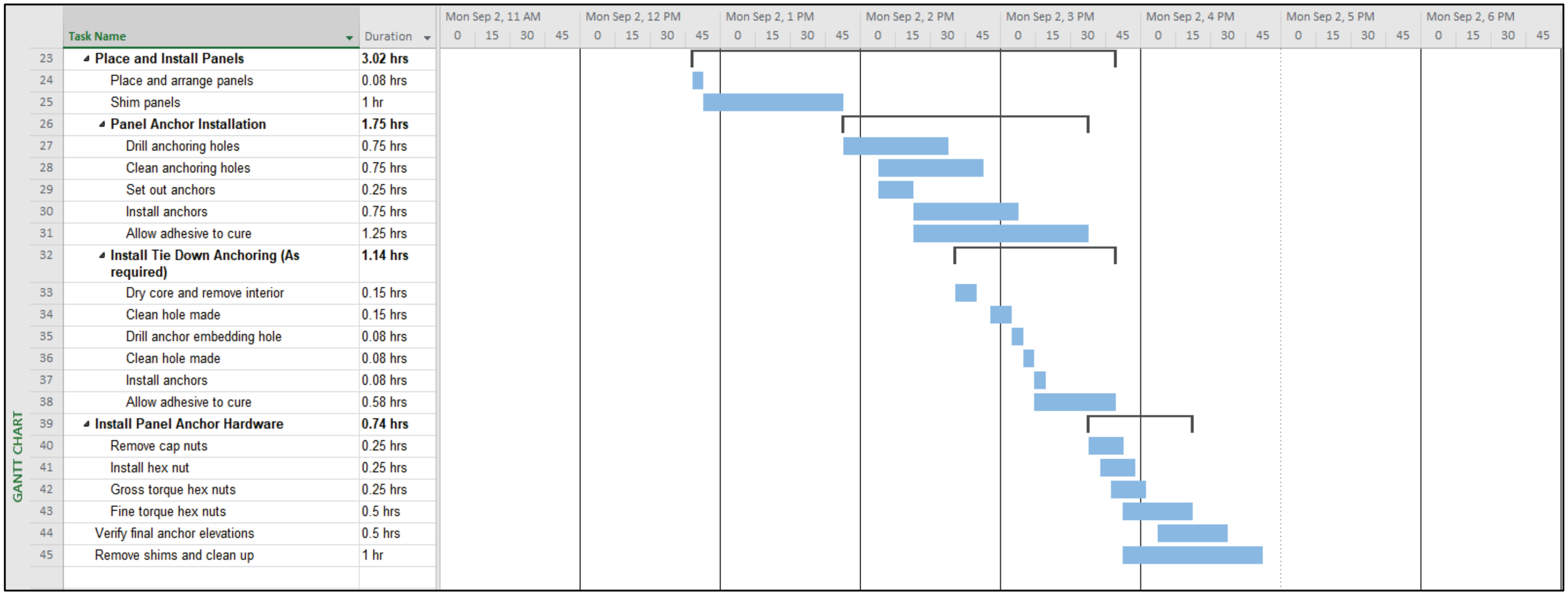

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c. Joint Sealing

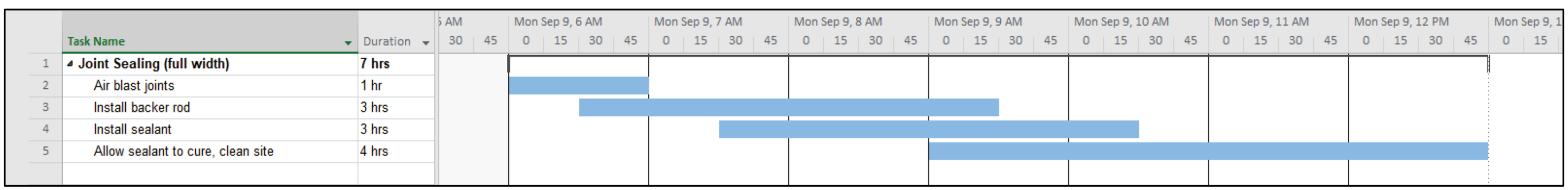

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Table 12 details the modified sequencing of work tasks with updated timing. Many of the items and equipment are currently in USAF inventories, and all may be delivered to the site by C-130 aircraft. Items not included in a standard SuPR kit include those previously listed for the traditional partial-depth repair method along with the additional items detailed in the major modifications listed.

One item for future investigation is whether installing a bedding layer and sawing drainage slots are necessary when the slot void is milled. Figure 31 shows the different surface textures made from demolition techniques used. The milled surface produced was grossly smooth with some texture as compared to surface removal by jackhammer. The elevation difference between the peaks and valleys was much smaller and more consistent across the surface when milled than when jackhammered. The roughness that remains could also be an alternative water drainage path, eliminating cutting a dedicated channel. Further investigation into paneling performance should be investigated to see whether the bedding layer is needed. Removal of the bedding layer tasks and drainage channel cutting removes a significant amount of time from the work day and makes this installation method a more attractive alternative.

Table 12. Optimized sequencing of required work tasks for PCC partial-depth repair method with demolition by milling.

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
1	1	Demolition	Mark transverse sawcuts.	150	2.75
2	1	Demolition	Saw cut slot perimeter.	150	2.75
3	1	Demolition	Wash saw slurry.	150	2.75
4	1	Demolition	Clean work zone.	150	2.75
9	2 Repeat five times	Demolition	Mill panel slot.	30	10.9
10	2 Repeat five times	Demolition	Trim excess material along edges.	30	10.9
12	2 Repeat five times	Demolition	Perform final slot inspection.	30	10.9
13	2 Repeat five times	Demolition	Vacuum slot.	30	10.9
14	2 Repeat five times	Demolition	Water blast slot.	30	10.9
15	2 Repeat five times	Demolition	Air blast slot.	30	10.9
16	2 Repeat five times	Bedding layer placement	Caulk slab edge joints and allow material to set up.	30	10.9
17	2 Repeat five times	Bedding layer placement	Apply bonding agent (as needed).	30	10.9
18	2 Repeat five times	Bedding layer placement	Place bedding layer.	30	10.9
19	2 Repeat five times	Bedding layer placement	Allow concrete to gain strength; clean site.	30	10.9
20	2 Repeat five times	Bedding layer placement	Cut joints in bedding layer.	30	10.9
21	2 Repeat five times	Bedding layer placement	Clean slot perimeter.	30	10.9
22	2 Repeat five times	Bedding layer placement	Perform final slot inspection.	30	10.9
23	2 Repeat five times	Bedding layer placement	Air blast slot.	30	10.9
24	2 Repeat five times	Bedding layer placement	Cut water drain slots.	30	10.9
25	2 Repeat five times	Bedding layer placement	Water blast completed slot.	30	10.9
26	2 Repeat five times	Bedding layer placement	Vacuum slot area.	30	10.9
27	2 Repeat five times	Bedding layer placement	Air blast completed slot.	30	10.9
28	2 Repeat five times	Panel anchorage installation	Place and arrange panels.	30	10.9
29	2 Repeat five times	Panel anchorage installation	Shim panels.	30	10.9
30	2 Repeat five times	Panel anchorage installation	Drill panel anchoring holes.	30	10.9
31	2 Repeat five times	Panel anchorage installation	Clean panel anchoring holes.	30	10.9
32	2 Repeat five times	Panel anchorage installation	Install panel anchors.	30	10.9
33	2 Repeat five times	Panel anchorage installation	Allow adhesive to cure; begin clean up.	30	10.9
34	2 Repeat five times	Panel anchorage installation	Install hardware on panel anchors.	30	10.9
35	2 Repeat five times	Panel anchorage installation	Verify final anchor elevations.	30	10.9
36	2 Repeat five times	Panel anchorage installation	Remove shims and finish cleanup	30	10.9

(Sheet 1 of 2)

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
37	2 Repeat five times	Tie-down anchorage installation (as required)	Core and demolish tie-down anchoring location.	30	12.9
38			Drill tie-down anchoring holes.		
39			Clean tie-down anchoring holes.		
40			Install tie-down anchor.		
41	3	Joint sealing	Air blast joints and anchor holes.	150	7.0
42			Install backer rod.		
43			Install sealant.		
44			Allow sealant to cure, clean site.		
					(Sheet 2 of 2)

Figure 31. Slot panel surface texture appearances after different demolition methods used.

(a) CTL with cold planer attachment.

(b) 40 lb hammer.

(c) 40 lb hammer with relief cuts.

(d) 40 lb hammer, relief cuts, cold planer.

3.3 Results for AC pavement installations

Two methods were investigated for the expedient installation of UHMW panels in AC pavements. The traditional method requires excavating the pavement soil to install a concrete foundation across the runway to anchor the panels onto. Installation of a series of micro-piles at typical panel anchoring points was also considered to reduce the need for installing a massive foundation across the runway.

3.3.1 Traditional method

The first option considered for asphalt-surfaced pavement installations was a variation of the full-depth utility cut method currently described in AFI 32-1043. A 3 ft deep trench is excavated along the projected panel location. The trench is backfilled with 1 ft of aggregate base material, and the majority of the remaining void is filled with concrete to provide the foundation needed for the panel anchors. Once the concrete hardens to a strength at which it can be drilled without damage, panel installation can begin as described in the PCC pavement installations.

Immediate time reductions were available by changing the backfill material type. Current ADR crater repair methods use rapid-setting flowable fill as the backfill beneath rapid-setting concrete caps for repair efforts. Priddy et al. (2013a, 2013b) reports that significant time savings can be achieved by use of flowable fill compared to compaction of aggregate for 10 ft wide by 10 ft long by 10 in. deep craters using 4 in. of backfill material. Since the volume backfilled with the traditional UHMW panel method is twice that described in the ADR timing data, the disparity between the construction methods grows, and the use of flowable fill for backfilling operations is the more efficient option based on the data shown. Additionally, the ADR data do not accurately complete an aggregate backfilled repair following UFC guidance. UFC guidance recommends aggregate backfill be compacted in 3 in. maximum lifts to assist in constructing a compacted, dense base for the repair. Assuming the difference in timing data is negligible between 3 and 4 in., use of the thinner lifts for compaction adds a fourth lift to all the material required. Considerations for thin lifts with flowable fill are not necessary since the material is fluid when placed monolithically and does not need to be compacted after placement. The flowable fill should be placed in a single 12 in. thick placement per work day. Timing projections may be quicker than those described by Priddy et al. (2013a) since continuous operations of flowable fill for monolithic placements reduce time lost to mobilization and setup of equipment.

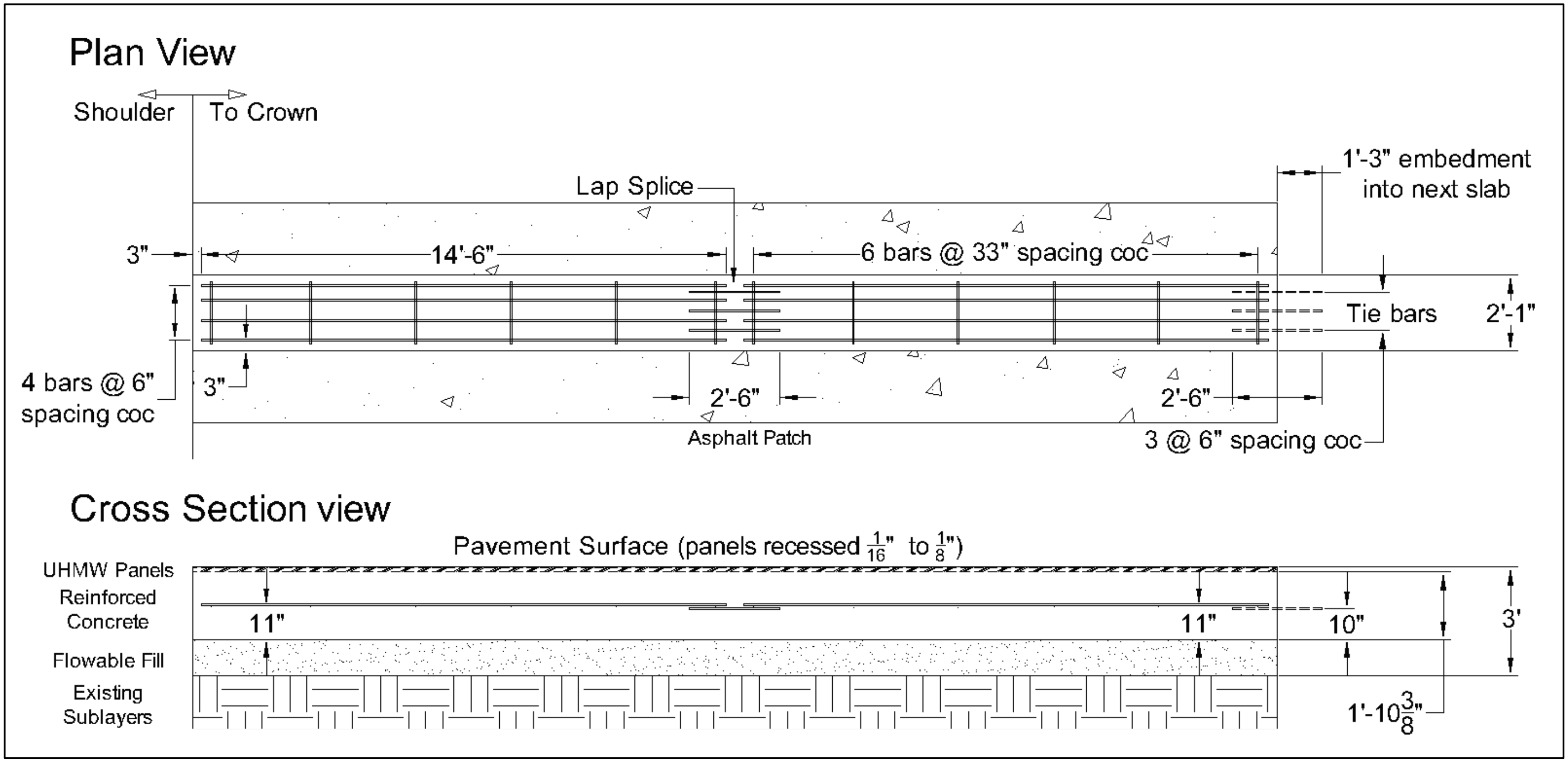
Flowable fill production and placement for current ADR repair work depend on the type of pavement repair made. Two methods are available in which the equipment used and the addition of water differ. The wet placement method uses prepackaged dry material that is mechanically mixed with water by a volumetric mixer before placement into the repair. The dry method involves placing the prepackaged dry material into the repair void in thin layers 4 to 6 in. thick. Water is then added to the surface of the freshly placed dry layer and allowed to percolate through the dry mass. Once all standing water disappears, the next lift is placed in the same manner. For ADR crater repairs, only repairs capped with concrete are allowed to use the dry placement method due to the loss in strength and bearing capacity experienced with material placed in this manner. Since the concrete foundation will be placed over the flowable fill backfill, either placement method is an available option.

Timing data from historical ADR testing in which rapid-setting concrete caps were placed upon rapid-setting flowable fill backfills for both PCC- and AC-surfaced pavements were reviewed to determine the best method to use with the expedient UHMW panel installation work. Backfilling rates determined for this phase of the crater repair work completed show dry placement backfilling ranges from 3.7 to 9.5 ft^3/min (Edwards et al. 2013; Priddy et al. 2013a; AFCEC 2014) as compared to 8.5 to 9.5 ft^3/min for wet placement backfilling (Carruth 2013; Carruth et al. 2015; AFCEC 2014), and the rates are variable depending on the crater dimensions for the repairs made. While the production rates show the two methods are within the same approximate range, the variability in the dry placement method makes it a less suitable choice for this specific work, and the flowable fill should be placed wet to ensure consistent material properties and production times for more reliable timing. However, consideration of the dry placement method may be necessary if only one volumetric mixer can be delivered to the site or if the only available mixers are needed for mixing and placing the rapid-setting concrete. For the timing data collected for this work, the dry-placed method was used due to limited equipment availability. Only one simplified volumetric mixer was available during the testing period.

A grid of reinforcement was added to the mid-height of the concrete cast to control cracking, as shown in Figures 32 and 33. American Concrete Institute (2005) 318 guidance for temperature and shrinkage steel design was used to select the reinforcement needs and specified items similarly to those of the full-depth PCC installation method described earlier. A minimum reinforcement ratio of 0.18% was used when selecting the amount of steel to use. A 5/8 in. diameter steel bar was selected since UFC guidance recommends the same size bar used for tie bars to minimize using multiple bar sizes. Using this information, four bars spaced at 6 in. center-to-center were selected for transverse steel. No cracking was expected in the longitudinal direction since the longitudinal repair width was much smaller than the minimum spacing; therefore, steel was not specified for crack control. Longitudinal bars were added at an approximately 30 to 36 in. spacing to help support the transverse bars and maintain their elevation while placing concrete. Material properties for the steel were similar to those required by UFGS 32.13.11 (UFGS 2015) for PCC pavement construction. Grids were assembled in advance of the work day on site from 20 ft stock lengths of reinforcement and worked with a manual cutting/bending tool to minimize the time needed on the runway for this task. Assembled grids were lightweight and rigid enough to be lifted and placed into the repair by hand using two personnel.

Figure 32. Reinforcement grid in traditional AC installation.

Figure 33. Schematic for reinforcement layout in traditional AC installation.



Two grids were installed for the 30 ft section of concrete to be placed. The reinforcing steel was supported just above the mid-height of foundation with two 11 in. tall steel high chairs tied to the short longitudinal reinforcement bar. A minimum bar cover of 3 in. for concrete exposed to earth to prevent corrosion was used and maintained. All bar intersections, both to other bars or accessory pieces, were tied using standard 16-gage tie wire to prevent movement after placement. Lap splices were used to provide continuous reinforcement between the grids placed. The length of the splices was made long enough to develop the bar splice.

Additional splices (ties) will be needed once multiple sections of concrete are installed. This was not tested during the timed trial study due to the duration of the exercise and the test pavement area available. It is expected that the vertical surface of the concrete face exposed during excavation for adjacent concrete will require trimming of any highly irregular surfaces to ensure good aggregate interlock between the concrete sections. A light jackhammer (less than 30 lb) with chisel, scaling, and bushing bits is expected to be needed for this work task since the dimensions of the work area will make using many pieces of heavy equipment difficult. A cutoff saw may also be needed to quickly trim irregular areas as needed. Once the surface is prepared, the ties can be installed with a hammer drill with masonry drill bit just below the midheight of the concrete slab. Installation procedures are similar to those for installing free dowels where a 1/8 in. oversized diameter hole is made and cleaned to the adhesive manufacturer's guidelines. Adhesive is applied into the hole from the interior out to prevent air pockets, and the steel is installed.

Drilling is recommended to be completed by handheld rotary hammer drills rather than a dowel drill for speed and accessibility. Precise drilling is not required for tie installation, and a true horizontal hole is not expected in this scenario. The exposed free end of the tie may be slightly bent into a horizontal position to correct its orientation once the adhesive hardens.

To assist with minimizing the potential for voids along the asphalt and foundation joint, the best option considered was to fill with grout any voids resulting from the foundation installation. Once the entire series of foundation blocks is installed, a saw is used to open the asphalt joint with the panels in place. Rapid-setting grout is placed by hand with a grout bag into the opened area and allowed to harden. With a solid material along the joint, the potential for joint damage is reduced.

Table 13 details the overview of the required sequence of work tasks identified before the trial began. Table 14 details the timing recorded for each task, scaled up to the appropriate runway width completed per work day. Process improvements and new projected timing are given.

Table 13. Sequencing of initially identified work tasks for traditional AC installation.

Task	Work Day	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
1	1	Demolition	Mark sawcuts.	150	4.5
2			Saw cut panel void perimeter.		
3			Wash saw slurry.		
4			Clean work zone.		
5	2-6 repeat five times		Remove AC surfacing for concrete foundation.	30	12.0
6			Trench excavation.		
7		Panel foundation placement	Backfill with flowable fill.		
8			Allow flowable fill to cure.		
9			Install reinforcement and ties.		
10			Cap with rapid-setting concrete.		
11			Perform final slot inspection.		
12			Air blast slot.		
13			Cut water drain holes.		
14			Water blast completed slot.		
15			Air blast completed slot.		
16		Panel anchorage installation	Place and arrange panels.		
17			Shim panels.		
18			Drill panel anchoring holes.		
19			Clean panel anchoring holes.		
20			Install panel anchors.		
21			Allow adhesive to cure; begin clean up.		
22			Install hardware on panel anchors.		
23			Verify final anchor elevations.		
24			Remove shims and finish cleanup.		
25		Tie-down anchorage installation (as required)	Core and demolish tie-down anchoring location.		
26			Drill tie-down anchoring holes.		
27			Clean tie-down anchoring holes.		
28			Install tie-down anchors.		
(Sheet 1 of 2)					

Task	Work Day	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
29	7	Perimeter grouting	Saw cut AC perimeter.	75	5.0
30			Place grout around void perimeter.		
31			Allow grout to harden.		
32			Clean site.		
33	8	Joint sealing	Air blast joints and anchor holes.	150	5.0
34			Install backer rod.		
35			Install sealant.		
36			Allow sealant to cure; clean site.		
					(Sheet 2 of 2)

Table 14. Installation timing information for traditional AC installation.

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended major Process improvement	Projected Timing (h:m)	Personnel Used	Major Equipment Changes or Additions
1	—[a]	5	Tape measure, chalk line	Break up into two teams: marking and chalking.	1:00	4	Same as before
2		2	Floor saw	None	2:15	3	Same as before
-	—	—	—	Add walk-behind saw to cut ends of 30 ft segments .	0:15	1	Walk-behind saw
3	0:07	1	Pressure washer	Add second pressure washer as team works toward crown to assist with additional cleaning area that will require cleaning.	1:00	2	Same as before
4	—	—	—	Add airfield sweeper cleaning for final debris removal.	0:30	1	Airfield sweeper truck
5	0:07	3	Backhoe or excavator	Rip AC pavement from surface instead of milling with CTL; use CTL to collect removed asphalt pieces for disposal.	0:10	4	CTL with bucket attachment
-	—	—	—	If milling asphalt surface is used, alternate with airfield sweeper truck.	0:32[b]	3	CTL with cold milling attachment
6	0:26[b]	—	Backhoe or excavator, shovels	Deposit removed material into dump truck directly or place clearly to one side of the trench for removal by the CTL with bucket. Some hand shoveling of excavated material around the trench will be needed to prevent a cave in caused by heavy wheeled equipment around the excavation.	1:00[b]	2	Same as before
-	—	—	—	Compact trench depth.	0:08	1	Rammer compactor
7	0:33	8	Telehandler forklift, water truck, hand tools	Backfill trench with dry placed flowable fill; have CTL with bucket available to remove excess material by shovel; add rebar sticks to perforate holes in flowable fill surface to assist in water penetration; calibrate water truck before work day to verify water flow rate.	0:30	10	5 ft rebar sticks, CTL with bucket attachment or backhoe
-	—	—	Telehandler forklift, volumetric mixer, hand tools	Backfill trench with wet placed flowable fill.	0:45	10	Same as before
8	1:00	0	—	Typical TTPs for ADR crater repair require wet placed flowable fill to cure for 30 min before concrete capping. Concrete can be placed immediately after	0:30	1	Schmitt Hammer or equivalent

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended major Process improvement	Projected Timing (h:m)	Personnel Used	Major Equipment Changes or Additions
				dry-placed flowable fill. Monitor strength gain with NDT equipment.			
9	0:10	2	Reinforcement grids, rebar tying tool	Add another person to help with setup.	0:10	3	Same as before
10	0:41	7	Volumetric concrete mixer	Prepare mixer off-site and deliver loaded, or have additional team prepare on-site while excavating.	0:45	8	Same as before
-	2:00	0	—	Monitor strength gain with NDT equipment.	2:00	1	Schmitt Hammer or equivalent
-	—	1	—	Begin marking areas in need of leveling when curing.	0:30	1	Depth guide, lumber crayon
11	0:00	4	Jackhammers, air compressor, hand tools	Inspect bedding later elevation; correct as needed.	0:45	4	Same as before
12	0:03	2	Backpack blower	None	0:03	1	Air compressor
13	0:15	2	Walk-behind saw	Add steel track piece along panel anchoring points.	0:15	2	Same as before
14	—	—	—	Water blast the slot to remove any latent material.	0:10	1	Pressure washer
-	—	—	—	Add airfield sweeper truck vacuuming to clean fine millings.	0:05	1	Airfield sweeper truck
15	0:05	1	—	Add air blast to remove standing water and dry surface.	0:03	1	Air compressor with air lance
16	0:05	4	—	Have panels pre-positioned and laid out close to site.	0:05	2	—
17	0:34	4	Shims, hammers, pry bars, stringline	Add additional shims for secure placement.	1:00	4	—
18-20	1:30	4	Hammer drill, air compressor, electric drill, adhesive gun, portable band saw	Add additional personnel to begin installation after cleaning. Set out hardware in advance; modify anchor lengths as needed.	1:15	6	Same as before
25-28	0:36		Hammer drill, air compressor, electric drill adhesive gun	Only one tie-down anchor installed for timing shown, time doubled for projected time incase two are installed as needed.	0:30		Same as before

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended major Process improvement	Projected Timing (h:m)	Personnel Used	Major Equipment Changes or Additions
21	—[a]	—	—	Time varies depending on product used. Select product that meets set time requirement at concrete slab temperature.	1:00[b]	—	—
22	1:00	6	1¼ in. socket	Use teams of people to remove/collect setting hardware or place/tighten nut; remove setting hardware with impact wrench, grossly tighten nut with impact wrench; stagger personnel and tasks to allow for more room to work.	0:45	6	Impact wrench, torque wrench
23	—[a]	1	Angle grinder	Modify setting hardware for more consistent anchor embedding; modify anchor length as needed before installing.	0:30	2	Same as before
24	0:15	2	Pressure washer, air compressor	Maintain a clean site over course of project; begin major cleaning site after adhesive is placed; begin sweep site after all work is complete.	1:00	2	Airfield sweeper truck
29-32	—	2	Floor saw	Do not remove panels; run saw blade along trench.	1:00	2	Same as before
	—	4	Grout bag, grout/mortar mixing equipment	Remove grouting task from work plan.	—	—	—
	—[a]	—	—	Time varies depending on product used. Select product that meets set time requirement at concrete slab temperature.	1:00[b]	—	—
	—	—	—	Water blast the slot to remove any latent material.	0:10	1	Pressure washer
-	—	—	—	Add airfield sweeper truck vacuuming to clean surface.	0:30	1	Airfield sweeper truck
-	—	—	—	Mill AC from prospective patch area with CTL and cold planer attachment; complete only one quarter of the patching required (36 in. wide by 75 ft long on one side of the paneling).	1:30[b]	3	CTL with cold planer attachment, airfield vacuum truck
-	—	—	—	Wet base material with up to 1 gal/yd^2 of water.	0:10[b]	1	Water truck

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended major Process improvement	Projected Timing (h:m)	Personnel Used	Major Equipment Changes or Additions
-	—	—	—	Remove panels from pavement.	0:45[b]	4	Impact hammer, wrecking bar
-	—	—	—	Compact soil in base area.	0:10[b]	1	Dual steel wheel vibratory roller
-	—	—	—	Install formwork for asphalt placement.	0:45[b]	4	Impact hammer, steel formwork
-	—	—	—	Apply AC binder tack material along asphalt perimeter.	0:15[b]	2	Roofing brush, liquid AC binder, PPE for asphalt work
-	—	—	—	Place and compact asphalt patch	0:45[b]	6	CTL with asphalt screed attachment, dual steel wheel vibratory roller, hand tools
-	—	—	—	Watershock pavement and allow to cool to 125˚F; monitor surface temperature with infrared thermometer.	1:00	1	Water truck, sprinkler or water distributor, infrared thermometer
-	—	—	—	Remove formwork	0:45[b]	4	Impact wrench
-	—	—	—	Reinstall panels	1:30[b]	6	Impact wrench, torque wrench
-	—	—	—	Airfield sweeper truck vacuuming to clean surface.	0:30	1	Airfield sweeper truck
33	1:00[a,b]	1	Air compressor	—	1:00	1	Same as before
34	3:00[a,b]	2	—	Use insertion tool to place at correct depth instead of by hand; use precut short longitudinal pieces.	1:30	2	Backer rod insertion tool
35	3:00[a,b]	2	Air compressor, sealant gun	—	3:00	2	Same as before
36	—[a]	—	—	Time varies depending on product used and environmental conditions. Allow surface to harden before trafficking	1:00[b]	—	—

a) No timing data collected
b) Estimated

Notable installation issues observed and applicable modifications made to specific work tasks are described below.

1. The utility cut made for the testing efforts did not follow all recommended aspects of the UFC guidance (Headquarters, Departments of the Army, Navy, and Air Force 2001e). Dimensions follow those used for full-depth patching in which only the surface is corrected in an attempt to minimize the time needed on the runway for repairing adjacent pavement. Since the utility cut disturbs a significant depth of material beyond that of a typical AC pavement surface repair, extra provisions given by the utility cut specifications are needed. The main item missing from the work completed was the 12 in. minimum additional width of asphalt surface material that needed to be removed on each side of the utility cut (Headquarters, Departments of the Army, Navy, and Air Force 2001c).

   A review of typical utility cut construction issues showed that this distance might not be enough when conducting repairs. Trench excavation for utilities loosens soil from its in situ state. The soil disturbed by the excavation can extend 2 to 3 ft back from the exposed soil face, and backfilling alone does not restore the soil to its original strength (Jensen et al. 2005). Removing additional surfacing material may be required to better return the pavement system to an undisturbed state.

   The additional surfacing width removed allows for re-compaction of disturbed soil, reduces voids potential under the existing pavement from undercutting soil, and reduces the potential for additional soil weakening from infiltrating water at the construction joint since it is moved farther away from the weakened repair area.

   Redensification of the soil along the trench is critical to the performance of the pavement to minimize surface irregularities along the concrete/asphalt construction joint as observed with the Southwest Asia expedient panel installation failure described earlier. Since time is at a premium from the mission requirements given, phasing the work must be conducted differently. Instead of completing one large repair when installing portions of the concrete foundation, restoration work to the underlying soil should be broken into a separate work activity to efficiently conduct all tasks. The 25 in. wide trench and installation of the concrete foundation should be conducted in the same individual sections previously described for the work (five sections of 30 ft each for a 150 ft wide runway). After the foundation is installed, work to correct the weakened underlying soil can be conducted by using a full-depth patch along each side of the panel system the full width of the runway. To assist in minimizing consolidation of the prospective loosened material along the trench, a 36 in. wide cut on each side of the panels should be made to best correct the prospective damage from excavation. Once the asphalt is removed, the upper portion of the disturbed soil can be wetted and recompacted. Additional base material may be added and scarified into the existing material as needed to fill.

A 36 in. wide cut will allow for two passes of the CTL with an 18 in. wide cold planer attachment and a 30 in. wide drum of the dual steel wheel vibratory compactor using the equipment available in the SuPR kit. Not all soil along the depth of the excavation will be redensified to preconstruction levels, but the upper 6 to 12 in. of soil loosened by excavation will be denser than completing no remediation work at all.

A larger, heavier roller can be used to compact the soil deeper into the cross-section depth, but this will most likely require a wider patch to accommodate the width of the drum. Equipment available will most likely not be a transportation issue since most rollers can be transported on military cargo aircraft, but the larger patch ultimately will require more time to construct and will require additional time on the runway.

2. Placement of the full-depth patch along the panels will require additional considerations to ensure proper density of the asphalt concrete used. Longitudinal construction joints along free edges of asphalt pavement are typically over paved, and approximately 2 to 3 in. of the rolled material at the edges is cut. The exterior, less compacted material along the unconfined edge is removed. A similar process is completed for transverse joints except that the amount of material sacrificed may be much greater and potentially cover the width of the concrete foundation placed. Both cases add additional tasks to the work planning that may damage the panel anchoring points when completed. To create a compacted construction joint with minimal additional effort, steel formwork should be erected along the panel void perimeter to provide the necessary confinement. The formwork should mimic the panels' layout and dimensions for ease of installation and

use. A channel, angle, or adequately stiff built-up section should be made to lie flat on the concrete foundation surface and resist deforming against the compaction forces. Multiple segments of formwork should be attached to the concrete at the anchoring points with slightly oversized holes for ease of construction. Figure 34 provides a drawing for the prospective formwork discussed.

3. To minimize the potential for excess pavement removal or damage when opening the trench surface, the saw cuts made 36 in. outside the perimeter of the trench for the full-depth patches should be made on a separate work day after the concrete foundation is installed. Completion of the work tasks required on this work day will take fewer than 6 hr. Saw cuts should be made the full width of the runway.
4. Use of the steel formwork will require the panels to be removed for the full-depth patch completed. To efficiently complete the patching and prevent the need to remove all panels across the runway, patching should be completed in two segments divided by the runway longitudinal centerline on both sides of the paneling.
5. Surface removal may be accomplished by ripping the asphalt with an excavator or backhoe or by milling. For this work, the asphalt pavement was easily ripped by the backhoe and stockpiled at one end of the project as it was ripped. Ripping was most likely easier than milling in this particular case since the asphalt was thin, brittle, and broke down into manageable pieces that could be disposed of by hand. Thicker and newer asphalt pavements are not expected to break down into manageable pieces that can be removed by hand. Milling the pavement may be a better demolition method for these scenarios since the spoil material can be cleaned much more easily by personnel or the airfield sweeper truck; however, milling and cleaning the pavement will take more time. Milling timing from the retrofit construction option showed that a 30 ft long, 18 in. wide by 1 in. deep volume of asphalt pavement was milled with the CTL with cold planer attachment in approximately 3 min including aligning the machine and setting drum height. If an additional minute is used by the airfield sweeper truck to collect the millings made after each pass of the CTL, 32 min should be allowed for a 4 in. thick surface layer the width of the panel slot.
6. Recompaction of the depth of the trench after excavation was added to work tasks to increase the subgrade's strength and minimize settlement of the foundation. Typically recompaction of the existing soils is not completed in current ADR crater repairs before flowable fill is placed, but compaction is recommended for this work to provide a higher

quality repair, since the structure cast is a permanent feature. A rammer compactor is recommended for this task since it is a hand-operated machine that is narrow enough to operate in the trench, does not use vibratory action, and is currently in SuPR kit inventories. Nonvibratory compaction equipment is recommended to minimize any caving-in of the weakened trench walls while completing this task. The 13 in. wide shoe will require two passes of the equipment to compact the trench width. The manufacturer of the compactor in the SuPR kit recommends a travel speed of approximately 50 ft per min for the equipment. With a 30 ft long trench, each pass of the compactor will be relatively quick and take less than 1 min. Two passes of the compactor are recommended, adding approximately 6 min to the work schedule, including placing and removing the compactor from the trench. It is recommended to raise and lower the compactor from the trench with the CTL, using a lifting strap for efficient and safe movement.

7. After further consideration, the grouting tasks previously described were deemed unnecessary because of the addition of the full-depth patching work to the construction tasks. Simply adding the grout to the joint area does not mitigate the damage to the pavement excavation cases since the disturbed volume of pavement does not get redensified. Grout will also not penetrate the full depth of the foundation placed and therefore will not correct all damage created. Recompaction of the soil after removing the asphalt concrete surface was believed to be the best approach to mitigating the damage caused by the construction, considering the time allowed on the runway.
8. Cooling of the asphalt surface can lead to significant lost time on the runway. The asphalt needs to be heated sufficiently to allow for required compaction before the material cools to approximately 175°F. Below that temperature, further compaction effort may damage the asphalt. After finishing compaction, the pavement must be allowed to cool sufficiently so that it can be trafficked by aircraft without rutting and personnel can complete any additional work tasks without being exposed to the high surface temperature. It is estimated that the asphalt should have sufficient rutting resistance once it reaches 150°F, but a cooler temperature is preferable for personnel safety when working around the patch. An optimal pavement temperature must be selected to provide safe working conditions while minimizing the closure of the runway.

The Occupational Safety and Health Administration does not specify a maximum temperature before insulation is required to avoid thermal burns to personnel. ASTM C1055 (ASTM 2014) has been used to determine acceptable heated surface temperatures where exposed skin contact may be made, even though the standard does not specify safe surface temperatures and criteria must be developed (designed) by the user. The standard states that high-temperature metallic surfaces greater than 158°F damage skin immediately after contact. Additionally, the standard also states that no short-term thermal hazard may be present if the surface is less than 110°F. Based on these temperature reference points, ASTM C1055 provides a temperature range in which personnel can be safely exposed (make contact) to a specified thermal hazard for a limited duration.

Since steel formwork must be removed after the patch is installed but before the UHMW panels are replaced, additional cooling past that allowed before aircraft trafficking resumes will be required before form removal begins. However, waiting until the pavement surface is cooler than 110°F to ensure no thermal hazard exists for personnel may not be efficient to minimize the runway closure time due to the way the pavement cools thermodynamically. Cooling occurs exponentially, where a large temperature reduction is seen early in the placed asphalt's life, and the rate of cooling decreases over time as the pavement temperature approaches the ambient temperature. Excessive down time may result if the surface temperature specified before work can resume is too low because personnel could work safely at the site for the expected operation temperature and contact duration.

Selection of an optimal maximum safe surface temperature by ASTM C1055 requires the user to determine the criteria for a safe working environment. It will be assumed that the surface temperature should not yield a first-degree burn if contact is made and that a typical "consumer item" contact time of 60 sec is a sufficient amount of time necessary for personnel to perform discrete tasks in which continuous contact is not necessary (e.g., like removing the formwork or hardware from the pavement and stockpiling removed formwork items on a pallet or bin located near the work site). These criteria may be conservative since personnel are expected to wear gloves (insulation) when working around the patch and will most likely not make contact with the heated surface, but the criteria will provide some additional protection. The approximate surface temperature to meet the stated criterion is 125°F from the plot within the standard. Therefore, when the patched area temperature is monitored after installation, physical work to the pavement within the project area is recommended to begin when a surface temperature of 125°F or less is achieved across the patch before removing the steel forms. The temperature of the formwork being removed should be monitored with an infrared thermometer gun at multiple locations to verify the project area is ready for work activities to be resumed. In a warmer location where the pavement temperature is expected to be greater than 125°F while installation work occurs, work is recommended to resume once the patch temperature is similar to that of the adjacent, existing pavement.

Figure 35 shows the prospective Gantt charts developed for the installation work days. Four different phases are needed to complete the necessary work. Many of the required work tasks are sequential, and little parallelization could be completed to reduce the total duration of the work. With the modified timing, one of the work phases is less than the preferred 6 hr time limit per work day. All work phases are projected to be less than the maximum 12 hr requirement. Eleven work days are required to install a UHMW panel system across a 150 ft asphalt surfaced runway with this option.

Table 15 details the modified sequencing of work tasks with updated timing. Many of the items and equipment are currently in USAF inventories, and all may be delivered to the site by C-130 aircraft. Items not included in a standard SuPR kit include those previously listed for the traditional partial-depth repair method along with the additional items detailed in the major modifications listed.

Figure 34. Concept drawing of asphalt formwork.

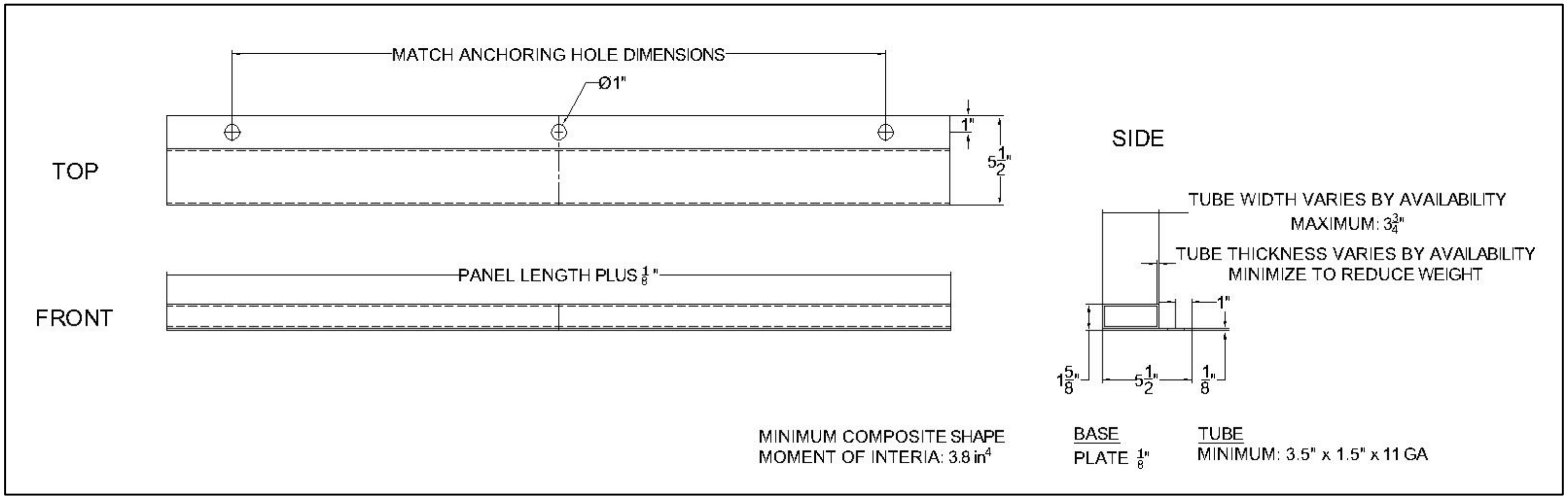
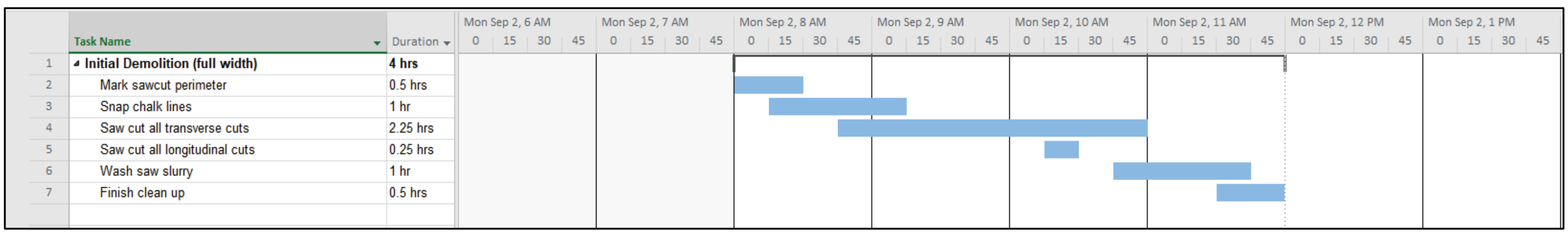


Figure 35. Gantt charts for traditional AC installation.

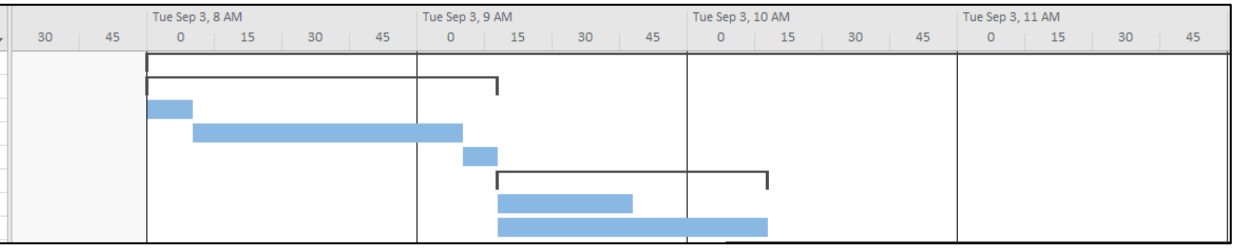
a. Initial demolition



(Sheet 1 of 1)

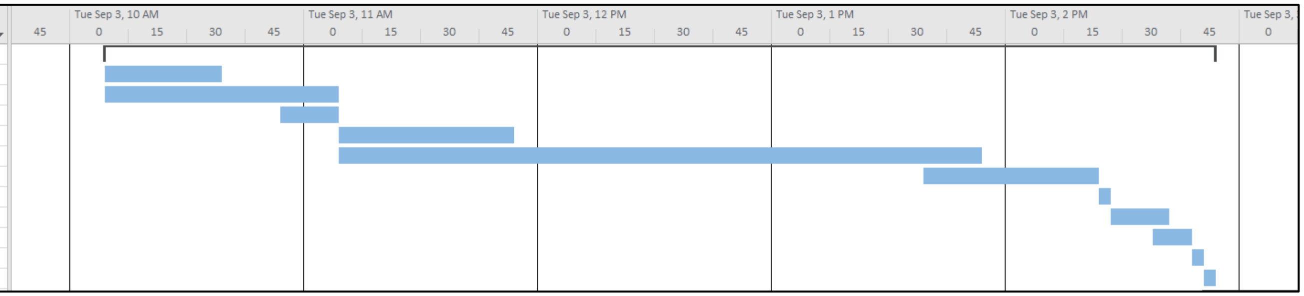
<u>b. Demolition and panel installation</u>

	Task Name	Duration
1	Demolition and Panel Installation (Partial width)	10.83 hrs
2	Demolition and Excavation	1.3 hrs
3	Remove surface with backhoe	0.17 hrs
4	Remove sublayer soil	1 hr
5	Compact bottom of trench	0.13 hrs
6	Backfilling Base	1 hr
7	Place rapid setting flowable fill	0.5 hrs
8	Allow flowable fill to gain strength	1 hr



(Sheet 1 of 3)

	Task Name	Duration
9	Concrete Foundation Placement	4.75 hrs
10	Install tie bars (as needed)	0.5 hrs
11	Allow adhesive to cure (if tie bars are installed)	1 hr
12	Install reinforcement grid	0.25 hrs
13	Place rapid setting concrete	0.75 hrs
14	Allow concrete to gain strength	2.75 hrs
15	Perform final slot inspection	0.75 hrs
16	Air blast slot	0.05 hrs
17	Cut water drain holes	0.25 hrs
18	Water blast completed slot	0.17 hrs
19	Vacuum slot area	0.05 hrs
20	Air blast completed slot	0.05 hrs



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	Task Name	Duration
21	Place and Install Panels	3.98 hrs
22	Place and arrange panels	0.08 hrs
23	Shim panels	1 hr
24	Panel anchor installation	1.75 hrs
25	Drill anchoring holes	0.75 hrs
26	Clean anchoring holes	0.75 hrs
27	Set out anchors	0.25 hrs
28	Install hardware	0.75 hrs
29	Allow adhesive to cure	1.25 hrs
30	Install Tie Down Anchoring (As required)	0.98 hrs
31	Dry core and remove interior	0.15 hrs
32	Clean hole made	0.15 hrs
33	Drill anchor embedding hole	0.1 hrs
34	Clean hole made	0.08 hrs
35	Install tie down anchor	0.08 hrs
36	Allow adhesive to cure	0.58 hrs
37	Install Panel Anchor Hardware	0.85 hrs
38	Remove setting hardware	0.25 hrs
39	Install hex nuts	0.25 hrs
40	Gross torque hex nuts	0.25 hrs
41	Fine torque hex nuts	0.5 hrs
42	Verify final anchor elevations	0.5 hrs
43	Finish cleanup	1 hr

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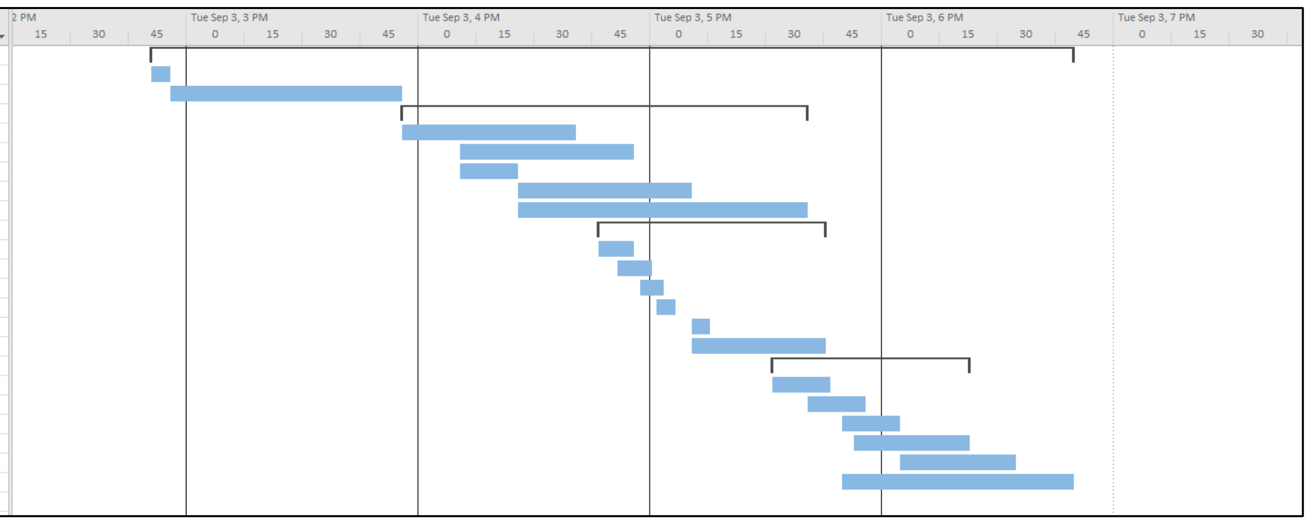

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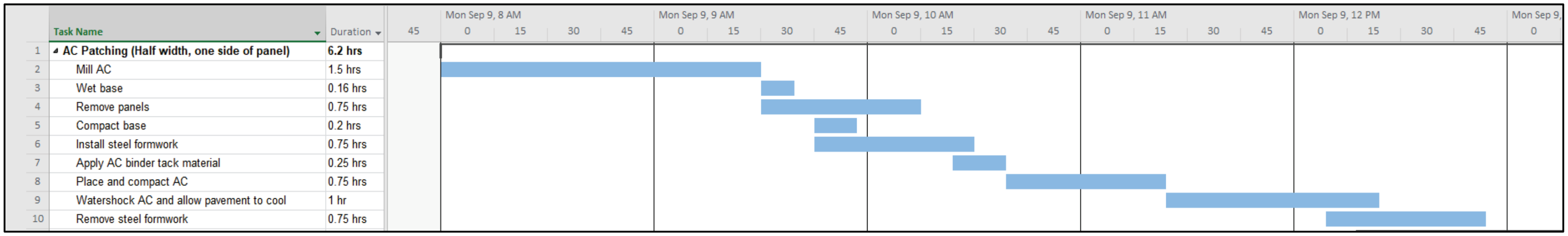
c. AC patching



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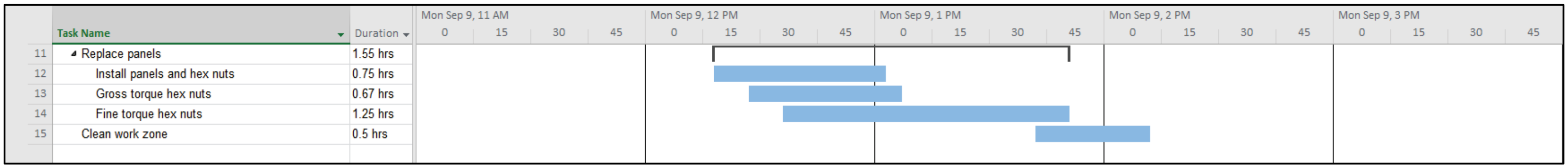

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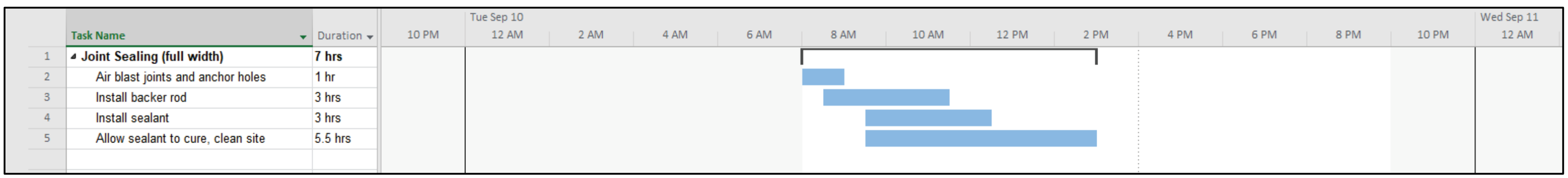
d. Joint sealing



(Sheet 1 of 1)

Table 15. Optimized sequencing of required work tasks for traditional AC installation.

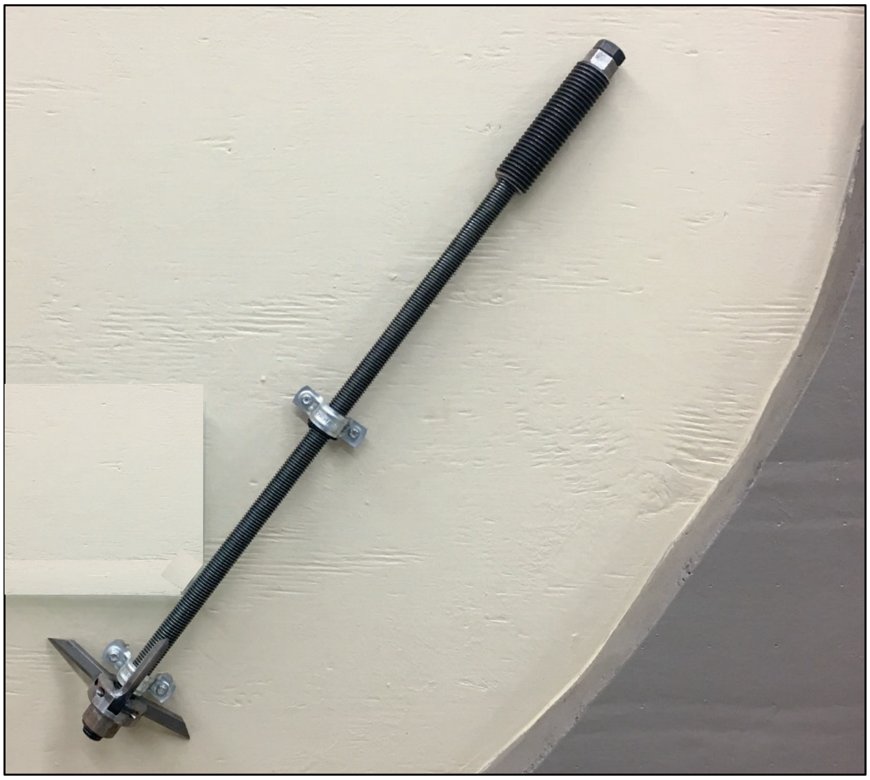
Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
1	1	Demolition	Mark sawcuts.	150	4.0
2			Saw cut panel area longitudinal and transverse cuts.		
3			Wash saw slurry.		
4			Finish cleanup.		
5	2 Repeat five times		Remove AC surfacing for concrete foundation.	30	10.8
6			Trench excavation.		
7		Panel foundation placement	Compact bottom of trench.		
8			Backfill with flowable fill.		
9			Allow flowable fill to cure.		
10			Install reinforcement and ties.		
11			Cap with rapid-setting concrete.		
12			Allow concrete to cure.		
13			Perform final slot inspection.		
13			Air blast slot.		
14			Cut water drain holes.		
15			Water blast completed slot.		
16			Vacuum slot area.		
17			Air blast completed slot.		
18		Panel anchorage installation	Place and arrange panels.		
19			Shim panels.		
20			Drill panel anchoring holes.		
21			Clean panel anchoring holes.		
22			Install panel anchor.		
23			Allow adhesive to cure; begin cleanup.		
24			Install hardware on panel anchors.		
25			Verify final anchor elevations.		
26			Remove shims and finish cleanup.		
27		Tie-down anchorage installation (as required)	Core and demolish tie-down anchoring location.		
28			Drill tie-down anchoring holes.		
29			Clean tie-down anchoring holes.		
30			Install tie-down anchor.		

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
31			Allow adhesive to cure.		
(Sheet 1 of 2)					
32	3 Repeat four times	AC patching	Mill AC pavement.	75 (one quarter of total patching completed per day)	6.2
33			Wet surface of base.		
34			Remove panels.		
35			Compact base.		
36			Install steel formwork.		
37			Apply tack material along asphalt perimeter.		
38			Place and compact AC.		
39			Water shock AC and allow to cool to 125°F.		
40			Reinstall panels.		
41			Clean site.		
42	4	Joint sealing	Air blast joints and anchor holes.	150	7.0
43			Install backer rod.		
44			Install sealant.		
45			Allow sealant to cure, clean site.		
(Sheet 2 of 2)					

3.3.1 Soil anchoring

The second option considered for asphalt-surfaced pavement installations used an innovative design taken from ADR installations for fiber-reinforced polymer (FRP) matting systems. Standard concrete anchors alone cannot be used to directly affix FRP matting to asphalt surfaces, and anchors must extend into the soil to resist the large vertical loads and pulling out of the pavement to support aircraft traffic (Rushing et al. 2016). The ERDC developed a micro (friction) pile called a tri-talon anchor (Gartrell 2007, 2008) that was live-flight certified (Priddy et al. 2011) and a modified equivalent using more generic materials as shown in Figure 36 (Rushing et al. 2016). The anchor consists of a steel skeleton inserted into a bored hole in the pavement backfilled with a cementitious mortar to fill the void made by boring. The cementitious mortar provides the rough surface that generates friction around the perimeter of the mortar to resist vertically applied loads. The upper portion of the coupler provides a reusable, vertically adjustable threaded connection point that can lie flush with the pavement surface.

Figure 36. Modified generic tri-talon anchor.



For a UHMW panel anchoring scenario, instead of having a threaded male end extending out of the pavement where the panel is affixed to the pavement by a nut, the upper portion of the tri-talon anchor provides a female connection that will require a bolt to be used. Standard tri-talon anchors are specified to include a 3 in. long, $^5/_8$-11 in. hex bolt that provides an untapped length of $1^1/_2$ in. The bolt length and diameter can accommodate the thickness of a standard UHMW panel with washer and anchoring holes in a standard panel without modifications.

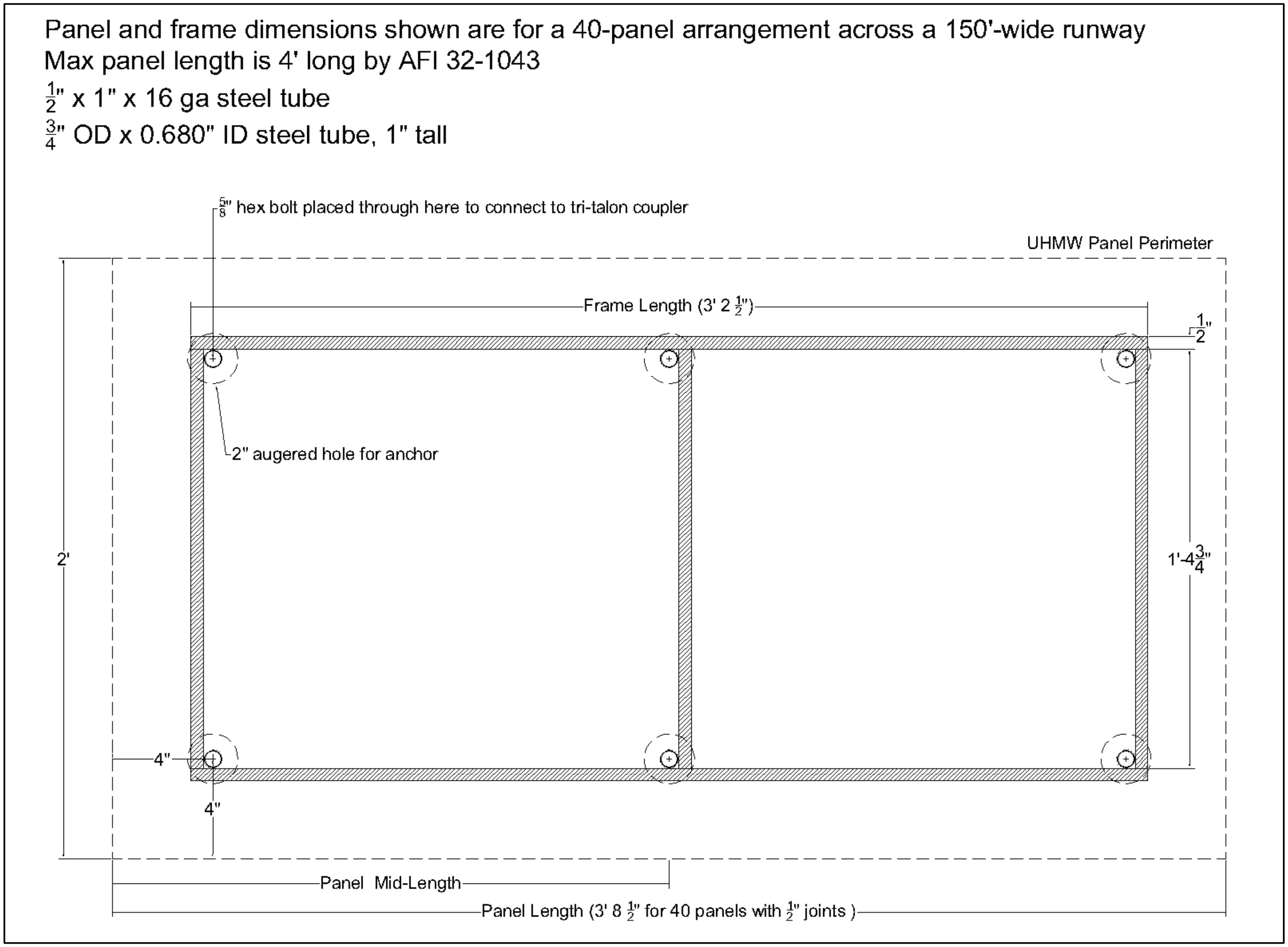
The USAF has modified FRP matting installation kits as an accessory collection of items to its Mobile Airfield Repair Equipment Set (MARES). A MARES kit includes enough materials and required equipment to install 120 tri-talon anchors (Rushing et al. 2016). Outside of the anchors themselves, a major piece of equipment included with the MARES kit inventory that is not in the collection of equipment in the SuPR kit inventory is the auger equipment needed to bore the holes for the anchors.

Items specific to installing the tri-talon and backfilling the anchor holes are also not included in a standard SuPR kit.

Alignment of the tri-talon anchors to easily install the UHMW panels was critical to the speed and accuracy of the installation process, since installed anchorage points would be difficult to modify once cast. To ensure the correct spacing and vertical alignment of the anchor couplers, additional formwork was constructed to hold the group of tri-talons for each panel in the proper alignment once the anchors were installed before backfilling, as shown in Figure 37. A drawing of the frame used is shown in Figure 38. The formwork is simple in construction and consists of a welded steel outer square tube frame with circular steel tubes at the prospective anchor locations. The tri-talon bolts are placed through the circular tube segments and tightened with a ratchet wrench to rigidly hold the group of six anchors together for the individual panel during backfilling. The open corner portions within the center of the frame allow for placement of cementitious grout in the augered holes with the transmission funnels within the MARES kit. Finishing the surface of the placed mortar may be difficult with the limited clearance and typical concrete floats and trowels available. Once the rapid-setting cementitious mortar hardens, the frame is removed and replaced with the UHMW panel.

Figure 37. Tri-talon installation formwork.

Figure 38. Drawing of tri-talon mounting formwork used.



Since a concrete foundation element is not installed across the runway with this option, pendant tie-down anchoring must be installed in addition to the tri-talon anchors. AFI 32-1043 provides a drawing for a reinforced cast-in-place concrete tie-down block for asphalt-surfaced pavements. The tie-down foundation depicted primarily relies on its self-weight to resist uplift (deadman anchor). A 2 ft square by 3 ft deep prism is specified, but the drawing notes allow for the construction of a circular 28 in. diameter cylinder as well as for augered excavations. Excavation by auger was expected to provide a faster return to service, since minimal handwork will be needed to bore a circular hole with standard heavy equipment as compared to over excavating with a backhoe and forming a square concrete element for the foundation; therefore, this method was selected for use. Augering attachments and their bits are standard pieces of equipment widely available on the commercial market.

Attachments for the CTL in the SuPR kit are available for augering, as shown in Figure 39; but this implement will need to be procured for this work since it is not in USAF inventories. Review of auger flights available by the CTL distributor (local rental company) showed that auger flight diameters come in 6 in. increments. Diameters of 18 and 24 in. were procured for this work since both flight diameters will fit within the 25 in. panel slot. Use of a smaller auger diameter requires a longer auger or extensions to be used when excavating to achieve the same weight foundation block. For the auger sizes selected, foundations lengths of 7.3 ft and 4.1 ft were required to maintain the same foundation weight as the 28 in. diameter foundation, respectively.

Figure 39. Auger attachment for CTL.

The reinforcement for the foundation was provided by using a piece of spiral shaped reinforcement, as shown in Figure 40, rather than the square cage depicted in the drawing. Spiral reinforcement was selected for its circular shape and is a standard reinforcement bent shape that can be readily procured from typical construction supply material vendors. Using a reinforcement ratio of 0.18% for a minimum reinforcement ratio temperature and shrinkage steel and 3 in. of cover for the reinforcement and standard 5/8 in. diameter, 60 ksi yield strength, the required maximum pitch of the reinforcement bent for 18 and 24 in. diameter tie-down blocks is 3.2 and 2.3 in., respectively.

Figure 40. Spiral bent reinforcement.

Table 16 details the overview of the required sequence of work tasks needed before the trial began. Table 17 details the timing recorded for each task, scaled up the appropriate runway width completed per work day. Process improvements and new projected timing are given.

Table 16. Initial sequencing of required work tasks for soil anchoring installation.

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
1	1	Demolition	Mark sawcuts.	150	4.0
2			Saw cut panel void perimeter.		
3			Wash saw slurry.		
4			Clean work zone.		
5	2 Repeat five times		Remove AC surfacing for concrete foundation.	30	12.0
6		Panel anchorage installation	Place and arrange panels.		
7			Shim panels.		
8			Drill pilot hole at panel anchoring locations.		
9			Remove panels and shims.		
10			Drill hole through remainder of AC for panel anchoring.		
11			Auger panel anchoring location.		
12			Install tri-talon anchoring.		
13			Activate and seat tri-talon anchoring.		
14			Install positioning frame.		
15			Backfill panel anchoring void with mortar.		
16			Allow rapid setting mortar to cure.		
17			Remove positioning frame.		
18			Place panel.	30	12.0
19			Install hardware.		
20			Finish cleanup.		
21	3 Install 1 per day as needed	Tie-down anchorage installation (as required)	Remove required panels.	37.5 or 75	Unknown
22			Locate center of foundation.		
23			Auger and remove soil.		
24			Place reinforcement.		
25			Place rapid setting concrete.		
26			Allow rapid setting concrete to cure.		
27			Remove any reinforcement holding accessories.		
28			Replace panel.		
29			Core and demolish tie-down anchoring location.		
30			Drill tie-down anchor embedding holes.		
31			Clean tie-down anchoring holes.		
32			Tie-down anchor installation.		
33			Finish cleanup.		
(Sheet 1 of 2)					

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
34	4	Joint Sealing	Air blast joints and anchor holes.	150	7.0
35			Install backer rod.		
36			Install sealant.		
37			Allow sealant to cure, clean site.		
					(Sheet 2 of 2)

Table 17. Installation timing information for soil anchoring installation.

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended Major Process improvement	Projected Timing (h:m)	Personnel Used	Major Equipment Changes or Additions
1	—[a]	5	Tape measure, chalk line	Break up into two teams: marking and chalking.	1:00	4	Same as before
2	—[a]	2	Floor saw	None	2:15	3	Same as before
-	—	—	—	Add walk-behind saw to cut ends of 30 ft segments.	0:15	1	Walk-behind saw
3	0:07	1	Pressure washer	Add second pressure washer as team works toward crown to assist with additional area that will require cleaning.	1:00	2	Same as before
4	—	—	—	Add airfield sweeper cleaning for final debris removal.	0:30	1	Airfield sweeper truck
5	0:07	3	Backhoe or excavator	Depends on thickness of AC layer encountered. It is projected that the AC layer will be thick enough to mill a slot into to locate the panels at the correct elevation. However, if the AC layer is not thick enough to be used as a bedding layer, the surfacing within the panel void should be removed full depth. Asphalt pavement should be ripped from within the panel slot area instead of milled with CTL for time savings and the CTL used to collect asphalt pieces for disposal. The time saved by ripping is then used to offset that needed for flowable fill placement.	0:10	4	CTL with bucket attachment depending on AC thickness
-	—	—	—	If milling with cold planer, clean surface with airfield sweeper truck after each milling increment to provide maximum traction of CTL.	0:32[b]	3	CTL with cold milling attachment, airfield sweeper truck
-	—	—	—	Placement of a thin layer of flowable fill may be needed if all the AC pavement is removed in the panel slot. Level areas of exposed base material. Wet and recompact aggregate base surface before placement. Produce and place material as needed to the specified depth to recess the panel.	0:30	6	Rammer compactor, CTL with concrete drum mixer or drill and paddle mixer depending on volume needed.
6	0:28[b]	4	None	None	0:02	4	Same as before
7			Hammer, pry bar, shims, string line	Trim of asphalt surface at the ends of the panel area to accommodate panel length, if required.	0:28	2	Same as before, cutoff saw

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended Major Process improvement	Projected Timing (h:m)	Personnel Used	Major Equipment Changes or Additions
8	0:09	2	Hammer drill, generator	None	0:10	2	Same as before
9	0:02	4	Pry bar	None	0:03	4	Same as before
10	0:25	2	Hammer drill, generator	None	0:25	2	Same as before
11	1:22	2-3	Hydraulic power pack, auger equipment	Third person monitors hydraulic hoses and assists operators. Additional personnel required to measure bore depth.	1:15	4	Tape measure
—	—	—	—	Airfield sweeper truck vacuums to remove bored soil with wand. Cleaning occurs after augering without getting in the personnel's way.	—	1	Airfield sweeper truck
12			Tri-talon anchors	Tri-talons should be prepared for insertion before arriving on site.			Same as before
13	0:58	3	Impact hammer, generator, tamping rod, sledge hammer	None	1:00	6	Same as before
14			Impact wrench, generator, ratchet, steel frames	None			Same as before
15	0:20	4	Drill and paddle mixer, funnels, concrete trowel	Have additional personnel help batch mortar for continuous transport and placement.	0:15	6	Same as before
16	—	—	None	Time varies depending on product used.	2:00	—	Same as before
17	0:03	2	Impact wrench, generator	Have two personnel with impact wrenches and one additional person collecting the bolts.	0:03	3	Same as before
–	—	—	—	Clean panel void before placing panel. Complete with vacuum sweeper truck wand instead of a shop vac.	0:05	1	Airfield sweeper truck
18	0:06	6	None	Have personnel parallel/stagger installation tasks instead of doing tasks in series together. Have personnel gross torqueing nuts and placing bolts.	0:06	2	Same as before
19	1:00	3	Ratchet and socket, torque wrench	Use impact wrench to quickly tighten bolt; use two teams of two with impact wrenches and torque wrenches each.	0:45	4	Impact wrench, generator

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended Major Process improvement	Projected Timing (h:m)	Personnel Used	Major Equipment Changes or Additions
20	0:07	1	Pressure washer	Add second pressure washer as team works toward crown to assist with additional cleaning of area.	1:00	2	Same as before
—	—	—	—	Add airfield sweeper cleaning for final debris removal.	0:30	1	Airfield sweeper truck
21	0:05[b]	1	Impact hammer, generator	None	0:05	1	Same as before
—	0:15	1	Tape measure, spray paint	Use stencil and lumber crayon to mark required saw cuts.	0:02[b]	1	Stencil, lumber crayon
—	—	1	Cutoff saw	None, not originally planned to complete work.	0:05	1	Same as before
—	—	1	Demolition Hammer	None, not originally planned to complete work. Have one person remove and collect large pieces while other breaks material.	0:10	2	Same as before
22	0:02	3	String line, spray paint	Use stencil to locate center of foundation; make surface impression with finger to mark center.	0:02	1	Stencil
23	0:10[a]	1	CTL with auger attachment, shovel and bucket, tape measure	Correct volume of foundation not achieved with this work. Timing is estimated to account for additional time needed to remove extra material. Use of 18 in. diameter flight will require multiple extensions to achieve the depth needed. Installing multiple extensions will take some time. Use airfield sweeper truck wand to collect removed material.	0:40[b]	2	CTL with auger attachment, auger flight extensions, airfield sweeper truck
24	0:05	2	Reinforcement cage, cage supports	Modified design required to allow for instant installation.	0:01[b]	2	Modified reinforcement cage design
25	—[a]	7	Concrete mixer for CTL	Add washout water collection equipment. Similar timing and process recommended as to traditional PCC repair bedding layer installation, since procedure is fairly similar. Timing reduced to 75% of that estimated since placement requires less finishing effort and 75% of the concrete volume is needed.	1:20[a]	8	Dump hopper, concrete mixer
26	2:00	0	—	Monitor strength gain with NDT equipment.	2:00	1	Schmidt hammer or equivalent
27	—[a]	1	Wire cutter	None	0:02	1	Same as before

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended Major Process improvement	Projected Timing (h:m)	Personnel Used	Major Equipment Changes or Additions
—	—	—	—	Verify foundation surface elevation sits below paneling with depth-checking tool from panel installation work. Locate high areas where panel will not seat well while concrete cures. Demolish with demolition tools as needed once concrete cure period ends.	0:30[a,b]	2	Demolition hammer with bits
—	—[a]	—	—	Water blast pavement around foundation to remove any material.	0:02	1	Pressure washer
—	—[a]	—	—	Air blast pavement within panel slot.	0:02	1	Air compressor
28	0:10[b]	4	Impact wrench, torque wrench	None	0:10	4	Same as before
—	0:07	1	Pressure washer	Pressure wash remaining affected pavement surface.	0:30	3	Pressure washer
—	—	—	—	Add airfield sweeper cleaning for final debris removal	0:30	1	Airfield sweeper truck
29-32	0:36	4	Hammer drill, air compressor, electric drill adhesive gun	Only one tie-down anchor installed for timing shown, time doubled for projected time incase two are installed as needed.	0:30	4	Same as before
33	—	—	—	Add airfield sweeper cleaning for final debris removal.	0:30	1	Airfield sweeper truck
Add AC patching work tasks given in traditional installation method to construct a smooth joint.							
-	—	—	—	Mill AC from prospective patch area with CTL and cold planer attachment. Complete only one quarter of the patching required (36 in. wide by 75 ft long on one side of the paneling).	1:30[b]	3	CTL with cold planer attachment, airfield vacuum truck
-	—	—	—	Wet base material with up to 0.5-gal/yd^2 of water.	0:10[b]	1	Water truck
-	—	—	—	Remove panels from pavement.	0:45[b]	4	Impact hammer, wrecking bar
-	—	—	—	Compact soil in base area.	0:10[b]	1	Dual steel wheel vibratory roller
-	—	—	—	Install formwork for asphalt placement.	0:45[b]	4	Impact hammer, steel formwork

Task	Measured Time (h:m)	Personnel Used	Major Equipment	Recommended Major Process improvement	Projected Timing (h:m)	Personnel Used	Major Equipment Changes or Additions
-	—	—	—	Apply AC binder tack material along asphalt perimeter.	0:15[b]	2	Roofing brush, liquid AC binder, PPE for asphalt work
-	—	—	—	Place and compact asphalt patch.	0:45[b]	6	CTL with asphalt screed attachment, dual steel wheel vibratory roller, hand tools
-	—	—	—	Watershock pavement and allow to cool to 125˚F; monitor surface temperature with infrared thermometer.	1:00	1	Water truck, sprinkler or water distributor, infrared thermometer
-	—	—	—	Remove formwork	0:45[b]	4	Impact wrench
-	—	—	—	Reinstall panels	1:30[b]	6	Impact wrench, torque wrench
-	—	—	—	Vacuum with airfield sweeper truck vacuuming to clean surface.	0:30	1	Airfield sweeper truck
34	1:00[a,b]	1	Air compressor	—	1:00	1	Same as before
35	3:00[a,b]	2	—	Use insertion tool to place at correct depth instead of by hand; use precut short longitudinal pieces.	1:30	2	Backer rod insertion tool
36	3:00[a,b]	2	Air compressor, sealant gun	—	3:00	2	Same as before
37	—[a]	—	—	Time varies depending on product used and environmental conditions. Allow surface to harden before trafficking.	1:00[b]	—	—

a) No timing data collected

b) Estimated

Notable installation issues observed and applicable modifications made to specific work tasks are described below.

1. The asphalt surface within the testing area was not as thick as expected after milling the panel slot. Since the surface was not as thick, the thin layer of asphalt projected to remain after milling was unevenly removed during the milling process and exposed the underlying base. A smooth surface was not available to place the panels on. To provide a smooth, consistent surface, the thin, irregular layer of asphalt concrete that remained in the panel slot was removed, and flowable fill was placed to replace the missing material volume. Flowable fill placement was similar to that described for the partial-depth PCC installation methods described earlier. If required in the field, material production depends on the volume of flowable fill required. It is projected that buckets of flowable fill will be mixed with a drill and paddle mixer for small quantities, since the amount of work required to make and place this volume of material is small (eight buckets are required to fill approximately 1/2 in. depth of panel slot). These items are in a standard SuPR kit, so there are no additional requirements. Production of greater quantities of material for deeper installations may require a drum mixer attachment for the CTL to reduce placement work due to the increase in volume, as shown in Figure 41. The optimized list of tasks for this repair method will include timing information for both full-depth removal and partial-depth milling for the slot. Milling the slot void will take more time than ripping the asphalt from the surface; but additional work tasks, equipment, and supplies are required to place the flowable fill needed.

Figure 41. Installation of flowable fill for thin asphalt pavement surfaces.

2. Use of the flowable fill to fill the missing volume left a hardened cap over the base layer. This had to be demolished before augering the tie-down foundation holes. A square hole was cut at the anchor locations (Figure 42), and the hardened material was demolished with a demolition hammer to expose the base.

Figure 42. Demolishing filling material for tie-down anchor installation.

3. Augering the tie-down foundation void does not allow for the installation of the center panel tri-talon anchors since they are in the cutting path of the auger flight. Anchoring points must be installed after the foundation is placed. Installation procedures for these anchors should follow those described for affixing panels to a concrete foundation. This work should be added to the tie-down anchoring installation work day, since the work tasks conducted are similar. Installing additional anchor elements that use the epoxy adhesive will require less overall time per item installed since a significant amount of the overall time needed is to allow the epoxy to cure to its minimum activation strength. Considerations for the minimum concrete side cover required need to be verified or addressed if the 18 in. diameter foundation is used to ensure the anchoring will support the loading required. For the adhesive used with this work (Powers Fasteners AC100+ vinyl ester epoxy), the minimum edge and anchor spacing given by the manufacturer are 3 3/4 and 5 in. from the center of the anchor, respectively. One option available is to move the two center panel anchor points more to the interior of the panel to accommodate the minimum side cover required by the adhesive manufacturer (Figure 43). This will require modification of the UHMW panel to align the panel anchoring holes to the interior location.
4. A simplified method is required to locate sawcuts and the center of the foundation once the panel is removed. Methods used included painting the panel tie-down hole while the panel is still installed and using two crossing string lines drawn between diagonal corner anchoring points. Perimeter saw cut locations required using a tape measure to assist with snapping a chalk line or spraying with paint. A single, reusable template or stencil should be used to quickly identify and mark the center of the foundation and the perimeter of the foundation where saw cutting is required to expose the base for augering. An example of a stencil is provided in Figure 44. The stencil should be large enough to use the panel anchoring points as reference points. Once the stencil is applied, a lumber crayon can be used to make the required markings. Spray paint is not allowed for transport on USAF aircraft and therefore is not an option for this work.
5. There was excessive wallowing of the augered hole. The holes drilled were approximately 3 in. larger in diameter at the surface than at the depth (Figure 45). This was attributed to the CTL's lowering the auger into the pavement with a rotational motion rather than a purely vertical motion. The excessive material removed at the surface created

a void larger than 24 in. in diameter in the pavement. This void was larger than the panel slot area. Use of this sized auger flight required a patch to be made in the pavement, creating an additional work task. The 18 in. diameter flight created an approximately 21 in. diameter hole at the surface.

6. The reinforcement used did not hold its shape (length), and the pitch of the reinforcement was not maintained, as shown in Figure 40. Field modification of trimming the excess material above the pavement surface was required (Figure 46). Future reinforcement detailing should include straight bars running axially along the spirals to which they can be tied. This will hold the reinforcement cage to the correct dimensions and ensure the correct pitch is maintained to provide the specified reinforcement ratio. At least two straight bars should be included within the interior of the spiral and the spiral tied to the straight bar at every other evolution.
7. The perimeter of the panel void was larger than expected with an uneven sawn joint along the transverse directions (Figure 47). Partial-depth patching of the transverse panel perimeter is needed to provide a smooth transition of an arresting hook across the paneling area. Patching efforts conducted should follow those given for the traditional AC method.
8. It is recommended that the tie-down anchoring hardware be installed on a separate work day from the day the foundations are cast. All other installation methods involved placement of tie-down anchor hardware at the time (shortly after) the panel anchoring was installed since installing a single eyebolt does not add a significant amount of extra time to the overall work phase. Condensing their installation to one day is more efficient since the soil anchoring method does not use the adhesive-based panel anchors. Work phasing does not have the adhesive readily available to use compared to phasing in which panel anchoring is used. Additionally, separating their installation reduces the overall foundation construction phase timing into two tasks that are fewer than 6 hr in duration. Optimized timing was prepared for both four- and eight-anchor installations to account for timing differences based on runway requirements.

Figure 43. Recommended tie-down panel configuration for 18 in. diameter foundations.

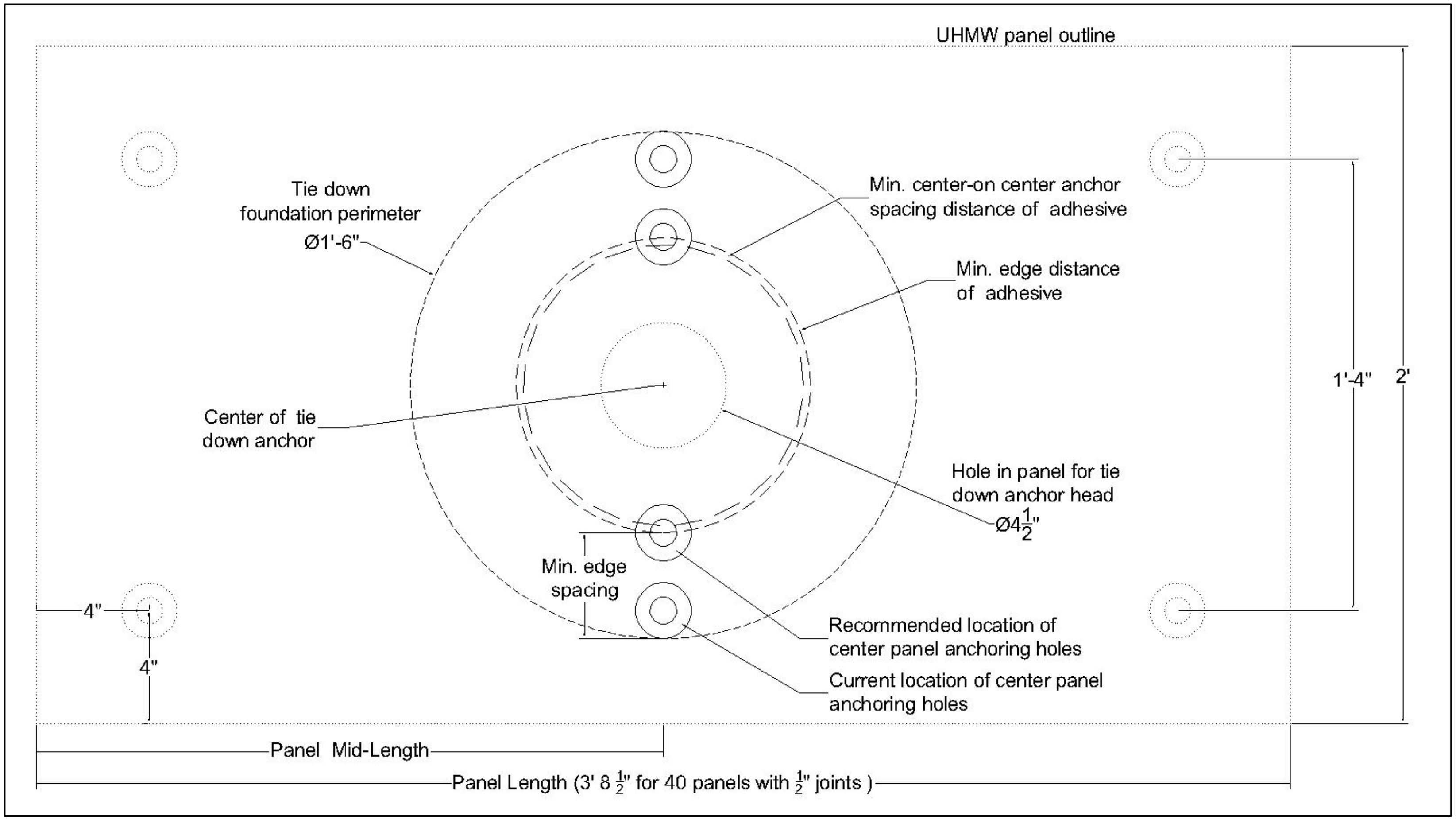


Figure 44. Recommended stencil dimensions for installing tie-down foundation.

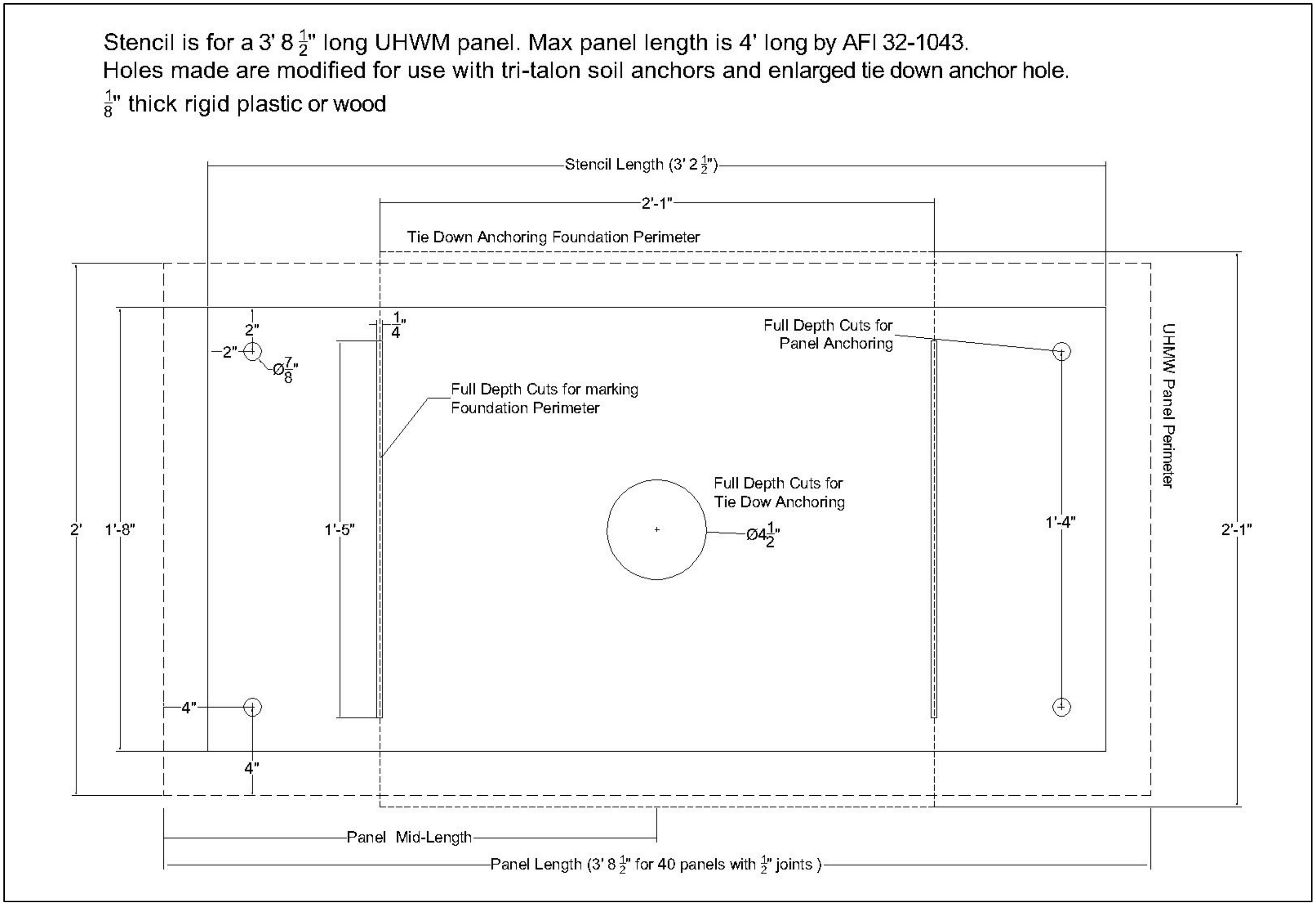


Figure 45. Augered hole after construction.

Figure 46. Field modification of tie-down anchoring reinforcement.

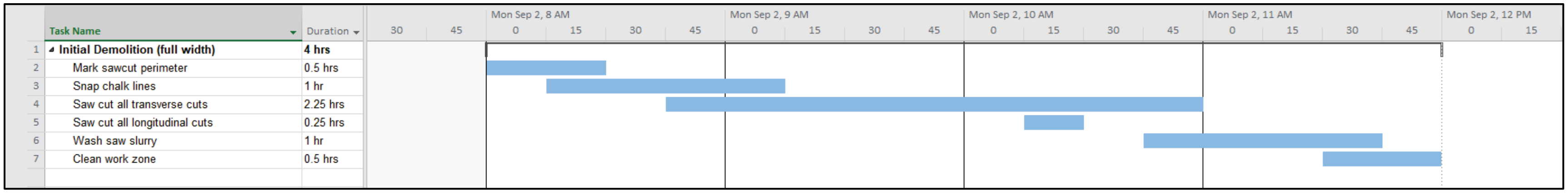
Figure 47. As-constructed jointing with panel installed.

Figure 48 shows the prospective Gantt charts developed for the installation work days. Six different phases are needed to complete the necessary work. Many of the required work tasks are sequential, and little parallelization could be completed to reduce the total duration of the work. With the modified timing, three of the work phases are less than the preferred 6 hr time limit per work day. All work phases are projected to be less than the maximum 12 hr requirement. Some work phases have options available to account for different scenarios the installation work encounters. A total of 16 work days is required to install a UHMW panel system across a 150 ft asphalt surfaced runway with this option.

Table 18 details the modified sequencing of work tasks with updated timing. Many of the items and equipment are currently in USAF inventories, and all may be delivered to the site by C-130 aircraft. Major items not included in a standard SuPR kit include the MARES kit and an auger attachment for the CTL; however, the MARES kit is in USAF inventories.

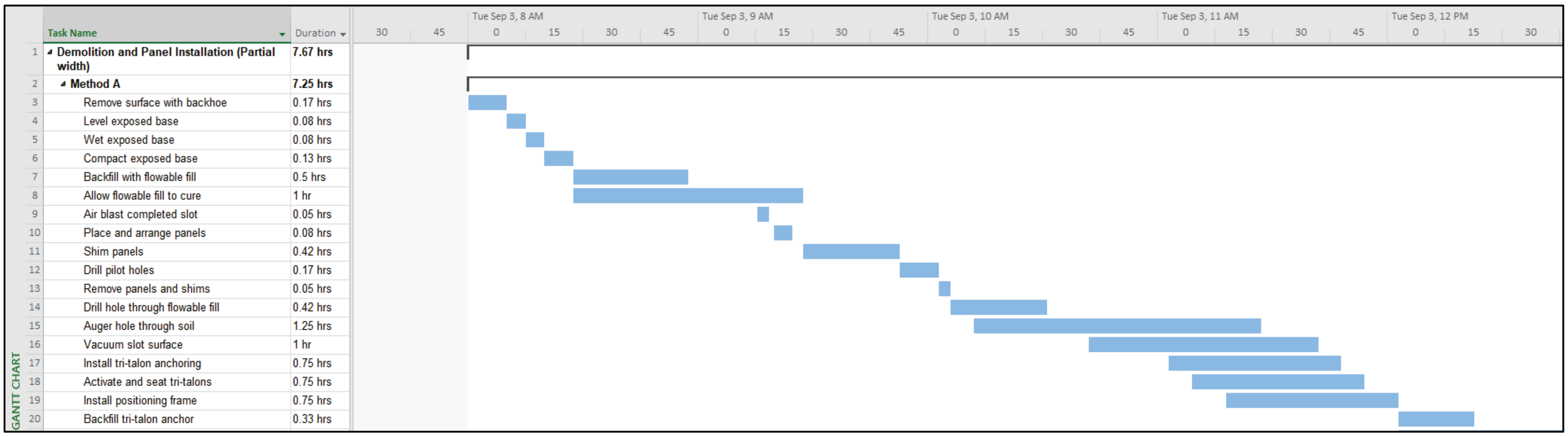
Figure 48. Gantt charts for soil anchoring installation.

a. Initial demolition



(Sheet 1 of 1)

b. Demolition and panel installation



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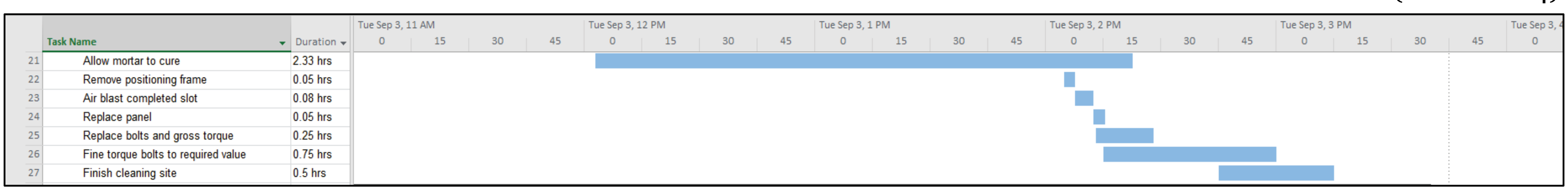

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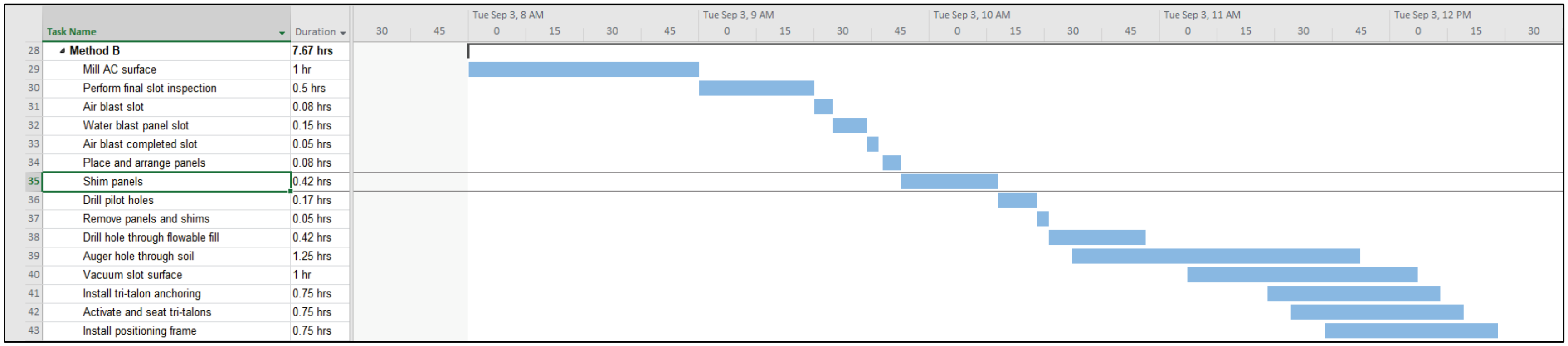
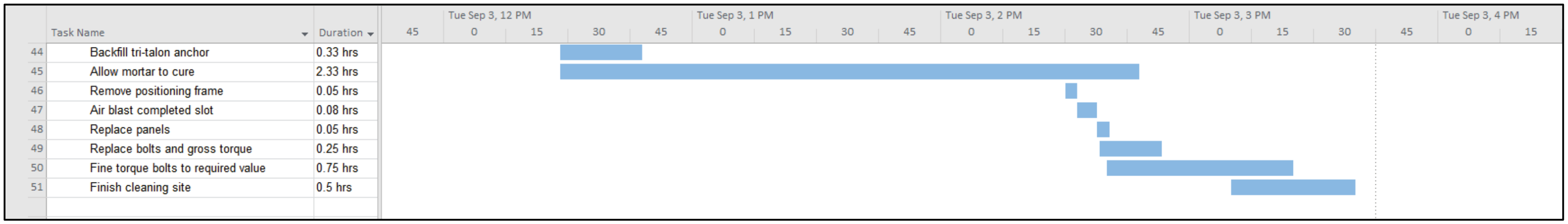


	Task Name	Duration
28	Method B	7.67 hrs
29	Mill AC surface	1 hr
30	Perform final slot inspection	0.5 hrs
31	Air blast slot	0.08 hrs
32	Water blast panel slot	0.15 hrs
33	Air blast completed slot	0.05 hrs
34	Place and arrange panels	0.08 hrs
35	Shim panels	0.42 hrs
36	Drill pilot holes	0.17 hrs
37	Remove panels and shims	0.05 hrs
38	Drill hole through flowable fill	0.42 hrs
39	Auger hole through soil	1.25 hrs
40	Vacuum slot surface	1 hr
41	Install tri-talon anchoring	0.75 hrs
42	Activate and seat tri-talons	0.75 hrs
43	Install positioning frame	0.75 hrs

(Sheet 3 of 4)



	Task Name	Duration
44	Backfill tri-talon anchor	0.33 hrs
45	Allow mortar to cure	2.33 hrs
46	Remove positioning frame	0.05 hrs
47	Air blast completed slot	0.08 hrs
48	Replace panels	0.05 hrs
49	Replace bolts and gross torque	0.25 hrs
50	Fine torque bolts to required value	0.75 hrs
51	Finish cleaning site	0.5 hrs

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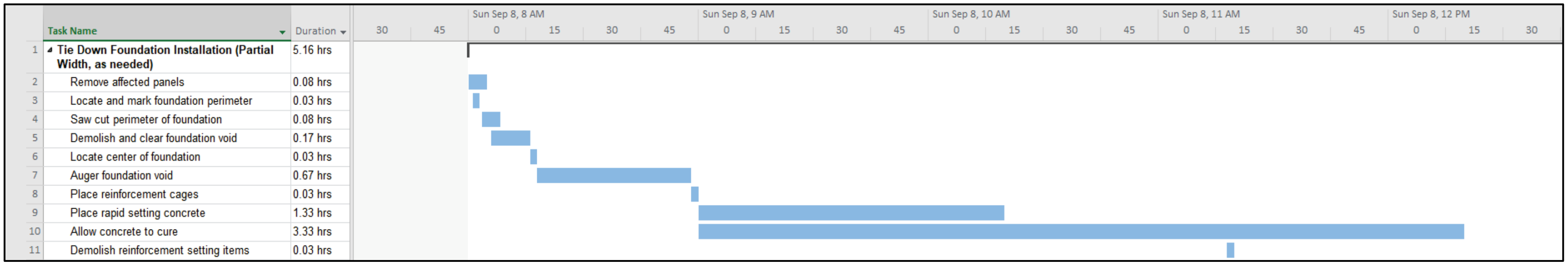
c. Tie-down foundation installation



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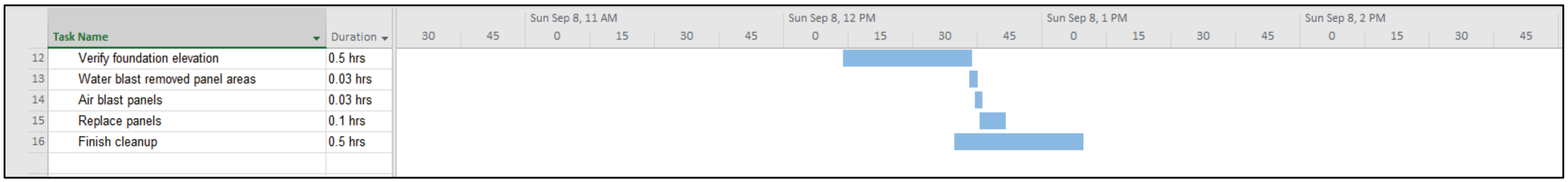

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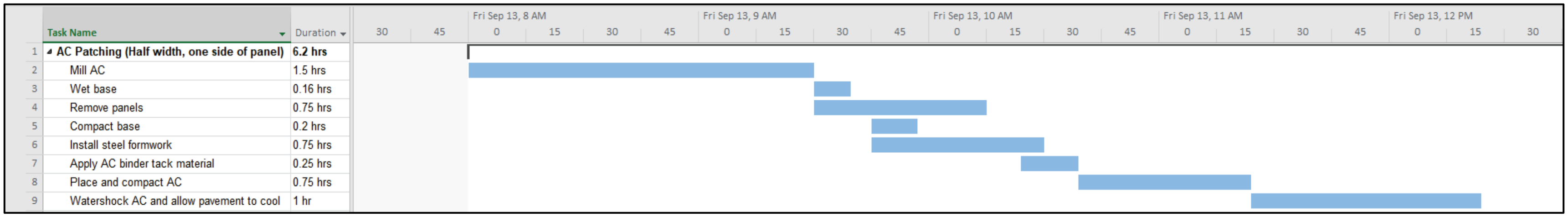
d. Tie-down anchoring hardware installation

(Sheet 1 of 1)

e. AC patching



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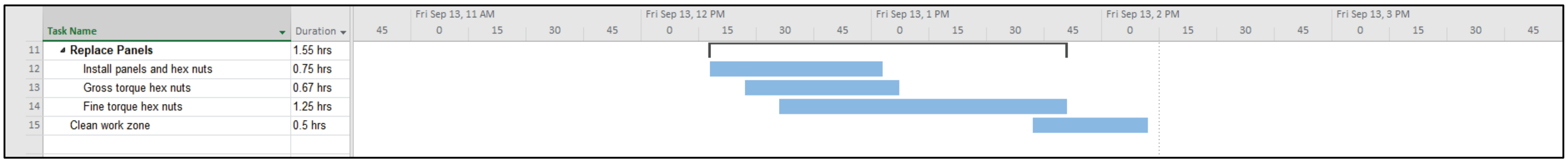

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f. Joint Sealing

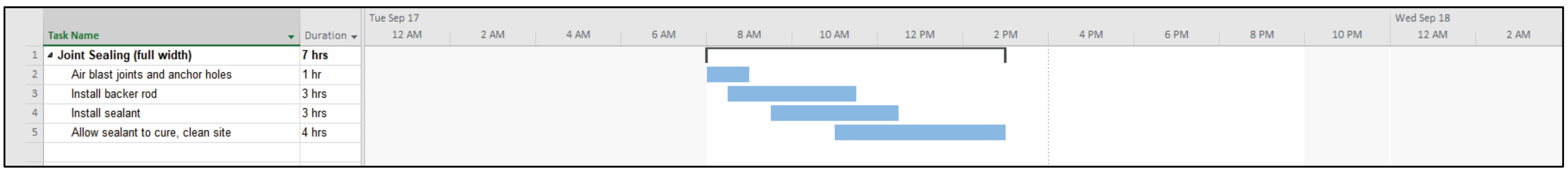

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Table 18. Optimized sequencing of required work tasks for soil anchoring installation.

Task	Work Day	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
1	1	Demolition	Mark sawcuts.	150	4.0
2			Saw cut panel void perimeter.		
3			Sawcut interior segment breaks.		
4			Wash saw slurry.		
5			Clean work zone.		
Method A – Full-depth removal for thin asphalt surfaces					
6	2-6 repeat five times	Demolition	Remove AC surfacing by ripping.	30	7.3
7		Panel anchorage installation	Level exposed base material.		
8			Compact exposed base material.		
9			Backfill with flowable fill.		
10			Allow flowable fill to cure.		
11			Air blast completed slot.		
12			Place and arrange panels.		
13			Shim panels.		
14			Drill pilot hole at panel anchoring locations.		
15			Remove panels and shims.		
16			Drill hole through flowable fill layer.		
17			Auger panel anchoring locations.		
18			Vacuum slot surface.		
19			Install tri-talon anchoring.		
20			Activate and seat tri-talon anchors.		
21			Install positioning frame.		
22			Backfill tri-talon anchoring with mortar.		
23			Allow mortar to cure, begin cleanup.		
24			Remove positioning frame.		
25			Air blast panel slot.		
26			Replace panels.		
27			Install hardware.		
28			Finish cleanup.		

(Sheet 1 of 3)

Task	Work Day	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
Method B –Partial-depth removal for thicker asphalt surfaces					
6	2-6 repeat five times	Demolition	Remove AC surfacing by milling.	30	7.7
7			Perform final slot inspection.		
8		Panel Anchorage Installation	Waterblast completed slot.		
9			Air blast completed slot.		
10			Place and arrange panels.		
11			Shim panels.		
12			Drill pilot hole at panel anchoring locations.		
13			Remove panels and shims.		
14			Drill hole through flowable fill layer.		
15			Auger panel anchoring locations.		
16			Vacuum panel slot.		
17			Install tri-talon anchoring.		
18			Activate and seat tri-talon anchors.		
19			Install positioning frame.		
20			Backfill tri-talon anchoring with mortar.		
21			Allow mortar to cure, begin cleanup.		
22			Remove positioning frame.		
23			Replace panels.		
24			Install hardware.		
25			Finish cleanup.		
Continuing with remaining work plan					
28	7-10 (repeat up to 4 times as needed)	Tie-down anchorage foundation installation	Remove required panels.	37.5 or 75 Max: 2 per work day	5.2
29			Mark sawcuts for foundation perimeter.		
30			Saw cut perimeter of foundation.		
31			Demolish pavement/flowable fill within perimeter.		
32			Locate foundation center.		
33			Auger and remove soil.		
34			Place reinforcement.		
35			Place rapid-setting concrete.		
36			Allow concrete to cure.		
37			Verify foundation surface elevation.		
38			Remove reinforcement setting accessories.		
(Sheet 2 of 3)					

Task	Work Day	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
39			Water blast removed panel areas.		
37			Air blast removed panel areas.		
38			Replace panel.		
39			Finish cleanup.		
For installation of 4 anchors					
40	11	Tie-Down Anchorage Installation	Core and demolish tie-down anchoring location.	150	1.8
41			Drill tie-down anchoring holes.		
42			Clean tie-down anchoring holes.		
43			Install tie-down anchors.		
44			Allow adhesive to cure.		
45			Finish cleanup.		
For installation of 8 anchors					
40	11	Tie-Down Anchorage Installation	Core and demolish tie-down anchoring location.	150	2.3
41			Drill tie-down anchoring holes.		
42			Clean tie-down anchoring holes.		
43			Install tie-down anchor.		
44			Allow adhesive to cure.		
45			Finish cleanup		
46	12-15 Repeat four times	AC Patching	Mill AC pavement.	75 (one quarter of total patching completed per day)	6.2
47			Wet surface of base material.		
48			Remove panels.		
49			Compact base.		
50			Install steel formwork.		
51			Apply tack material along asphalt perimeter.		
52			Place and compact AC.		
53			Water shock AC and allow to cool to 125°F.		
54			Reinstall panels.		
55			Clean site.		
56	16	Joint Sealing	Air blast joints and anchor holes.	150	7.0
57			Install backer rod.		
58			Install sealant.		
59			Allow sealant to cure, clean site.		
(Sheet 3 of 3)					

3.4 Results for combined PCC and AC pavement installation

A combined installation method in which panels were placed in both concrete and asphalt pavements across the width of a runway was also considered. Construction efforts focused on installing panels within a 75 ft wide concrete keel pavement section centered in the runway with $37^{1}/_{2}$ ft wide asphalt pavement exteriors. Construction materials and installation techniques will be the same as those previously considered for the full-width asphalt or concrete installations, except that work phase timing is modified to accommodate the difference in plan area dimensions (length) of the project area.

Previous timing focused on installing paneling in 30 ft segments of asphalt or approximately two to three slabs for concrete sections, depending on the slab width encountered. The partial-depth repair concrete and traditional asphalt options were considered for this work since they best accommodated the timing requirements of the options considered. Timing was extrapolated to $37^{1}/_{2}$ ft for the asphalt portion to complete all demolition and panel installation work needed in one day. To accommodate the longer width of asphalt pavement, the reinforcement layout for the concrete foundation element was modified with longer spans of transverse reinforcement, as shown in Figure 49. The installation of reinforcement ties is not required with this phase of construction since the foundation elements are placed in one monolithic section without construction joints.

Figure 49. Modified recommended reinforcement layout schematic for AC portions with combined PCC and AC installations.

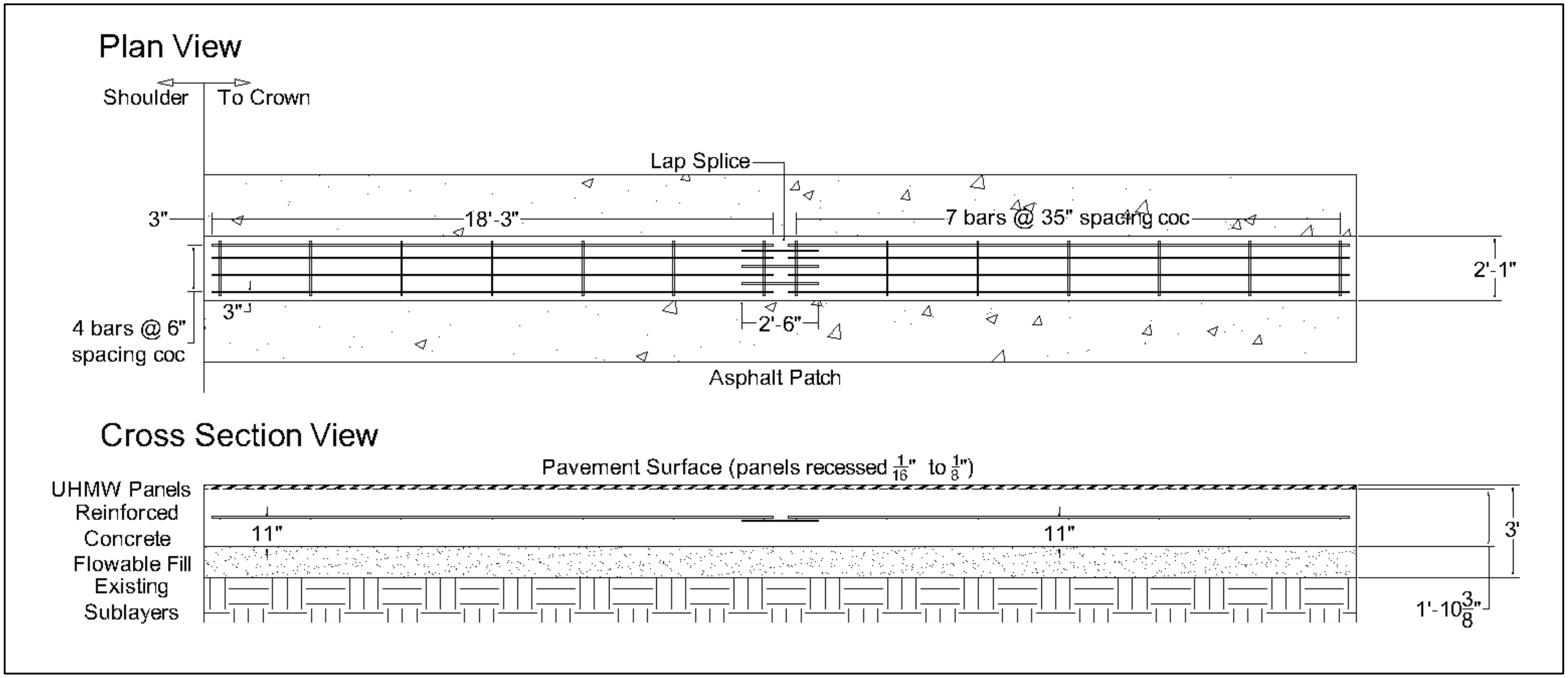


Figure 50 shows the Gantt charts developed for the installation work days. Seven different phases are needed to complete the necessary work. Many of the required work tasks are sequential, and little parallelization could be completed to reduce the total duration of the work. This is expected, since both PCC and AC pavement are encountered and the installation techniques for each are significantly different. Four of the work phases are less than the preferred 6 hr time limit per work day. Two work phases are less than the 12 hr maximum time requirement. Scaling the timing up to accommodate the larger project area increases the demolition and panel installation work phases for the concrete surfaced pavement section just past the 12 hr maximum time requirement. Additionally, work required for the larger asphalt-surfaced pavement portions approached the 12 hr requirement. A total of 10 work days is required to install a UHMW panel system across a 150 ft asphalt-surfaced runway with this option.

A reconfigured schedule was developed for both the concrete- and asphalt-surfaced pavement panel installation phases to provide an option that significantly reduced the total time of the phasings below the 12 hr maximum requirement. Figure 51 shows time reductions of approximately 3.9 and 2.5 hr can be achieved by reducing the project area to half of that given in Figure 50 and extending required work over more days for concrete- and asphalt-surfaced pavement installations, respectively. A total of 14 to 16 construction days is required for the reconfigured schedule, depending on the PCC pavement slab widths on site.

The time reductions show that total work timing for the phases is not proportionally reduced by reducing the length of the panel installation. This is due to the curing of the flowable fill, concrete, and epoxy construction materials. Curing materials create dead time to the installation process, since no work can be completed until a minimum material strength is achieved. Even if one item is placed, the minimum cure time must be applied. Placing more items per work event that require curing, such as larger volumes of cementitious material or installing more anchors, is more efficient to the overall process since less overall time is lost to curing per unit or area installed even though more time is added for the specific work task. While using shorter project area length meets the mission requirements, using the longer project area length reduces the overall time on the runway by 1 work day for each installation day and allows the runway to be open for an additional 4.7 and 6.9 hr for the individual PCC and AC panel installation phases over the duration of the entire project, respectively.

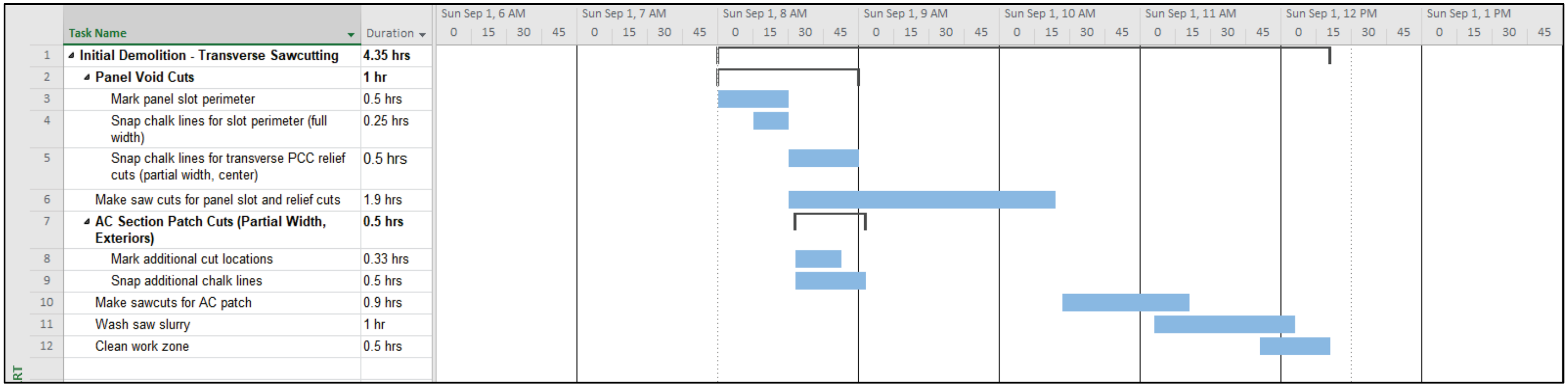
Additional time is lost to the asphalt-surfaced panel portion of the installation work due to the installation of tie bars. Breaking the foundation into two separate placements requires that the separately cast concrete elements be tied. Use of a single larger concrete placement reduces the number of work tasks and the amount of time lost to the tie-bar epoxy cure, since no epoxying is needed. Figure 52 details the reinforcement and tie layout required for installing the asphalt exteriors half of their length.

Tables 19 and 20 detail the sequencing of work tasks for the recommended option with larger installation length and timing necessary to meet the mission requirements using half the required installation width, respectively. Both phase sequences were provided to be used as airfield operations allow. Although the recommended timing does not meet the maximum runway closure time requirement, the work described makes better use of the allotted time on site since it reduces the overall project time and overall runway closure time.

Many of the items and equipment are currently in USAF inventories, and all may be delivered to the site by C-130 aircraft. Major items not included in a standard SuPR kit include a water truck, an airfield sweeper truck, an air compressor lance, a pneumatic adhesive dispensing gun, a torque wrench, a caulk compound, a steel cup brush, wooden shims, and a pneumatic sealant dispensing gun as described before in the partial-depth PCC installation option and the modifications listed in the traditional AC installation section.

Figure 50. Gantt charts for the recommended method for combined PCC and AC installations.

a. Initial demolition – transverse sawcutting



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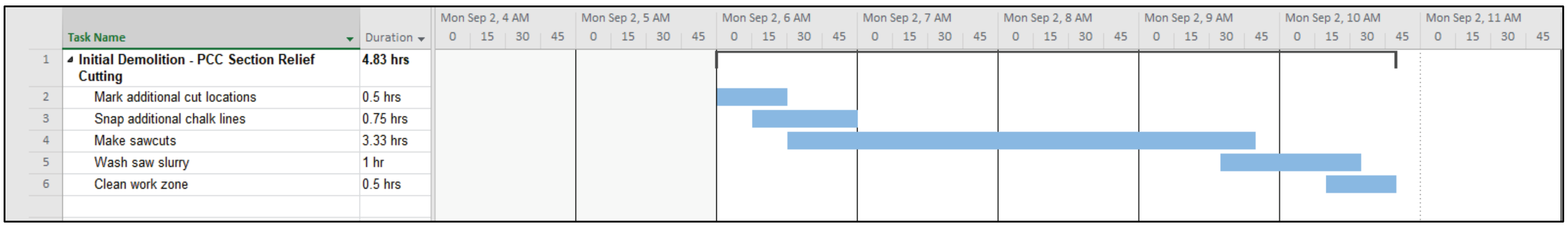
b. Initial demolition – longitudinal sawcutting of PCC relief cuts



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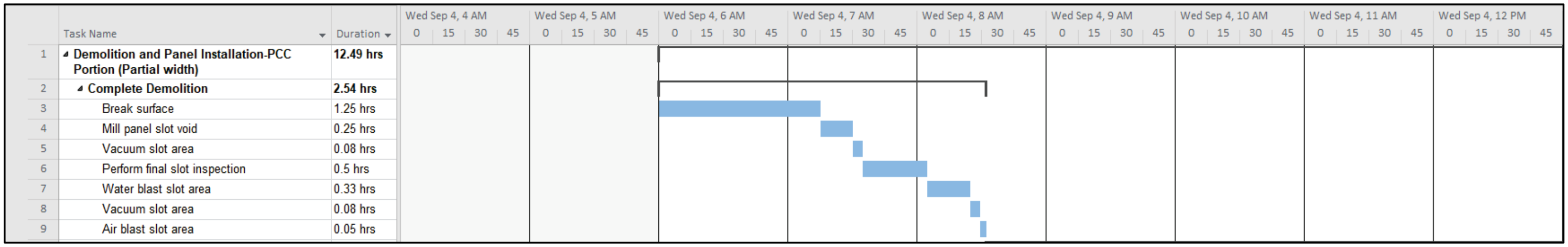
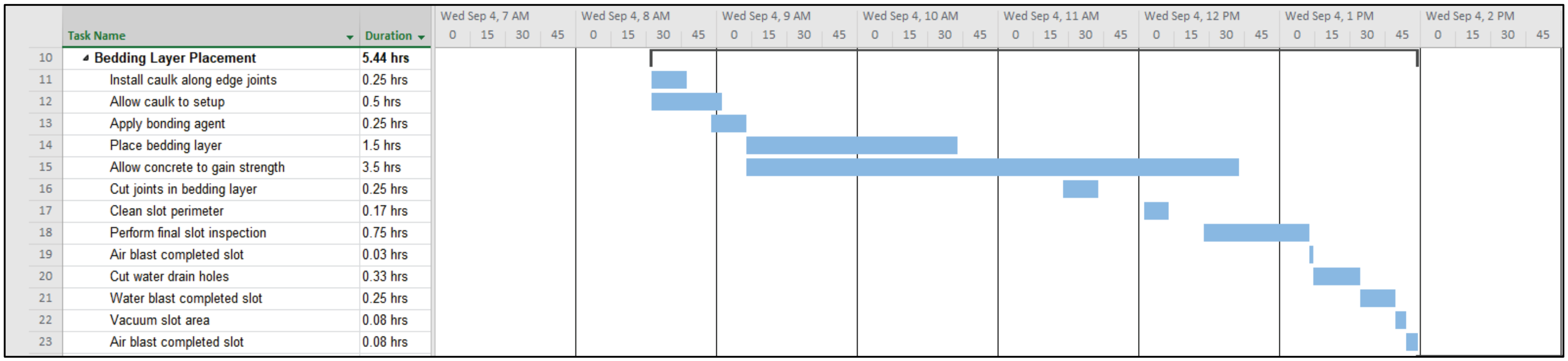
c. Demolition and panel installation - PCC section



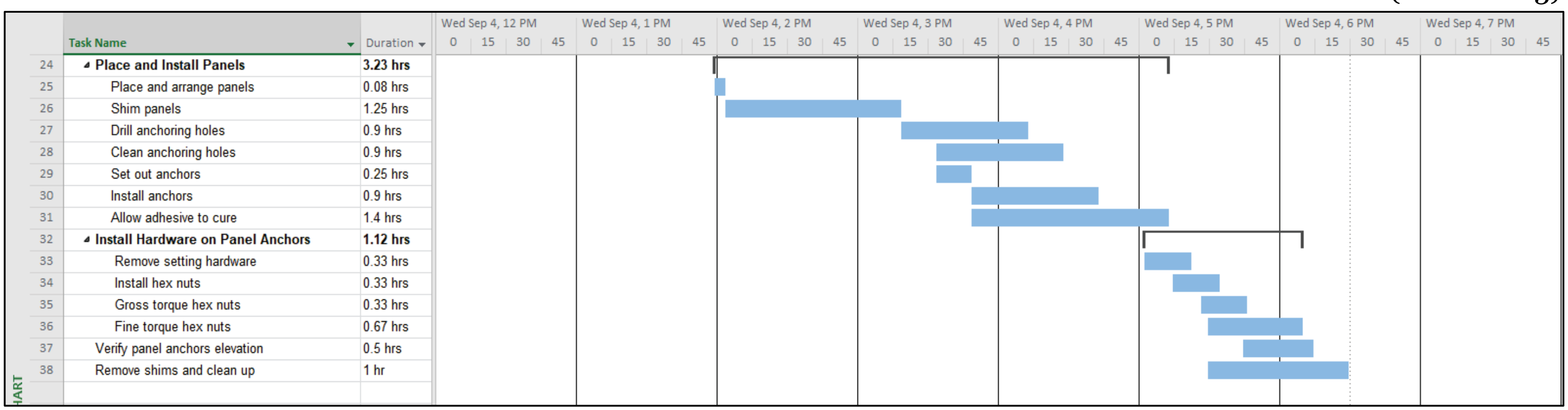
	Task Name	Duration
1	Demolition and Panel Installation-PCC Portion (Partial width)	12.49 hrs
2	Complete Demolition	2.54 hrs
3	Break surface	1.25 hrs
4	Mill panel slot void	0.25 hrs
5	Vacuum slot area	0.08 hrs
6	Perform final slot inspection	0.5 hrs
7	Water blast slot area	0.33 hrs
8	Vacuum slot area	0.08 hrs
9	Air blast slot area	0.05 hrs

(Sheet 1 of 3)



	Task Name	Duration
10	Bedding Layer Placement	5.44 hrs
11	Install caulk along edge joints	0.25 hrs
12	Allow caulk to setup	0.5 hrs
13	Apply bonding agent	0.25 hrs
14	Place bedding layer	1.5 hrs
15	Allow concrete to gain strength	3.5 hrs
16	Cut joints in bedding layer	0.25 hrs
17	Clean slot perimeter	0.17 hrs
18	Perform final slot inspection	0.75 hrs
19	Air blast completed slot	0.03 hrs
20	Cut water drain holes	0.33 hrs
21	Water blast completed slot	0.25 hrs
22	Vacuum slot area	0.08 hrs
23	Air blast completed slot	0.08 hrs

(Sheet 2 of 3)

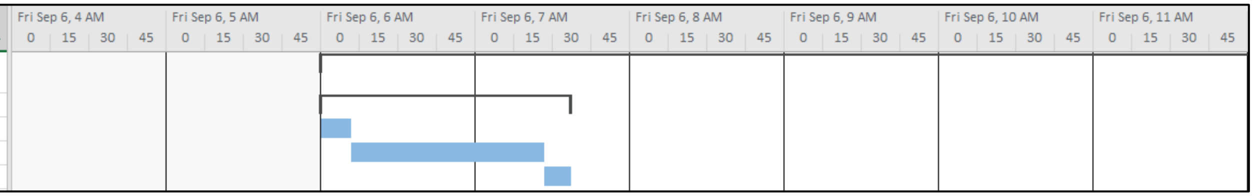


	Task Name	Duration
24	Place and Install Panels	3.23 hrs
25	Place and arrange panels	0.08 hrs
26	Shim panels	1.25 hrs
27	Drill anchoring holes	0.9 hrs
28	Clean anchoring holes	0.9 hrs
29	Set out anchors	0.25 hrs
30	Install anchors	0.9 hrs
31	Allow adhesive to cure	1.4 hrs
32	Install Hardware on Panel Anchors	1.12 hrs
33	Remove setting hardware	0.33 hrs
34	Install hex nuts	0.33 hrs
35	Gross torque hex nuts	0.33 hrs
36	Fine torque hex nuts	0.67 hrs
37	Verify panel anchors elevation	0.5 hrs
38	Remove shims and clean up	1 hr

(Sheet 3 of 3)

d. Demolition and panel installation - AC sections

	Task Name	Duration
1	**Demolition and Panel Installation-AC Portion (Partial width)**	**11.94 hrs**
2	**Demolition and Excavation**	**1.62 hrs**
3	Remove surface pavement	0.2 hrs
4	Remove sublayer soil	1.25 hrs
5	Compact bottom of trench	0.17 hrs



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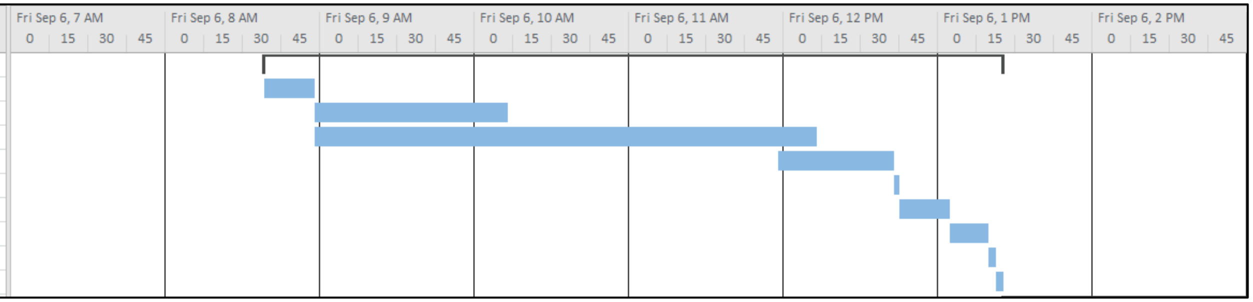
	Task Name	Duration
9	**Concrete Foundation Placement**	**4.79 hrs**
10	Install reinforcement grid	0.33 hrs
11	Place rapid-setting concrete	1.25 hrs
12	Allow concrete to gain strength	3.25 hrs
13	Perform final slot inspection	0.75 hrs
14	Air blast slot	0.03 hrs
15	Cut water drain holes	0.33 hrs
16	Water blast completed slot	0.25 hrs
17	Vacuum completed slot	0.05 hrs
18	Air blast completed slot	0.05 hrs



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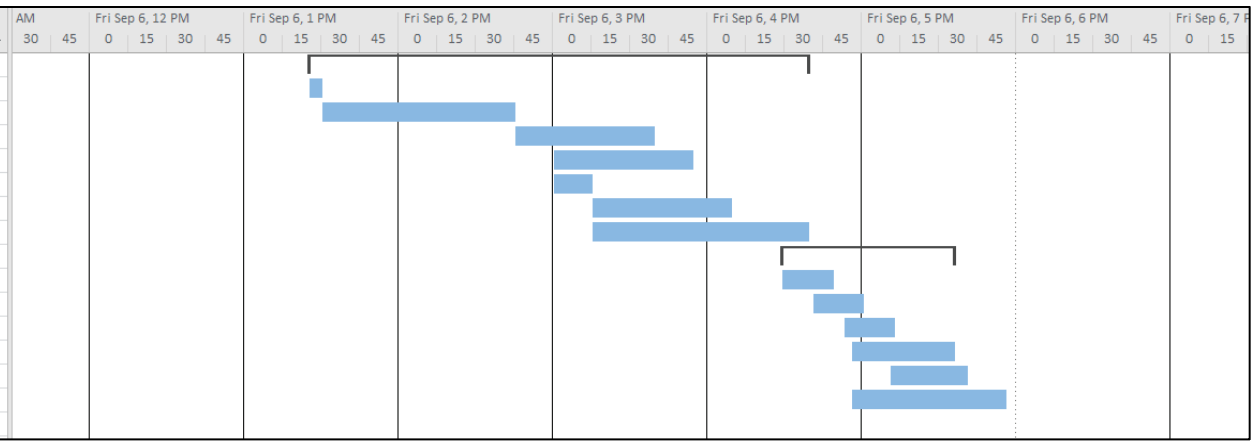
	Task Name	Duration
19	**Place and Install Panels**	**3.23 hrs**
20	Place and arrange panels	0.08 hrs
21	Shim panels	1.25 hrs
22	Drill anchoring holes	0.9 hrs
23	Clean anchoring holes	0.9 hrs
24	Set out anchors	0.25 hrs
25	Install panel anchor hardware	0.9 hrs
26	Allow adhesive to cure	1.4 hrs
27	**Install Panel Anchor Hardware**	**1.12 hrs**
28	Remove setting hardware	0.33 hrs
29	Install hex nuts	0.33 hrs
30	Gross torque hex nuts	0.33 hrs
31	Fine torque of hex nuts	0.67 hrs
32	Verify final anchor elevations	0.5 hrs
33	Remove shims and clean up	1 hr



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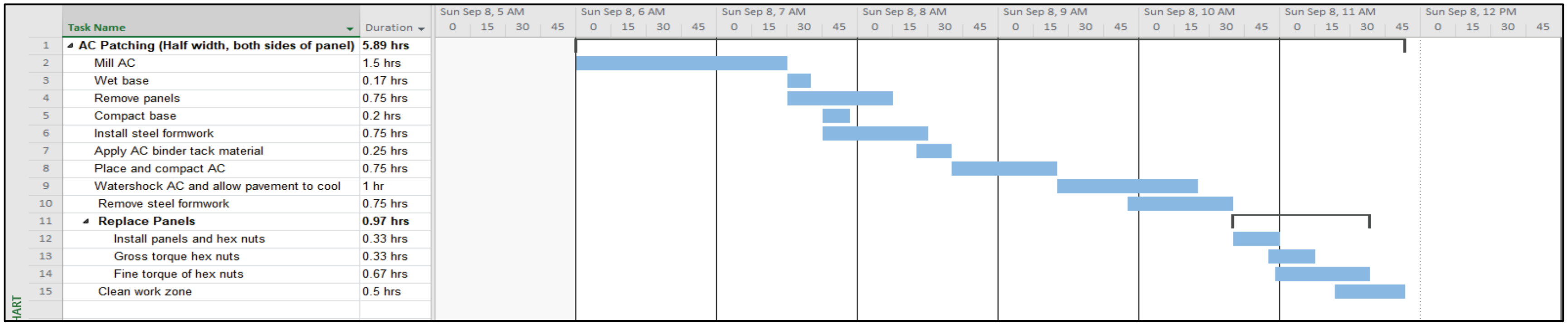
e. AC patching



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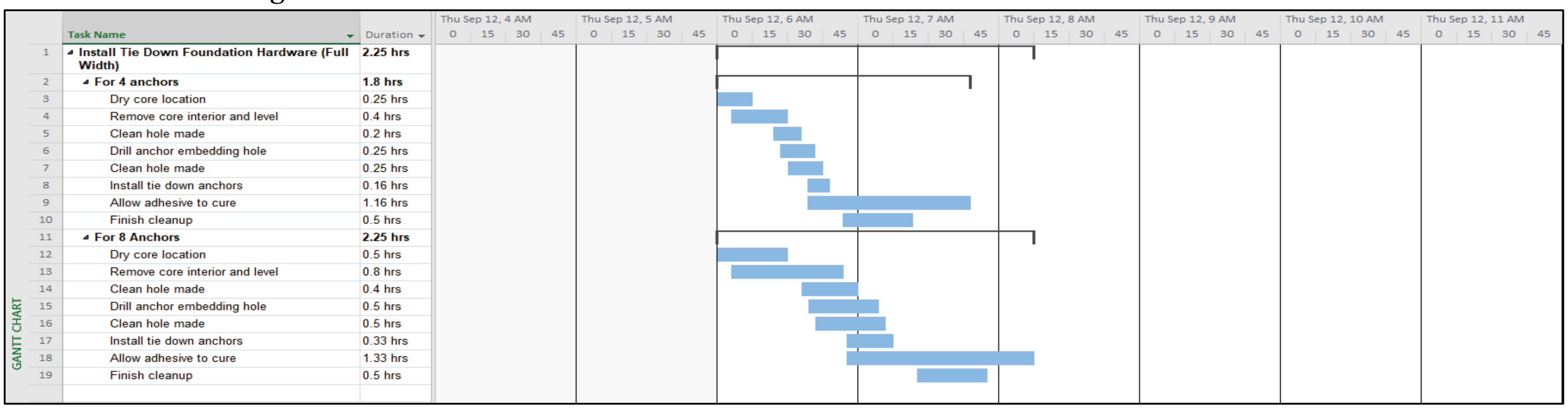
f. Tie-down anchoring hardware installation



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f. Joint Sealing

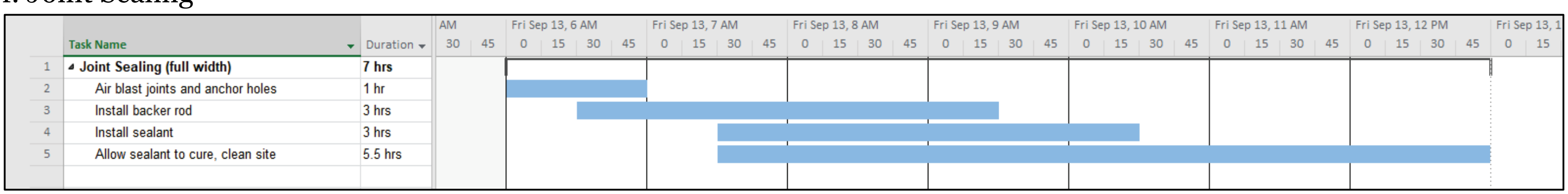

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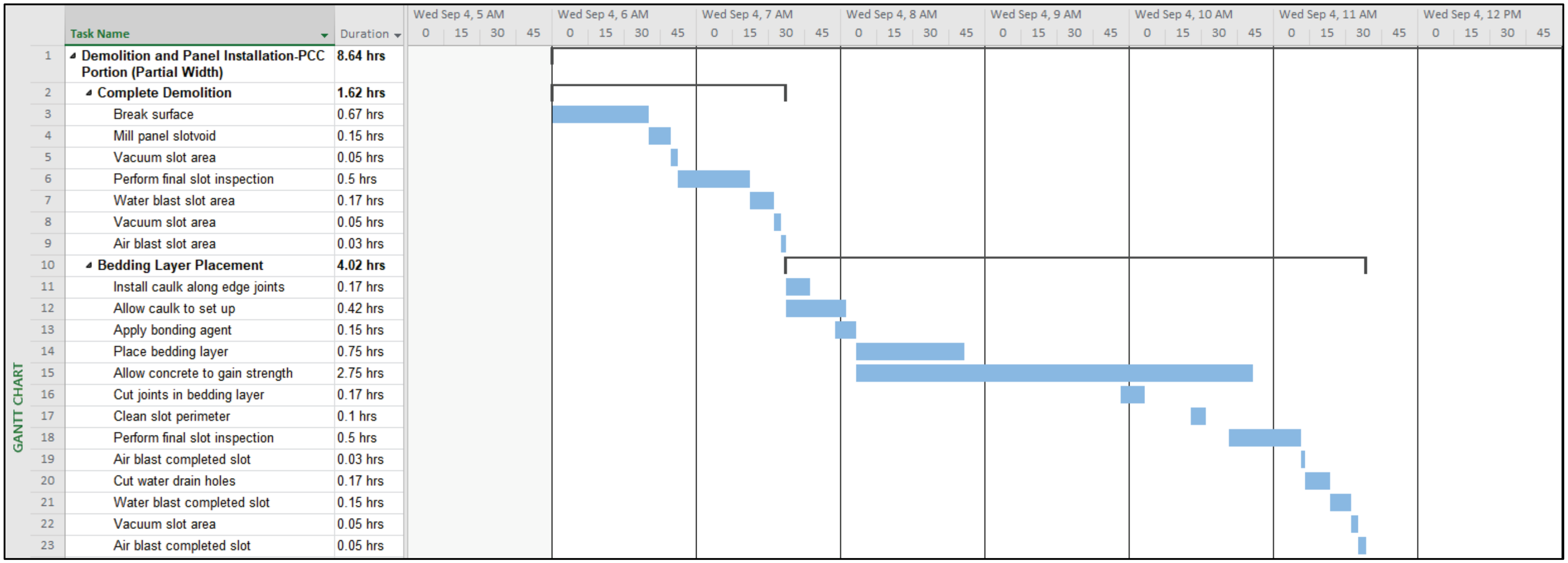
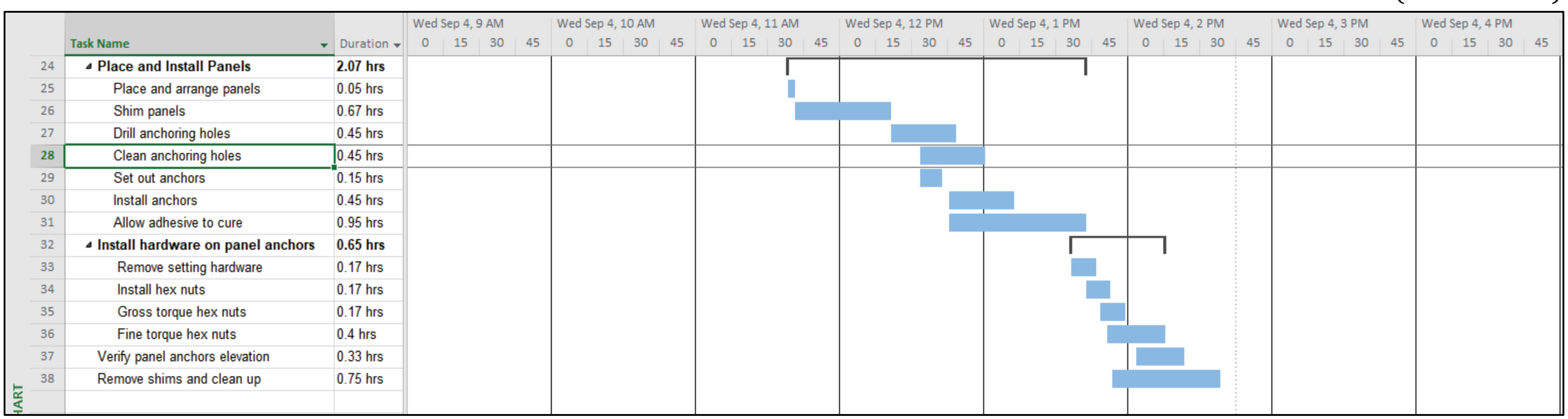
Figure 51. Modified Gantt charts for the demolition and panel installation work phases for combined PCC and AC installations that meet closure requirement.

c. Demolition and panel installation - PCC section



	Task Name	Duration
1	**Demolition and Panel Installation-PCC Portion (Partial Width)**	**8.64 hrs**
2	**Complete Demolition**	**1.62 hrs**
3	Break surface	0.67 hrs
4	Mill panel slotvoid	0.15 hrs
5	Vacuum slot area	0.05 hrs
6	Perform final slot inspection	0.5 hrs
7	Water blast slot area	0.17 hrs
8	Vacuum slot area	0.05 hrs
9	Air blast slot area	0.03 hrs
10	**Bedding Layer Placement**	**4.02 hrs**
11	Install caulk along edge joints	0.17 hrs
12	Allow caulk to set up	0.42 hrs
13	Apply bonding agent	0.15 hrs
14	Place bedding layer	0.75 hrs
15	Allow concrete to gain strength	2.75 hrs
16	Cut joints in bedding layer	0.17 hrs
17	Clean slot perimeter	0.1 hrs
18	Perform final slot inspection	0.5 hrs
19	Air blast completed slot	0.03 hrs
20	Cut water drain holes	0.17 hrs
21	Water blast completed slot	0.15 hrs
22	Vacuum slot area	0.05 hrs
23	Air blast completed slot	0.05 hrs

(Sheet 1 of 2)

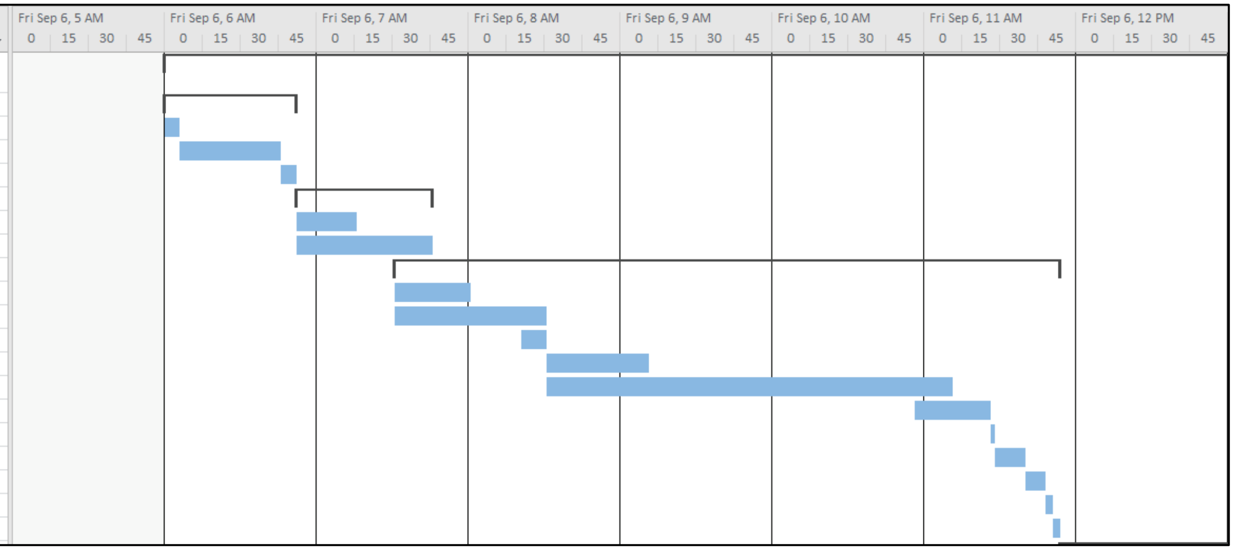


	Task Name	Duration
24	**Place and Install Panels**	**2.07 hrs**
25	Place and arrange panels	0.05 hrs
26	Shim panels	0.67 hrs
27	Drill anchoring holes	0.45 hrs
28	Clean anchoring holes	0.45 hrs
29	Set out anchors	0.15 hrs
30	Install anchors	0.45 hrs
31	Allow adhesive to cure	0.95 hrs
32	**Install hardware on panel anchors**	**0.65 hrs**
33	Remove setting hardware	0.17 hrs
34	Install hex nuts	0.17 hrs
35	Gross torque hex nuts	0.17 hrs
36	Fine torque hex nuts	0.4 hrs
37	Verify panel anchors elevation	0.33 hrs
38	Remove shims and clean up	0.75 hrs

(Sheet 2 of 2)

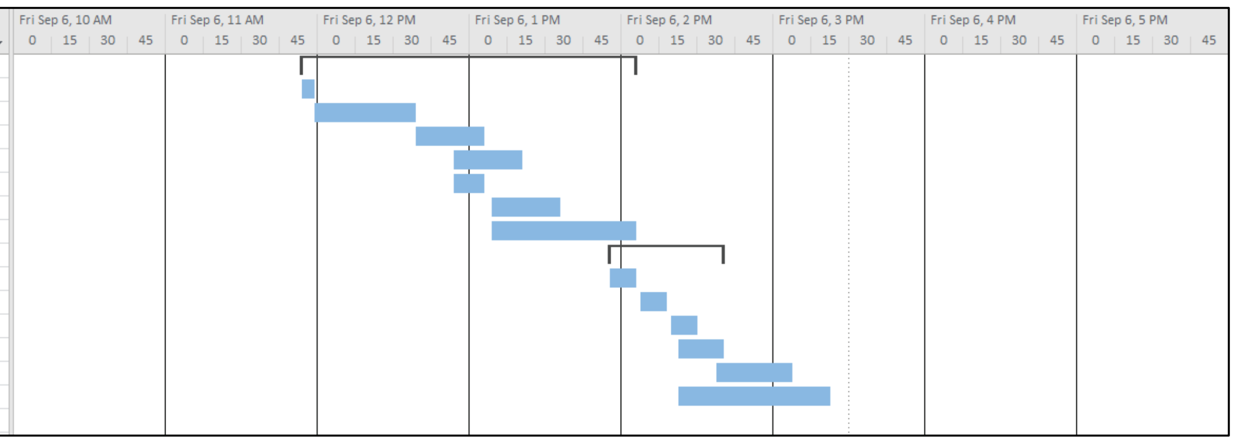
d. Demolition and panel installation - AC sections

	Task Name	Duration
1	**Demolition and Panel Installation - AC Portion (Partial width)**	**9.38 hrs**
2	**Demolition and Excavation**	**0.87 hrs**
3	Remove surface pavement	0.1 hrs
4	Remove sublayer soil	0.67 hrs
5	Compact bottom of trench	0.1 hrs
6	**Backfilling Base**	**0.9 hrs**
7	Place rapid setting flowable fill	0.4 hrs
8	Allow flowable fill to gain strength	0.9 hrs
9	**Concrete Foundation Placement**	**4.38 hrs**
10	Install tie bars (as needed)	0.5 hrs
11	Allow adhesive to cure (if tie bars are installed)	1 hr
12	Install reinforcement grid	0.17 hrs
13	Place rapid setting concrete	0.67 hrs
14	Allow concrete to gain strength	2.67 hrs
15	Perform final slot inspection	0.5 hrs
16	Air blast slot	0.03 hrs
17	Cut water drain holes	0.2 hrs
18	Water blast completed slot	0.13 hrs
19	Vacuum completed slot	0.05 hrs
20	Air blast completed slot	0.05 hrs



(Sheet 1 of 2)

	Task Name	Duration
21	**Place and Install Panels**	**2.2 hrs**
22	Place and arrange panels	0.08 hrs
23	Shim panels	0.67 hrs
24	Drill anchoring holes	0.45 hrs
25	Clean anchoring holes	0.45 hrs
26	Set out anchors	0.2 hrs
27	Install hardware	0.45 hrs
28	Allow adhesive to cure	0.95 hrs
29	**Install Panel Anchor Hardware**	**0.75 hrs**
30	Remove setting hardware	0.17 hrs
31	Install hex nuts	0.17 hrs
32	Gross torque hex nuts	0.17 hrs
33	Final torque hex nuts	0.3 hrs
34	Verify final anchor elevations	0.5 hrs
35	Remove shims and clean up	1 hr



(Sheet 2 of 2)

Figure 52. Modified reinforcement layout schematic for AC portions with combined PCC and AC installations for half AC widths.

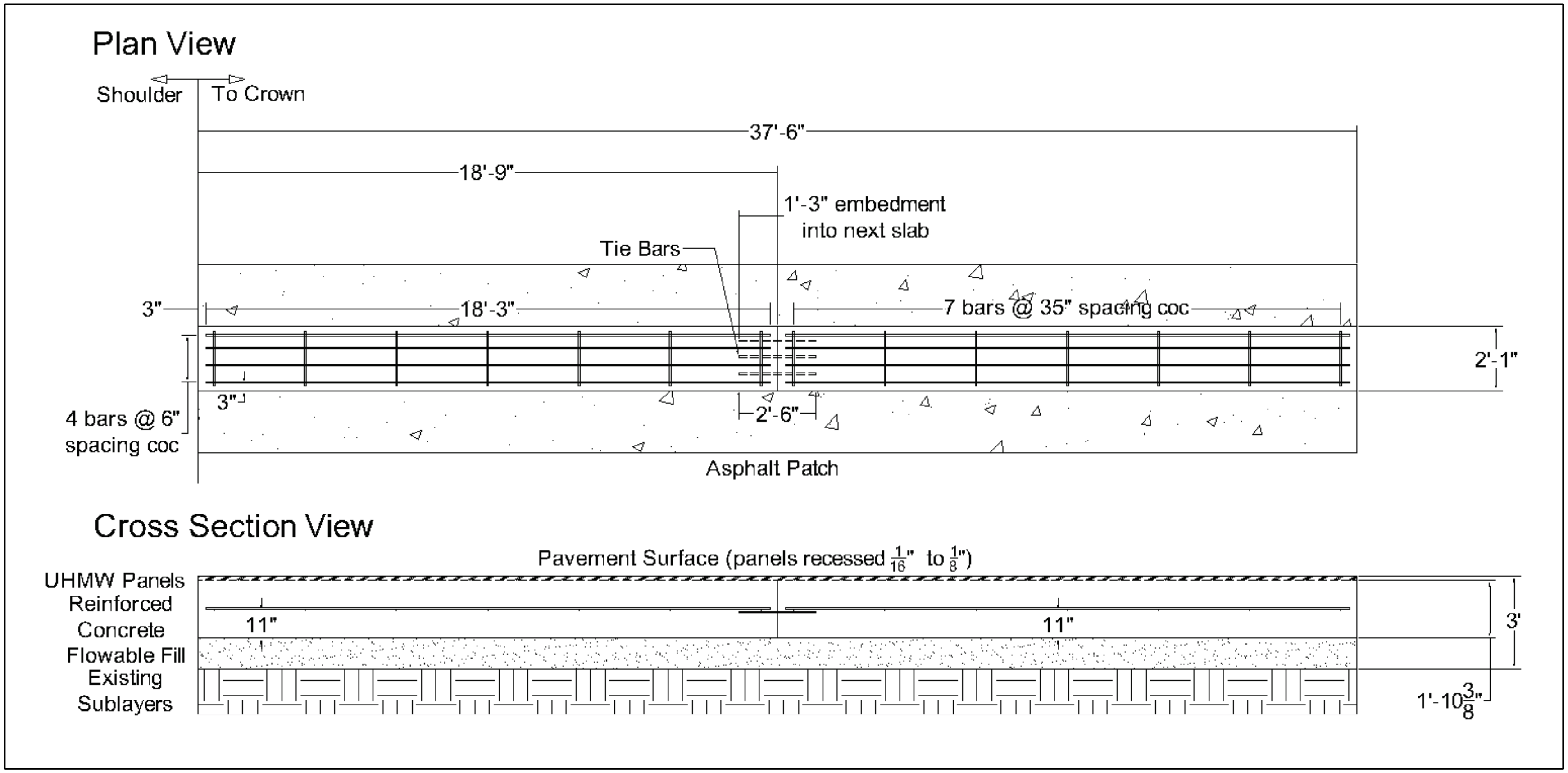


Table 19. Recommended sequencing of required work tasks for combined PCC and AC installation.

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
1	1	Demolition	Mark panel void perimeter and PCC transverse relief sawcuts.	Panel: 150 Relief cuts: 75	4.4
2			Saw cut panel void perimeter and PCC transverse relief sawcuts.		
3			Mark AC patch sawcuts.		
4			Saw cut AC patch sawcuts.		
5			Wash saw slurry.		
6			Clean work zone.		
7	2		Mark longitudinal PCC relief sawcuts.	75	4.8
8			Saw cut relief cuts.		
9			Wash saw slurry.		
10			Clean work zone.		
11	3 Repeat two times	Demolition	Break surface.	25 - 37.5, varies on slab size	12.5
12			Mill slot depth.		
13			Vacuum demolished panel slot.		
14			Perform final slot inspection.		
15			Water blast slot.		
16			Vacuum slot.		
17			Air blast slot.		
18		Bedding layer placement	Caulk slab edge joints and allow material to set up.		
19			Apply bonding agent (as needed).		
20			Place bedding layer.		
21			Allow concrete to gain strength; clean site.		
22			Cut joints in bedding layer.		
23			Clean slot perimeter.		
24			Perform final slot inspection.		
25			Air blast slot.		
26			Cut water drain holes.		
27			Water blast completed slot.		
28			Vacuum slot area.		
29			Air blast completed slot.		

(Sheet 1 of 3)

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
30	3 Repeat two times	Panel anchorage installation	Place and arrange panels.	25 - 37.5, varies on slab size	12.5
31			Shim panels.		
32			Drill panel anchoring holes.		
33			Clean panel anchoring holes.		
34			Install panel anchors.		
35			Allow adhesive to cure; begin clean up.		
36			Install hardware on panel anchors.		
37			Verify final anchor elevations.		
38			Remove shims and finish cleanup.		
39	4 Repeat two times	Demolition	Remove AC surfacing for concrete foundation.	37.5	11.9
40		Panel anchorage installation	Trench excavation.		
41			Compact bottom of trench.		
42			Backfill with flowable fill.		
43			Allow flowable fill to cure.		
44			Install reinforcement.		
45			Cap with rapid-setting concrete.		
46			Final slot inspection.		
47			Air blast slot.		
48			Cut water drain holes.		
49			Water blast completed slot.		
50			Vacuum slot area.		
51			Air blast completed slot.		
52			Place and arrange panels.		
53			Shim panels.		
54			Drill panel anchoring holes.		
55			Clean panel anchoring holes.		
56			Install panel anchors.		
57			Allow adhesive to cure; begin cleanup.		
58			Install hardware on panel anchors.		
59			Verify final anchor elevations.		
60			Remove shims.		
61			Finish cleanup.		

(Sheet 2 of 3)

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
62	5 Repeat two times	AC patching	Mill AC pavement.	37.5 (both sides of paneling completed per day)	5.9
63			Wet surface of base surface.		
64			Remove panels.		
65			Compact base.		
66			Install steel formwork.		
67			Apply tack material along asphalt perimeter.		
68			Place and compact AC.		
69			Water shock AC and allow to cool to 125°F.		
70			Reinstall panels.		
71			Clean site.		
For installation of 4 anchors					
72	6	Tie-down anchorage installation	Core and demolish tie-down anchoring location.	150	1.8
73			Drill tie-down anchoring holes.		
74			Clean tie-down anchoring holes.		
75			Install tie-down anchors.		
76			Allow adhesive to cure.		
77			Finish cleanup.		
For installation of 8 anchors					
78	6	Tie-down anchorage installation	Core and demolish tie-down anchoring location.	150	2.3
79			Drill tie-down anchoring holes.		
80			Clean tie-down anchoring holes.		
81			Install tie-down anchors.		
82			Allow adhesive to cure.		
83			Finish cleanup.		
84	7	Joint sealing	Air blast joints and anchor holes.	150	7.0
85			Install backer rod.		
86			Install sealant.		
87			Allow sealant to cure, clean site.		

(Sheet 3 of 3)

Table 20. Work task sequencing meeting 12 hr closure requirements for combined PCC and AC installation.

Task	Work Day	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
1	1	Demolition	Mark panel void perimeter and PCC transverse relief sawcuts.	Panel: 150 Relief cuts: 75	4.4
2			Saw cut panel void perimeter and PCC transverse relief sawcuts.		
3			Mark AC patch sawcuts.		
4			Saw cut AC patch sawcuts.		
5			Wash saw slurry.		
6			Clean work zone.		
7	2		Mark longitudinal PCC relief sawcuts.	75	4.8
8			Saw cut relief cuts.		
9			Wash saw slurry.		
10			Clean work zone.		
11	3 Repeat three to five times	Demolition	Break surface.	~1 slab, varies on slab size	8.6
12			Mill slot depth.		
13			Vacuum demolished panel slot.		
14			Perform final slot inspection.		
15			Water blast slot.		
16			Vacuum slot.		
17			Air blast slot.		
18		Bedding layer placement	Caulk slab edge joints and allow material to set up.		
19			Apply bonding agent (as needed).		
20			Place bedding layer.		
21			Allow concrete to gain strength; clean site.		
22			Cut joints in bedding layer.		
23			Clean slot perimeter.		
24			Perform final slot inspection.		
25			Air blast slot.		
26			Cut water drain holes.		
27			Water blast completed slot.		
28			Vacuum slot area.		
29			Air blast completed slot.		

(Sheet 1 of 3)

Task	Work Day	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
30	3 Repeat four to five times	Panel anchorage installation	Place and arrange panels.	4-5 slabs, varies on slab size	8.6
31			Shim panels.		
32			Drill panel anchoring holes.		
33			Clean panel anchoring holes.		
34			Install panel anchors.		
35			Allow adhesive to cure; begin cleanup.		
36			Install hardware on panel anchors.		
37			Verify final anchor elevations.		
38			Remove shims and finish cleanup.		
39	4 Repeat four times	Demolition	Remove AC surfacing for concrete foundation.	~19	9.4
40		Panel anchorage installation	Excavate trench.		
41			Compact bottom of trench.		
42			Backfill with flowable fill.		
43			Allow flowable fill to cure.		
44			Install reinforcement.		
45			Cap with rapid-setting concrete.		
46			Perform final slot inspection.		
47			Air blast slot.		
48			Cut water drain holes.		
49			Water blast completed slot.		
50			Vacuum slot area.		
51			Air blast completed slot.		
52			Place and arrange panels.		
53			Shim panels.		
54			Drill panel anchoring holes.		
55			Clean panel anchoring holes.		
56			Install panel anchors.		
57			Allow adhesive to cure; begin cleanup.		
58			Install hardware on panel anchors.		
59			Verify final anchor elevations.		
60			Remove shims.		
61			Finish cleanup.		

(Sheet 2 of 3)

Task	Work Day	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
62	5 Repeat two times	AC patching	Mill AC pavement.	37.5 (both sides of paneling completed per day)	5.9
63			Wet surface of base surface.		
64			Remove panels.		
65			Compact base.		
66			Install steel formwork.		
67			Apply tack material along asphalt perimeter.		
68			Place and compact AC.		
69			Water shock AC and allow to cool to 125°F.		
70			Reinstall panels.		
71			Clean site.		
For installation of 4 anchors					
72	6	Tie-down anchorage installation	Core and demolish tie-down anchoring location.	150	1.8
73			Drill tie-down anchoring holes.		
74			Clean tie-down anchoring holes.		
75			Install tie-down anchors.		
76			Allow adhesive to cure.		
77			Finish cleanup.		
For installation of 8 anchors					
78	6	Tie-down anchorage installation	Core and demolish tie-down anchoring location.	150	2.3
79			Drill tie-down anchoring holes.		
80			Clean tie-down anchoring holes.		
81			Install tie-down anchors.		
82			Allow adhesive to cure.		
83			Finish cleanup.		
84	7	Joint sealing	Air blast joints and anchor holes.	150	7.0
85			Install backer rod.		
86			Install sealant.		
87			Allow sealant to cure, clean site.		

(Sheet 3 of 3)

3.6 Results for pavement retrofit option

Retrofitting of a defective or deficient paneling system is a significant concern to the operations of an arresting system on an airfield. Instead of providing a high level of economical and long-term assistance with arresting aircraft, the paneling system is a detriment to the arresting system and aircraft capture process since the potential for hook skips increases. Ultimately the paneling system must be dealt with and brought back into compliance with AFI 32-1043 and UFC 3-260-01. This has the potential to be a challenging operation, especially with concrete-surfaced pavements, since significant demolition may be required to repair or reconstruct the pavement within the vicinity of the arresting system. Significant demolition will require extensive time to complete and result in longer-than-desired runway closure times or significantly more short duration work days to complete the work and leave the runway operational after construction efforts. An innovative design and work phasing is required to best tailor the work required to the time available.

Originally, work plans focused on the scenario described earlier in this report at the Southwest Asia airfield, where an expediently installed foundation was placed across the full width of an asphalt-surfaced runway. To minimize the amount of demolition and resulting reconstruction work from removing the in-place concrete, the concrete slabs were demolished partial depth and overlaid with asphalt to return the pavement near the arresting pendant to a continuous pavement type. The concrete that remained would be recycled and serve as the foundation for the anchoring. However, previous issues with panel anchoring of an in-place UHMW panel system at Bagram Air Base, Afghanistan, in 2015 showed additional consideration should be given to evaluating the structural adequacy of the existing anchoring to determine whether any of the existing components could be reused. Therefore, considerations for an additional option that involved testing of the anchorage points, following the test methods developed and used by the USAF for the Bagram airfield, and reusing any adequate anchor points in order to reduce the overall work is required.

3.6.1 Complete panel system retrofit method

The first option considered was for a retrofit of a series of concrete slabs centered along the arresting system pendant. The existing anchors, both panel and tie down, are removed and replaced with rapid-setting concrete patches. Removing the existing anchors is a necessity since the carbide-tipped masonry bits used to drill new anchor holes cannot cut through the in-place anchors and new anchors that are installed may not align exactly with the previous anchor arrangement. Additional rapid-setting concrete is placed in the panel void to fill the void and create a temporary large patch since the panels cannot be reinstalled within the 12 hr maximum closure requirement after removing the panel anchors. The large patch levels the pavement surface and allows the runway to be returned to service after the paneling is removed. The surfaces of the concrete slabs and large patch are demolished partial depth and overlaid with asphalt to construct a large patch over the concrete. Once the patch is constructed, a new panel slot is milled in the asphalt surface until the underlying concrete is reached and the panels are installed similarly to the method that used for the partial-depth installation concrete pavements with paneling installed on a concrete bedding layer.

Coring of the anchoring was not tested in the field work completed at the Silver Flag test area. It is expected that coring will take approximately 10 to 15 min per anchor removed, including set-up time and moving the equipment between individual anchors in need of removal. A portable coring rig with a 4 in. outer diameter diamond-tipped core barrel is expected for this task. A 6 in. diameter core barrel may be needed for the tie-down anchoring, depending on the size of the anchor head. A trailer-mounted coring drill can also be used if available and can reduce the time needed for coring by reducing both alignment and cutting time. Once the cores are cut and removed, placement of concrete should begin by filling the cleaned core holes first, followed by the panel slot, to ensure the core holes are cast as one monolithic piece. Sufficient long-term bond between the concrete interface of the cores and the panel slot is not necessary since the majority of the concrete placed will be removed before overlaying with asphalt, but the bond needs to be strong enough to remain intact to the slab until it is demolished.

The largest time saving that occurs with this installation plan is reusing the concrete that is in place as the foundation for the concrete anchoring. Abandoning and fully demolishing the slabs for reconstruction of the pavement around the sacrificial panel system will take significant time to complete. Furthermore, additional time is used to replace a concrete foundation in a reconstructed section when one is in place. Reuse of the slab for some purpose in the overall plan helps alleviate timing issues with these two work items as long as it is structurally sufficient and can meet mission requirements.

UFC 3-260-01 and AFI 32-1043 give requirements for runway pavements and sacrificial paneling systems and state that (1) changes in pavement type are not allowed within ±200 ft of an arresting system cable, (2) interfaces between rigid and flexible pavements are not allowed within ±200 ft of an arresting system cable, (3) rigid inlays may not be used as the repair material surface in flexible pavement runway systems, and (4) no part of the rigid foundation required for sacrificial paneling anchoring can be used as the wearing surface for rigid and flexible pavement systems (Headquarters, Departments of the Army, Navy, and Air Force 2008, Department of the Air Force 2012); Department of the Air Force 2012). Partially removing the concrete surface and replacing with an asphalt overlay assist in restoring three of the four requirements listed (numbers 2, 3, and 4). The only requirement that is not met is that the pavement type is not restored to a flexible pavement after the retrofit work is complete. UFC 3-260-03 (Headquarters, Departments of the Army, Navy, and Air Force 2001b) details eight different types of pavements the DoD considers for airfield pavement evaluation, ranging from traditional pavement materials to design and corresponding overlay combinations. The retrofit work considered would turn the sacrificial paneling foundation from a plain concrete (rigid) pavement into a non-rigid overlay on a rigid pavement upon completion since an asphalt overlay is placed over an existing plain concrete pavement. By this definition, merely changing the surface type back to an asphalt surface does not constitute a change back to the original pavement type. Therefore, the retrofit option described would not truly meet the restorative nature desired to meet pavement design requirements and ultimately leaves full demolition of the foundation as the only option for a full restoration of the runway back to its original status. To use the retrofitting option in the future for this situation, additional statements will be required in the UFC and AFI documents to allow this method to be used as a viable design option. Wording considered should be similar to that given for the concrete tie-down foundation blocks that allow for their use.

Since a significant portion of the concrete slab is expected to remain after partial demolition, the asphalt overlay is not expected to add significant structural support to the constructed pavement for the arrester paneling system. The overlay is superficial and used to restore the pavement surface to asphalt. Barker et al. (2011) recommends a minimum of 4 in. of AC be placed in at least 2 in. lifts to assist in constructing high-performance asphalt overlays that minimize distress and achieve proper density. This thickness is a little greater than the minimum 3$^{5}/_{8}$ in. thickness required to install the UHMW panels on a bedding layer, but additional material must be removed to eliminate any asphalt binder coating the concrete surface and result in preventing good bond of the bedding layer concrete to the foundation slab. When the panels are reinstalled, the panel slot must be milled to at least 4$^{1}/_{8}$ in. in depth to remove any asphalt residue that remains. Additional milling may be required to fully remove asphalt material in the valleys of the surface if the surface is extremely rough. Use of the relief cutting method to assist in controlling and limiting the depth of the concrete is expected to minimize the discrepancies in the depth (peaks and valleys of the surface).

Since the asphalt overlay is essentially a large patch, UFC patch guidance was applied to assist in planning the repair area dimensions (Headquarters, Departments of the Army, Navy, and Air Force 2001c). Asphalt pavement full-depth patches should be square or rectangular and extend at least 12 in. past the distressed area. To efficiently remove the additional pavement, the CTL with cold planer was considered, since it has the capability to remove material to the desired depth. Ripping and removing the pavement in the patch area are not expected to be applicable since the in-place asphalt surface may be thicker than the required depth of removal. In such cases, milling the additional patched area reduces the volume of the repair needed and the time needed to install it. The SuPR kit cold planer attachment is 18 in. wide and allows for this additional patch width to be cut in one pass per increment of depth. Saw cuts to delineate the prospective patch area should be made before the concrete surface is to be removed. Asphalt milling work should be completed before partial-depth removal of the concrete surface to allow both skis of the cold planer attachment to be used as a reference point for monitoring the removal depth. The airfield sweeper truck should be used to quickly and efficiently remove the millings generated as with other previously discussed repair methods that used the cold planer equipment.

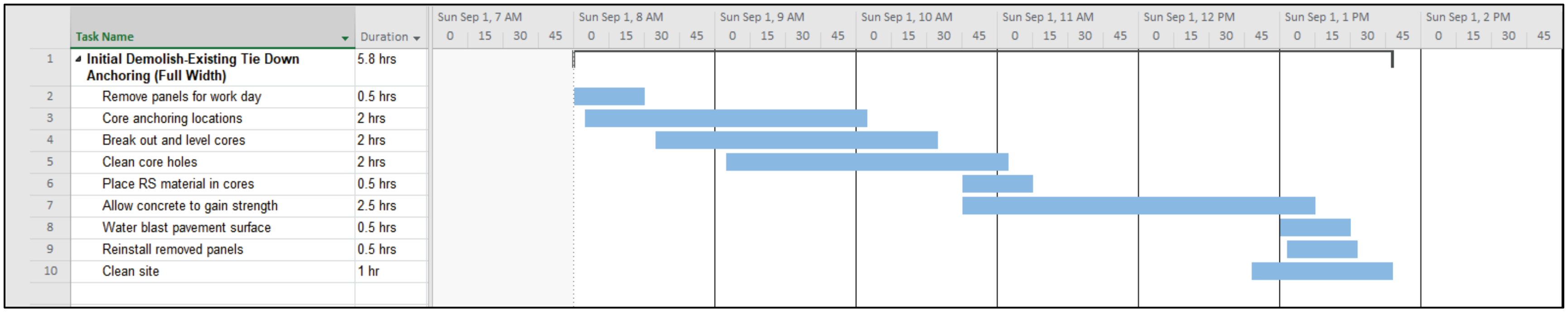
Figure 53 shows the prospective Gantt charts developed for the installation work days. Eight different phases are needed to complete the necessary work. Many of the required work tasks are sequential. Some parallelization was available during demolition tasks to reduce the total duration of the work. Multiple options for replacing both tie-down and panel anchors are presented to best tailor the amount of work required to the project at hand for flexible planning. The anchor replacement work shows that it is more efficient to install more anchors per work day.

Four of the work phases are less than the preferred 6 hr time limit per work day. All work phases are projected to be less than the maximum 12 hr requirement. Some work phases have options available to account for different scenarios the installation work encounters. The total project time varies depending on the work phasing option selected, but a minimum of 27 work days is required to remove the existing anchoring, partially demolish the existing concrete foundation, overlay the foundation with asphalt, and reinstall a UHMW panel system across a 150 ft asphalt surfaced runway with this option.

Table 21 details the sequencing of work tasks with projected timing. Many of the items and much of the equipment are currently in USAF inventories, and all may be delivered to the site by C-130 aircraft. Additional floor and walk-behind saws can be used for further work parallelization in the demolition preparation work. Additional equipment will reduce the total number of work days needed rather than reduce the time spent on the runway for any given work day.

Figure 53. Gantt charts for complete retrofit of sacrificial paneling system.

a. Initial demolition – remove existing tie-down anchoring



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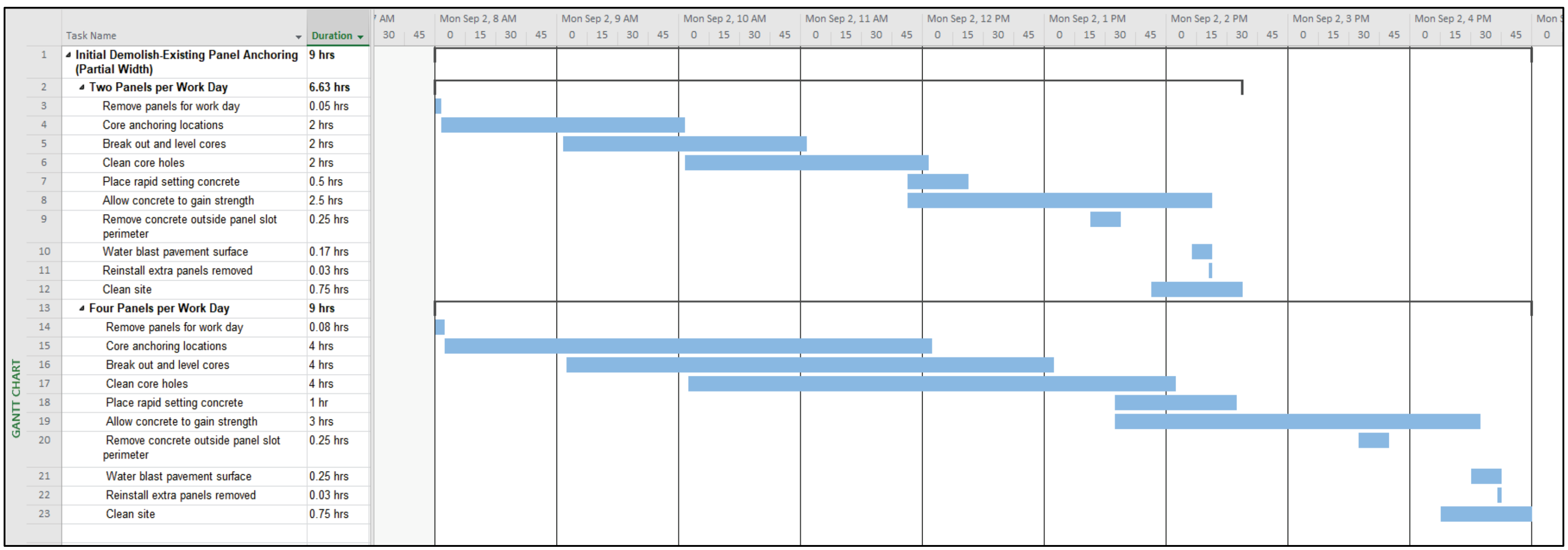
b. Initial demolition – remove existing panel anchoring



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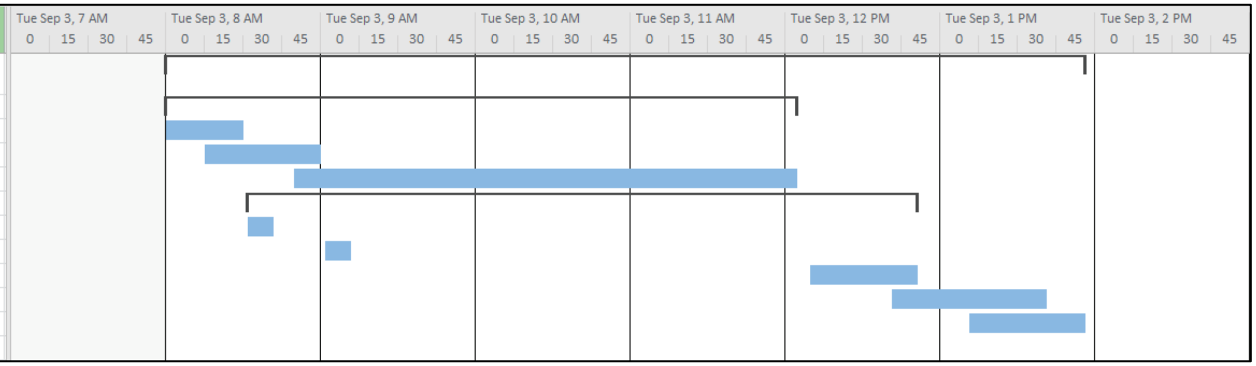
c. Demolition preparations – transverse sawcutting

	Task Name	Duration
1	Demolition Preparation (Half Width, Transverse)	5.94 hrs
2	PCC Relief Sawcuts	4.08 hrs
3	Mark cut locations	0.5 hrs
4	Snap chalk line	0.75 hrs
5	Saw cut transverse relief cuts	3.25 hrs
6	AC Patch Sawcuts	4.33 hrs
7	Mark cut locations	0.17 hrs
8	Snap chalk line	0.17 hrs
9	Saw cut AC patch cuts	0.7 hrs
10	Wash saw slurry	1 hr
11	Clean work zone	0.75 hrs



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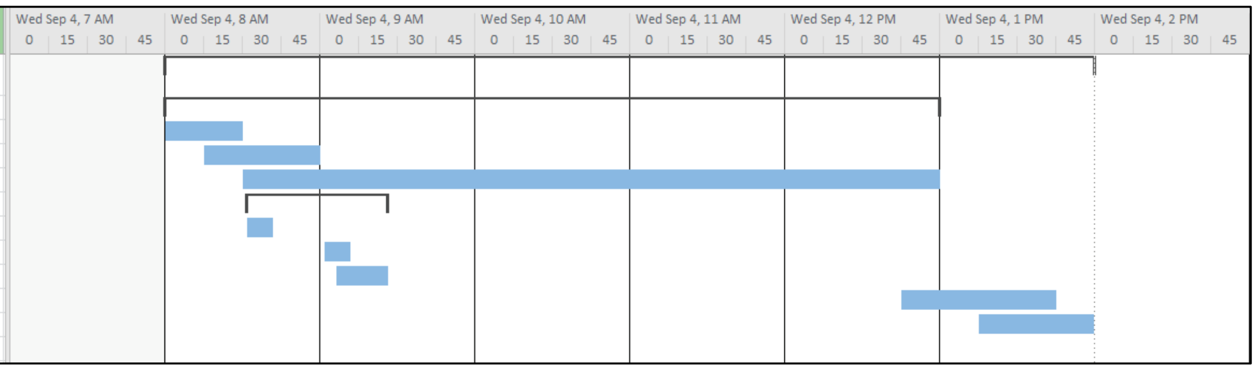
d. Demolition preparations – longitudinal sawcutting

	Task Name	Duration
1	Demolition Preparation (Quarter Width, Longitudinal)	6 hrs
2	PCC relief cuts	5 hrs
3	Mark cut locations	0.5 hrs
4	Snap chalk line	0.75 hrs
5	Saw cut relief cuts	4.5 hrs
6	AC cuts	0.91 hrs
7	Mark cut locations	0.17 hrs
8	Snap chalk line	0.17 hrs
9	Make cuts	0.33 hrs
10	Wash saw slurry	1 hr
11	Clean work zone	0.75 hrs



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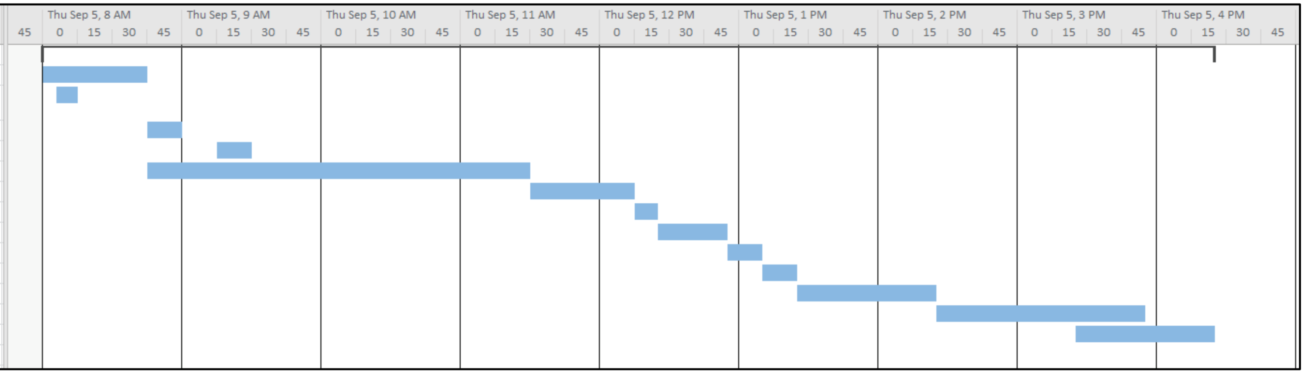
e. Surface demolition and asphalt overlaying

	Task Name	Duration
1	AC Overlaying (Partial Width)	8.42 hrs
2	Mill AC at foundation ends	0.75 hrs
3	Make sawcut in previously placed AC for clean construction joint	0.15 hrs
4	Wet base material	0.25 hrs
5	Compact base layer	0.25 hrs
6	Break PCC surface	2.75 hrs
7	Mill PCC within patch area	0.75 hrs
8	Vacuum patch area	0.17 hrs
9	Water blast patch area	0.5 hrs
10	Heavily air blast patch area	0.25 hrs
11	Place tack coat	0.25 hrs
12	Place AC patch	1 hr
13	Watershock AC patch	1.5 hrs
14	Clean work site	1 hr



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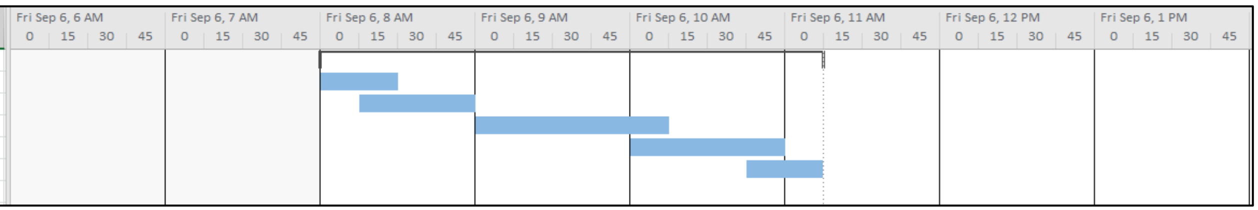
f. Panel installation preparation

	Task Name	Duration
1	Panel Installation Preparation (Full Width)	3.25 hrs
2	Mark slot perimeter	0.5 hrs
3	Snap chalk lines	0.75 hrs
4	Saw cut slot perimeter	1.25 hrs
5	Water blast slot	1 hr
6	Clean site	0.5 hrs



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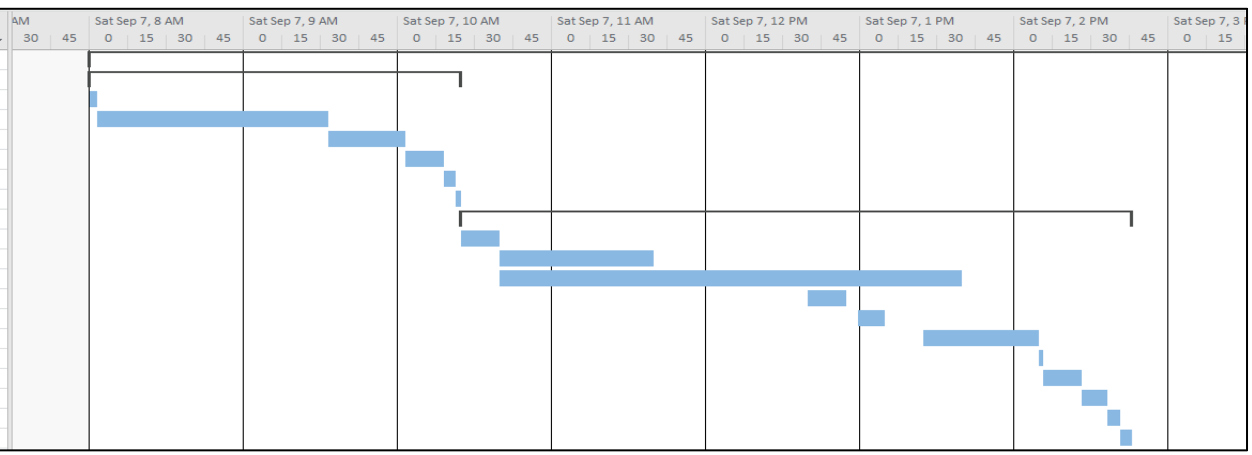
g. Panel installation

	Task Name	Duration
1	Panel Installation (Partial Width)	10.95 hrs
2	Panel Slot Demolition	2.41 hrs
3	Remove any previously placed panels	0.05 hrs
4	Remove slot material	1.5 hrs
5	Perform final slot inspection	0.5 hrs
6	Water blast slot	0.25 hrs
7	Vacuum the slot area	0.08 hrs
8	Air blast slot	0.03 hrs
9	Bedding Layer Placement	4.36 hrs
10	Apply bonding agent	0.25 hrs
11	Place bedding layer	1 hr
12	Allow concrete to gain strength	3 hrs
13	Reestablish joints	0.25 hrs
14	Clean slot perimeter	0.17 hrs
15	Perform final slot inspection	0.75 hrs
16	Air blast slot	0.03 hrs
17	Cut water drain holes	0.25 hrs
18	Water blast slot	0.17 hrs
19	Vacuum the slot area	0.08 hrs
20	Air blast slot	0.08 hrs



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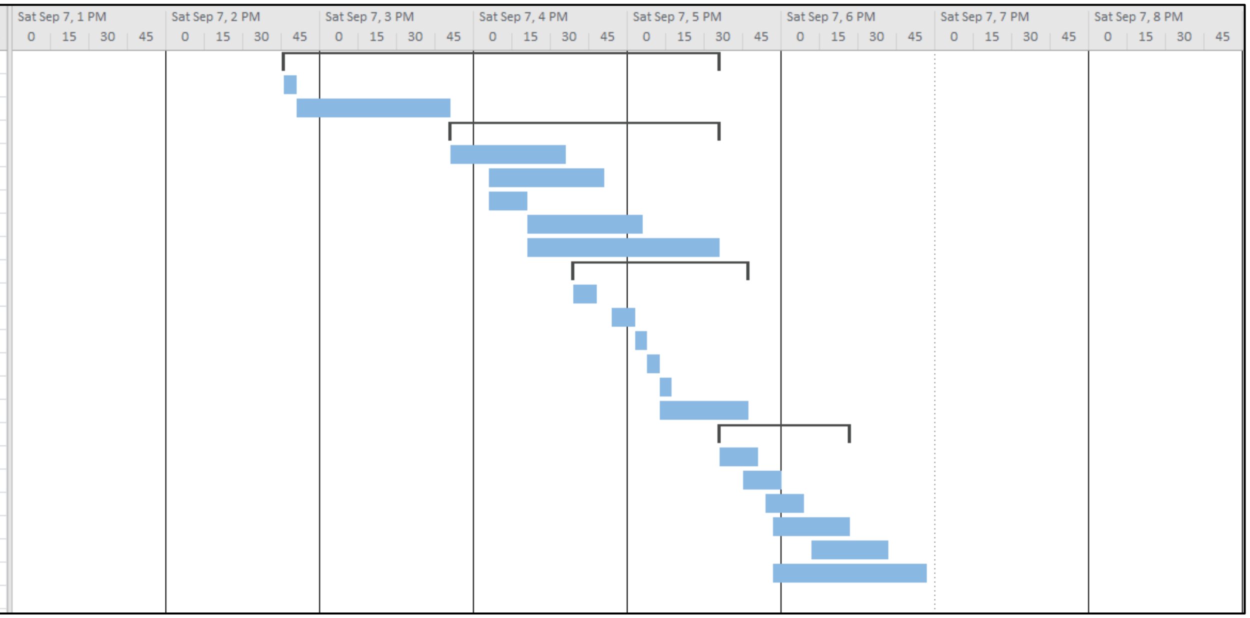
GANTT CHART

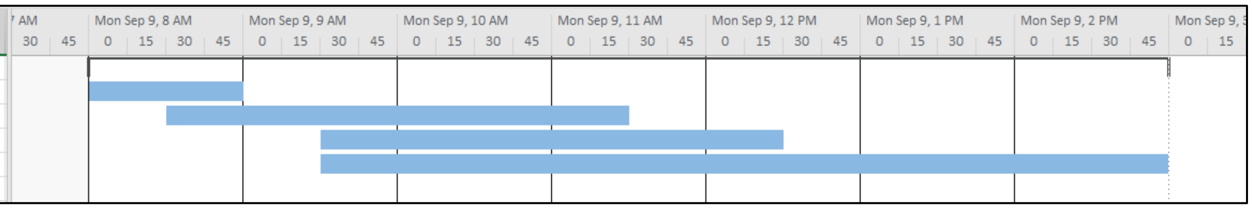
	Task Name	Duration
21	**Place and Install Panels**	**2.83 hrs**
22	Place and arrange panels	0.08 hrs
23	Shim panels	1 hr
24	**Panel Anchor Installation**	**1.75 hrs**
25	Drill anchoring holes	0.75 hrs
26	Clean anchoring holes	0.75 hrs
27	Set out anchors	0.25 hrs
28	Install hardware	0.75 hrs
29	Allow adhesive to cure	1.25 hrs
30	**Install Tie Down Anchoring (As Required)**	**1.14 hrs**
31	Dry core and remove interior	0.15 hrs
32	Clean hole made	0.15 hrs
33	Drill anchor embedding hole	0.08 hrs
34	Clean hole made	0.08 hrs
35	Install tie down anchors	0.08 hrs
36	Allow adhesive to cure	0.58 hrs
37	**Install Hardware on Panel Anchors**	**0.85 hrs**
38	Remove setting hardware	0.25 hrs
39	Install hex nuts	0.25 hrs
40	Gross torque hex nuts	0.25 hrs
41	Fine torque hex nuts	0.5 hrs
42	Verify panel anchors elevation	0.5 hrs
43	Remove shims and clean up	1 hr



(Sheet 2 of 2)

h. Joint sealing

	Task Name	Duration
1	**Joint Sealing (Full Width)**	**7 hrs**
2	Air blast joints and anchor holes	1 hr
3	Install backer rod	3 hrs
4	Install sealant	3 hrs
5	Allow sealant to cure, begin clean up	5.5 hrs



(Sheet 1 of 1)

Table 21. Sequencing of required work tasks for complete retrofit of sacrificial paneling system.

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
1	1	Demolition - Existing anchor removal	Remove panels with tie-down anchoring.	150 Up to 8 anchors	5.8
2			Core tie-down anchoring locations.		
3			Break out and level cores.		
4			Clean core holes.		
5			Place concrete in core holes.		
6			Allow concrete to gain strength.		
7			Water blast pavement surface.		
8			Reinstall removed panels.		
9			Clean site.		
7	2 Repeat 10-20 times, depends on total number of panels across runway		Remove panels for work day.	2 or 4 panels per work day	2 panels: 6.6 4 panels: 9.0
8			Core panel anchoring locations.		
9			Break out and level cores.		
10			Clean core holes.		
11			Place concrete in core holes.		
12			Allow concrete to gain strength.		
13			Remove/trim concrete outside panel slot perimeter.		
14			Water blast pavement surface.		
15			Reinstall additional removed panels.		
16			Clean site.		
17	3 Repeat two times	Demolition – Preparations for overlaying	Mark transverse PCC relief cut locations.	75	5.6
18			Saw cut transverse PCC relief cuts.		
19			Mark transverse AC patch perimeter cut locations.		
20			Saw cut transverse AC patch perimeter.		
21			Water blast slot.		
22			Vacuum project area.		
23	4 Repeat 1-4 times depending on saws used		Mark longitudinal PCC relief cut locations.	37.5 for every saw team used	6.0
24			Saw cut longitudinal PCC relief cuts.		
25			Mark longitudinal AC patch perimeter cut locations.		
26			Saw cut longitudinal AC patch perimeter.		
27			Water blast slot.		
28			Air blast slot.		

(Sheet 1 of 3)

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
29	5 Repeat five times	Surface demolition and AC overlay	Mill AC at PCC foundation ends.	30	8.4
30			Saw cut construction joint along previously placed AC edge (days 2, 3, 4, and 5 only).		
31			Wet base material.		
32			Compact base layer.		
33			Break PCC surface.		
34			Vacuum patch area.		
35			Water blast patch area.		
36			Air blast patch area.		
37			Apply tack coat.		
38			Place AC patch.		
39			Watershock AC patch.		
40			Clean site.		
41	6	Panel installation preparations	Mark slot perimeter.	150	3.3
42			Saw cut slot perimeter.		
43			Water blast pavement.		
44			Clean site.		
45	7 Repeat five times	Panel installation	Remove any previously placed panels.	30	11.0
46			Remove AC surfacing in panel slot.		
47			Inspect panel slot.		
48			Water blast slot.		
49			Vacuum slot area.		
50			Air blast slot.		
51			Apply bonding agent.		
52			Place bedding layer.		
53			Allow concrete to gain strength.		
54			Reestablish joints.		
55			Clean slot perimeter.		
56			Perform final slot inspection.		
57			Air blast slot.		
58			Cut water drain holes.		
59			Water blast completed slot.		
60			Vacuum slot area.		
61			Air blast completed slot.		
62			Place and arrange panels.		
63			Shim panels.		

(Sheet 2 of 3)

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
64	7 Repeat 5 times	Panel installation	Drill panel anchoring holes.	30	11.0
65			Clean panel anchoring holes.		
66			Install panel anchor.		
67			Allow adhesive to cure, begin cleanup.		
68			Install tie-down anchoring (as needed).		
69			Install hardware on panel anchors.		
70			Verify final anchor elevations.		
71			Remove shims and finish cleanup.		
72	8	Joint sealing	Air blast joints and anchor holes.	150	7.0
73			Install backer rod.		
74			Install sealant.		
75			Allow sealant to cure, clean site.		
					(Sheet 3 of 3)

3.6.2 Partial panel system retrofit method

A second retrofit option that used a less intrusive work plan that recycled more of the existing sacrificial panel system than previously described was considered. The plan was developed from the work completed at Bagram Air Base, Afghanistan, where multiple defective panel anchors were discovered after a sacrificial paneling installation across the runway. Of the 992 anchors in the sacrificial paneling system, 502 were defective and needed to be replaced (USAF 2014).

The goal with this work was to salvage the paneling foundation and as many of the anchors as possible to reduce the amount of work and time the runway would have to be closed. A significant reduction in time can be achieved compared to completely abandoning or partially demolishing the in-place system since removing the anchorage points takes a large amount of time. Not removing the paneling anchoring points can eliminate 11 to 21 days of work from the overall retrofitting effort.

If any anchor point is not in acceptable working order, it should be removed and replaced before the asphalt overlay in order to complete future work tasks that use the anchor points. The USAF developed a three-step method to test anchor points to determine their adequacy. The first step was a torque (spin) test to determine whether the anchor is adequately bonded to the foundation. Second, the length of the anchor is determined by ultrasonic testing to determine the risk of damaging the surrounding concrete surface and creating spalls that will need repair.

Third, nondestructive tension proof testing of the anchor is conducted to determine its load-carrying capacity for comparison with design values. The three tests are recommended to be completed in the order described. Failure of the torque or proof loading test warrants removal and replacement of the individual anchor by coring, demolition of the concrete core, backfilling the core hole with rapid setting concrete, and reinstalling the anchor. Testing the anchors will take some time; therefore, the full time savings will be less than the 11 to 21 days previously stated. Some reduction in schedule is possible by replacing groups of previously tested anchors while new anchors are tested by using separate teams for each type of work.

Ultrasonic testing is used to determine the length of the anchor before proof loading to verify that the loading to be applied will not damage the concrete. Anchors with shorter-than-expected or specified embedment lengths may produce cone-shaped failures when loaded to higher-than-designed loads rather than debonding of the adhesive from either the concrete or the anchor rod. This cone-shaped damage produces spalls that must be repaired before reinstalling the paneling. Catching the anchors that are not long enough to survive proof loading will save the installation team time since additional corrective work is not needed. Ultrasonic testing of tie-down anchorage may not be possible due to its geometry. Adequacy testing is not required for the complete retrofit option described earlier since all anchorage points are demolished and replaced, but recycling should be considered if the total project timeline is longer than required or desired. If more information on the anchor testing is needed, it is recommended to contact the AFCEC for assistance.

The scenario posed for this retrofit work will focus around that previously described in which a series of concrete slabs was placed within a runway. After the anchors are tested with the method developed by the USAF, the individual defective anchors are removed and replaced along the panel system. Once the panel anchors are corrected, a similar plan of attack is used to restore the pavement into a more compliant cross section as with the complete retrofit method. The concrete surface is cut partial depth, removed, and overlaid with asphalt to create two large patches on each side of the panel system. Depending on the amount of work required for the sacrificial panel system at hand, some phases of work may not be needed and can be removed from the work plan to best tailor the work to the project at hand.

It is possible that not all anchors within a panel will need replacement. If a panel has two adequate anchors after testing, panel shimming may not be necessary to help position the individual panel within the slot.

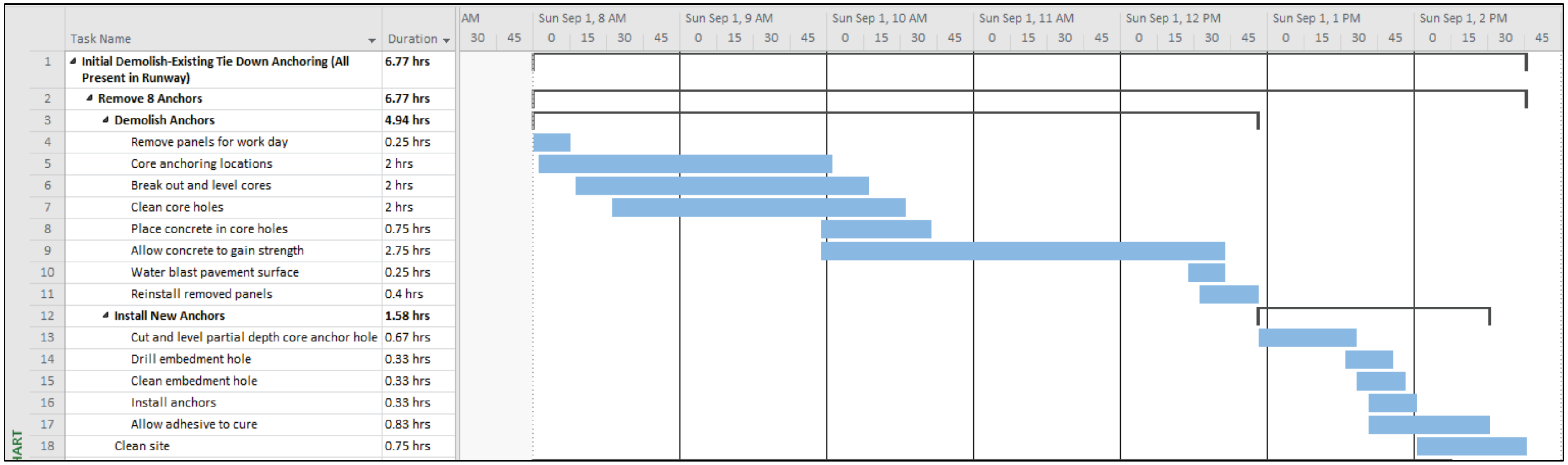
Note that the partial retrofitting option can be used only if the existing panel anchoring locations are adequate. If the UHMW panel dimensions change for whatever reason, the panel anchoring locations ultimately change and will not align with the in-place anchor pattern. This leaves the full retrofit option as the only corrective method.

Figure 54 shows the prospective Gantt charts developed for the installation work days. Seven different phases are needed to complete the necessary work. Many of the required work tasks are sequential, but some parallelization was achieved with demolition tasks to reduce the total duration of the work for these tasks as a whole. Multiple options for replacing both tie-down and panel anchors are presented to best tailor the amount of work required to the project at hand for flexible planning. All installation timing presented is less than the 12 hr maximum closure. Replacement of more anchors per work day is more efficient than fewer anchors due to time losses in curing and cleaning time. Replacing fewer panel anchors to achieve the preferred 6 hr closure time will take a considerable amount of work days to accomplish and is not recommended.

Once all defective anchors are replaced, three of the work phases are less than the preferred 6 hr time limit per work day. All remaining work phases are projected to be less than the maximum 12 hr requirement. Some work phases have options available to account for different scenarios the installation work encounters. The total project time varies depending on the number of tie-down and panel anchors replaced, but a minimum of 11 work days is required to demolish the existing concrete foundation, overlay the foundation with asphalt, and reinstall a UHMW panel system across a 150 ft asphalt surfaced runway after all defective anchors are replaced with this option. Table 22 details the sequencing of work tasks with projected timing. Many of the items and equipment are currently in USAF inventories, and all may be delivered to the site by C-130 aircraft.

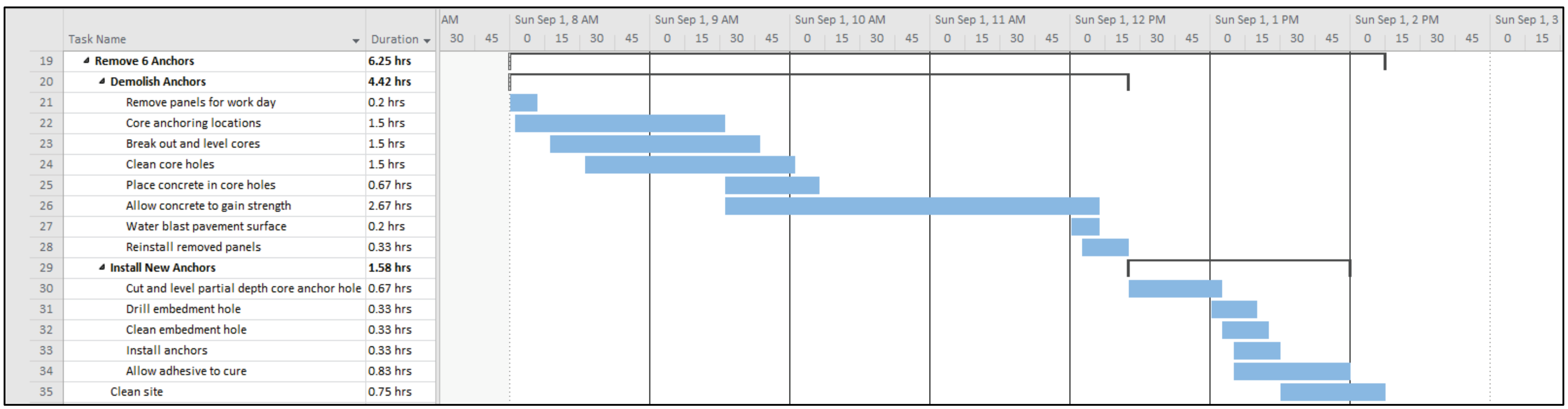
Figure 54. Gantt charts for partial retrofit of sacrificial paneling system.

a. Initial demolition – Remove existing tie-down anchoring



	Task Name	Duration
1	**Initial Demolish-Existing Tie Down Anchoring (All Present in Runway)**	**6.77 hrs**
2	**Remove 8 Anchors**	**6.77 hrs**
3	**Demolish Anchors**	**4.94 hrs**
4	Remove panels for work day	0.25 hrs
5	Core anchoring locations	2 hrs
6	Break out and level cores	2 hrs
7	Clean core holes	2 hrs
8	Place concrete in core holes	0.75 hrs
9	Allow concrete to gain strength	2.75 hrs
10	Water blast pavement surface	0.25 hrs
11	Reinstall removed panels	0.4 hrs
12	**Install New Anchors**	**1.58 hrs**
13	Cut and level partial depth core anchor hole	0.67 hrs
14	Drill embedment hole	0.33 hrs
15	Clean embedment hole	0.33 hrs
16	Install anchors	0.33 hrs
17	Allow adhesive to cure	0.83 hrs
18	Clean site	0.75 hrs

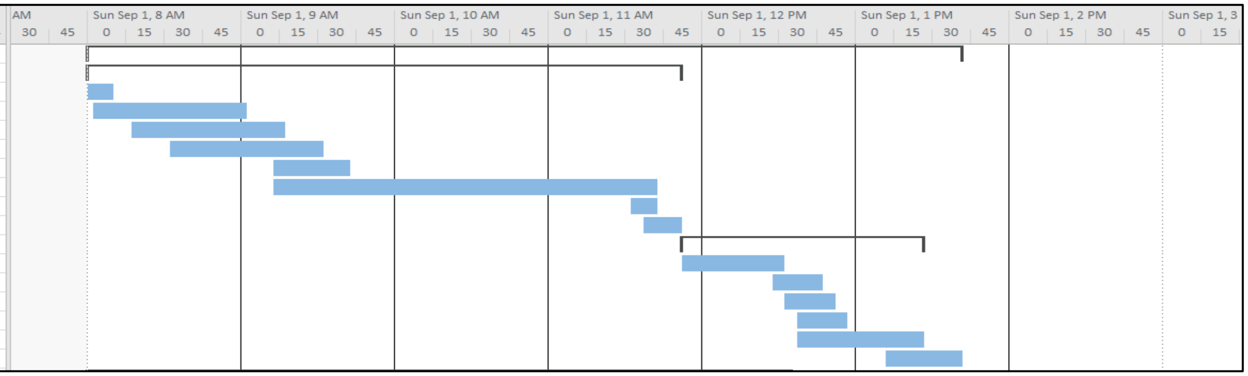
(Sheet 1 of 5)z



	Task Name	Duration
19	**Remove 6 Anchors**	**6.25 hrs**
20	**Demolish Anchors**	**4.42 hrs**
21	Remove panels for work day	0.2 hrs
22	Core anchoring locations	1.5 hrs
23	Break out and level cores	1.5 hrs
24	Clean core holes	1.5 hrs
25	Place concrete in core holes	0.67 hrs
26	Allow concrete to gain strength	2.67 hrs
27	Water blast pavement surface	0.2 hrs
28	Reinstall removed panels	0.33 hrs
29	**Install New Anchors**	**1.58 hrs**
30	Cut and level partial depth core anchor hole	0.67 hrs
31	Drill embedment hole	0.33 hrs
32	Clean embedment hole	0.33 hrs
33	Install anchors	0.33 hrs
34	Allow adhesive to cure	0.83 hrs
35	Clean site	0.75 hrs

(Sheet 2 of 5)

	Task Name	Duration
36	Remove 4 Anchors	5.7 hrs
37	Demolish Anchors	3.87 hrs
38	Remove panels for work day	0.17 hrs
39	Core anchoring locations	1 hr
40	Break out and level cores	1 hr
41	Clean core holes	1 hr
42	Place concrete in core holes	0.5 hrs
43	Allow concrete to gain strength	2.5 hrs
44	Water blast pavement surface	0.17 hrs
45	Reinstall removed panels	0.25 hrs
46	Install New Anchors	1.58 hrs
47	Cut and level partial depth core anchor hole	0.67 hrs
48	Drill embedment hole	0.33 hrs
49	Clean embedment hole	0.33 hrs
50	Install anchors	0.33 hrs
51	Allow adhesive to cure	0.83 hrs
52	Clean site	0.5 hrs



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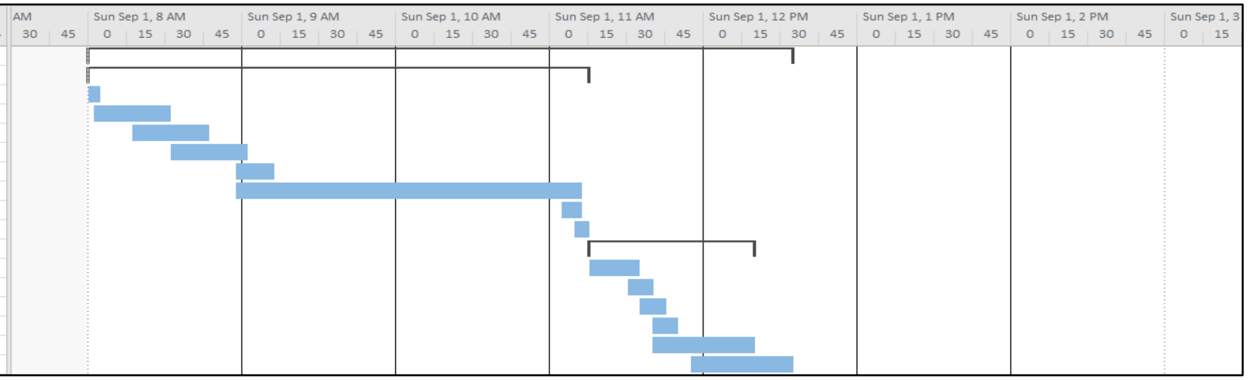
	Task Name	Duration
53	Remove 2 Anchors	4.59 hrs
54	Demolish Anchors	3.26 hrs
55	Remove panels for work day	0.08 hrs
56	Core anchoring locations	0.5 hrs
57	Break out and level cores	0.5 hrs
58	Clean core holes	0.5 hrs
59	Place concrete in core holes	0.25 hrs
60	Allow concrete to gain strength	2.25 hrs
61	Water blast pavement surface	0.13 hrs
62	Reinstall removed panels	0.1 hrs
63	Install New Anchors	1.08 hrs
64	Cut and level partial depth core anchor hole	0.33 hrs
65	Drill embedment hole	0.17 hrs
66	Clean embedment hole	0.17 hrs
67	Install anchors	0.17 hrs
68	Allow adhesive to cure	0.67 hrs
69	Clean site	0.67 hrs



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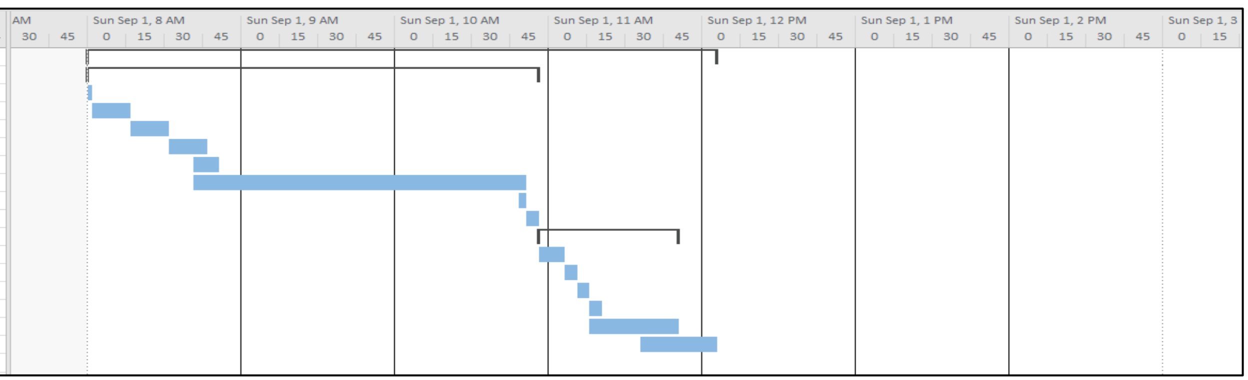
	Task Name	Duration
70	Remove 1 Anchor	4.1 hrs
71	Demolish Anchor	2.94 hrs
72	Remove panels for work day	0.03 hrs
73	Core anchoring locations	0.25 hrs
74	Break out and level cores	0.25 hrs
75	Clean core holes	0.25 hrs
76	Place concrete in core holes	0.17 hrs
77	Allow concrete to gain strength	2.17 hrs
78	Water blast pavement surface	0.05 hrs
79	Reinstall removed panels	0.08 hrs
80	Install New Anchors	0.91 hrs
81	Cut and level partial depth core anchor hole	0.17 hrs
82	Drill embedment hole	0.08 hrs
83	Clean embedment hole	0.08 hrs
84	Install anchors	0.08 hrs
85	Allow adhesive to cure	0.58 hrs
86	Clean site	0.5 hrs



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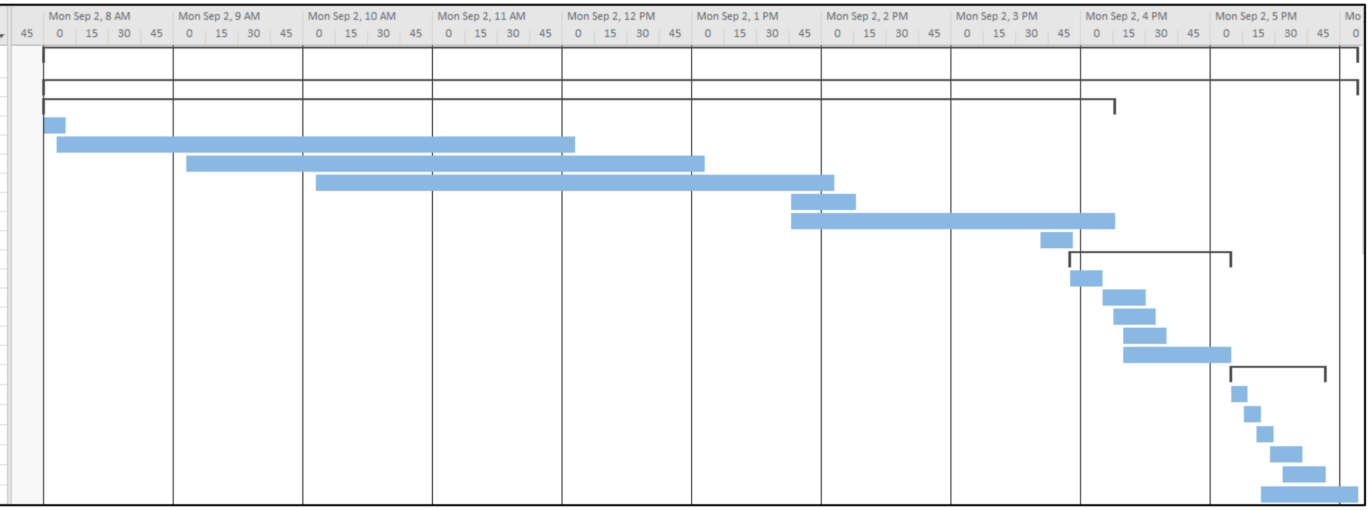
b. Initial demolition – Remove existing panel anchoring

	Task Name	Duration
1	Initial Demolish-Existing Panel Anchoring (Partial Width)	10.14 hrs
2	Demolish 24 Anchors	10.14 hrs
3	Demolish Anchors	8.27 hrs
4	Remove panels for work day	0.17 hrs
5	Core anchoring locations	4 hrs
6	Break out and level cores	4 hrs
7	Clean core holes	4 hrs
8	Place concrete in core holes	0.5 hrs
9	Allow concrete to gain strength	2.5 hrs
10	Water blast pavement surface	0.25 hrs
11	Install New Anchors	1.24 hrs
12	Replace and shim panels	0.25 hrs
13	Drill embedment hole	0.33 hrs
14	Clean embedment hole	0.33 hrs
15	Install anchors	0.33 hrs
16	Allow adhesive to cure	0.83 hrs
17	Install Hardware on Panel Anchors	0.73 hrs
18	Remove cap nuts	0.13 hrs
19	Install hex nuts	0.13 hrs
20	Gross torque hex nuts	0.13 hrs
21	Fine torque hex nuts	0.25 hrs
22	Verify panel anchors elevation	0.33 hrs
23	Clean site	0.75 hrs



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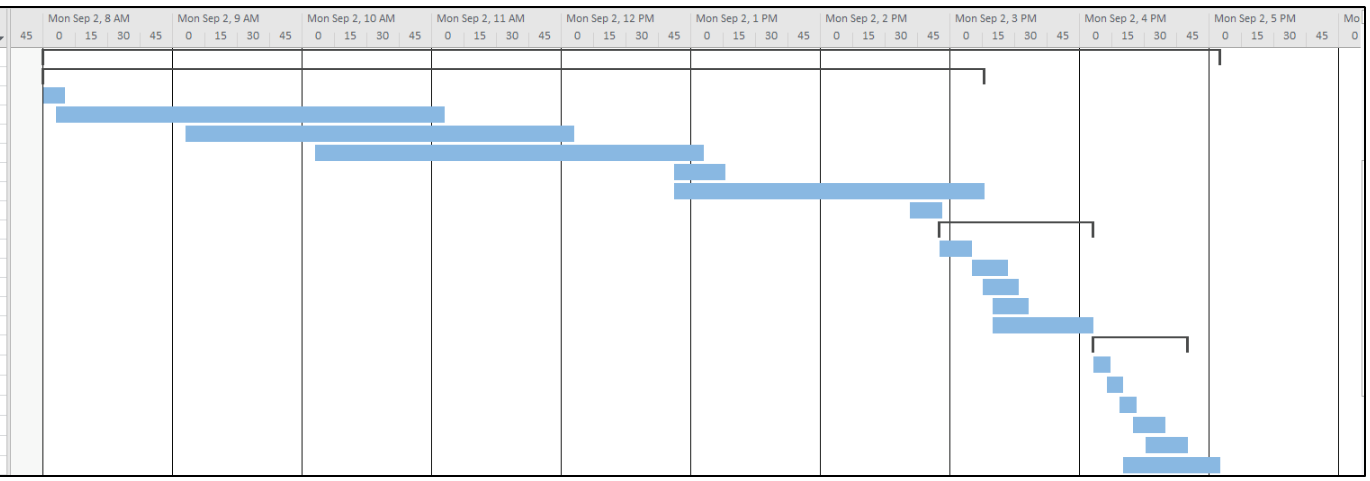
	Task Name	Duration
24	Demolish 18 Anchors	9.09 hrs
25	Demolish Anchors	7.27 hrs
26	Remove panels for work day	0.17 hrs
27	Core anchoring locations	3 hrs
28	Break out and level cores	3 hrs
29	Clean core holes	3 hrs
30	Place concrete in core holes	0.4 hrs
31	Allow concrete to gain strength	2.4 hrs
32	Water blast pavement surface	0.25 hrs
33	Install New Anchors	1.19 hrs
34	Replace and shim panels	0.25 hrs
35	Drill embedment hole	0.28 hrs
36	Clean embedment hole	0.28 hrs
37	Install anchors	0.28 hrs
38	Allow adhesive to cure	0.78 hrs
39	Install Hardware on Panel Anchors	0.73 hrs
40	Remove cap nuts	0.13 hrs
41	Install hex nuts	0.13 hrs
42	Gross torque hex nuts	0.13 hrs
43	Fine torque hex nuts	0.25 hrs
44	Verify panel anchors elevation	0.33 hrs
45	Clean site	0.75 hrs



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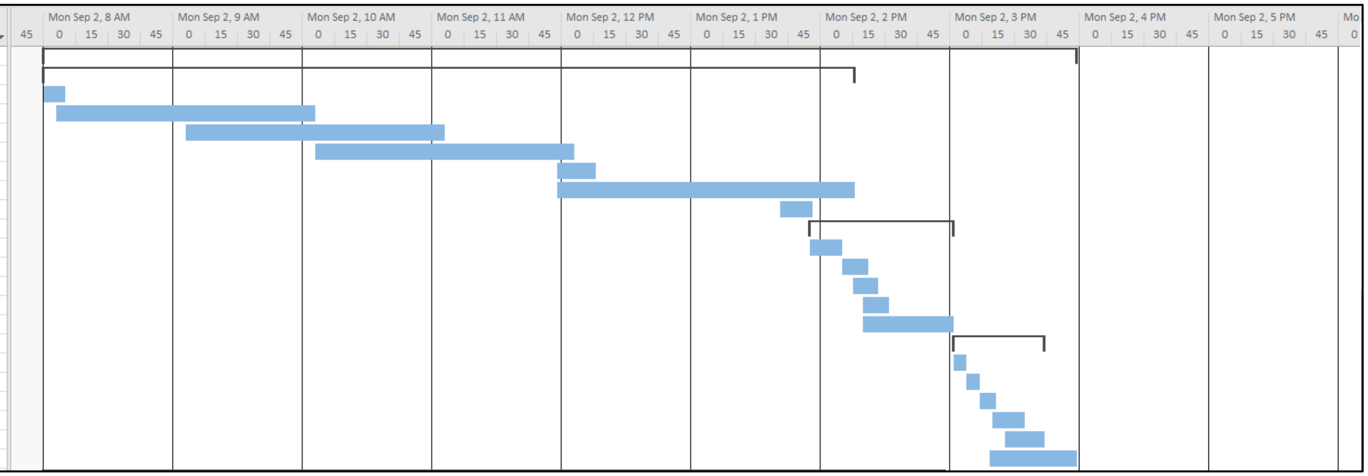
GANTT CHART

	Task Name	Duration
46	**Demolish 12 Anchors**	**7.98 hrs**
47	**Demolish Anchors**	**6.27 hrs**
48	Remove panels for work day	0.17 hrs
49	Core anchoring locations	2 hrs
50	Break out and level cores	2 hrs
51	Clean core holes	2 hrs
52	Place concrete in core holes	0.3 hrs
53	Allow concrete to gain strength	2.3 hrs
54	Water blast pavement surface	0.25 hrs
55	**Install New Anchors**	**1.11 hrs**
56	Replace and shim panels	0.25 hrs
57	Drill embedment hole	0.2 hrs
58	Clean embedment hole	0.2 hrs
59	Install anchors	0.2 hrs
60	Allow adhesive to cure	0.7 hrs
61	**Install Hardware on Panel Anchors**	**0.7 hrs**
62	Remove cap nuts	0.1 hrs
63	Install hex nuts	0.1 hrs
64	Gross torque hex nuts	0.13 hrs
65	Fine torque hex nuts	0.25 hrs
66	Verify panel anchors elevation	0.3 hrs
67	Clean site	0.67 hrs



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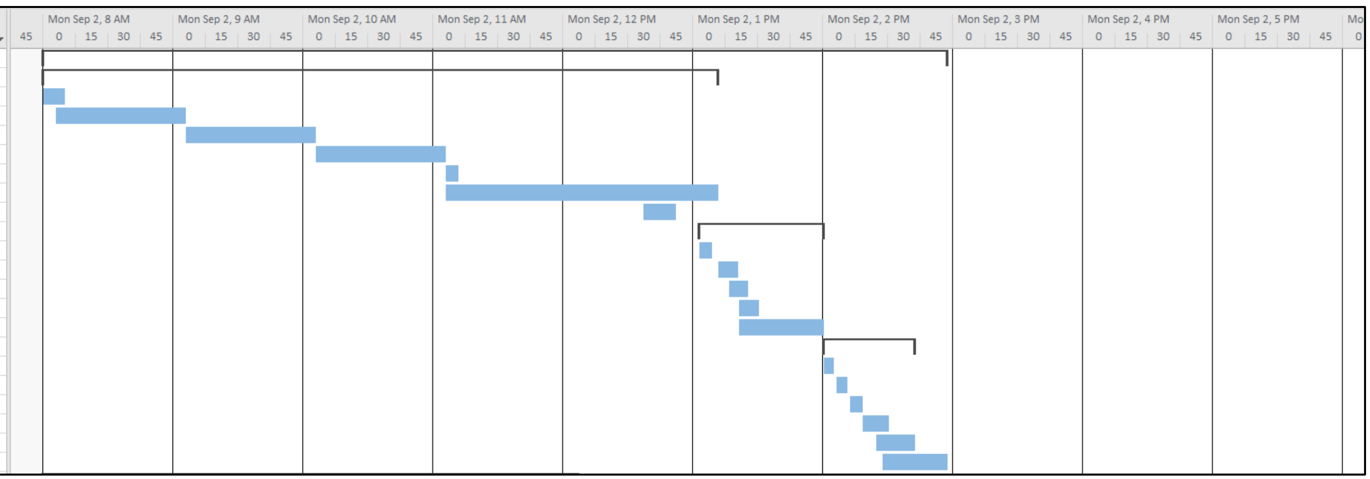
GANTT CHART

	Task Name	Duration
68	**Demolish 6 Anchors**	**6.96 hrs**
69	**Demolish Anchors**	**5.2 hrs**
70	Remove panels for work day	0.17 hrs
71	Core anchoring locations	1 hr
72	Break out and level cores	1 hr
73	Clean core holes	1 hr
74	Place concrete in core holes	0.1 hrs
75	Allow concrete to gain strength	2.1 hrs
76	Water blast pavement surface	0.25 hrs
77	**Install New Anchors**	**0.96 hrs**
78	Replace and shim panels	0.1 hrs
79	Drill embedment hole	0.15 hrs
80	Clean embedment hole	0.15 hrs
81	Install anchors	0.15 hrs
82	Allow adhesive to cure	0.65 hrs
83	**Install Hardware on Panel Anchors**	**0.7 hrs**
84	Remove cap nuts	0.08 hrs
85	Install hex nuts	0.08 hrs
86	Gross torque hex nuts	0.1 hrs
87	Fine torque hex nuts	0.2 hrs
88	Verify panel anchors elevation	0.3 hrs
89	Clean site	0.5 hrs



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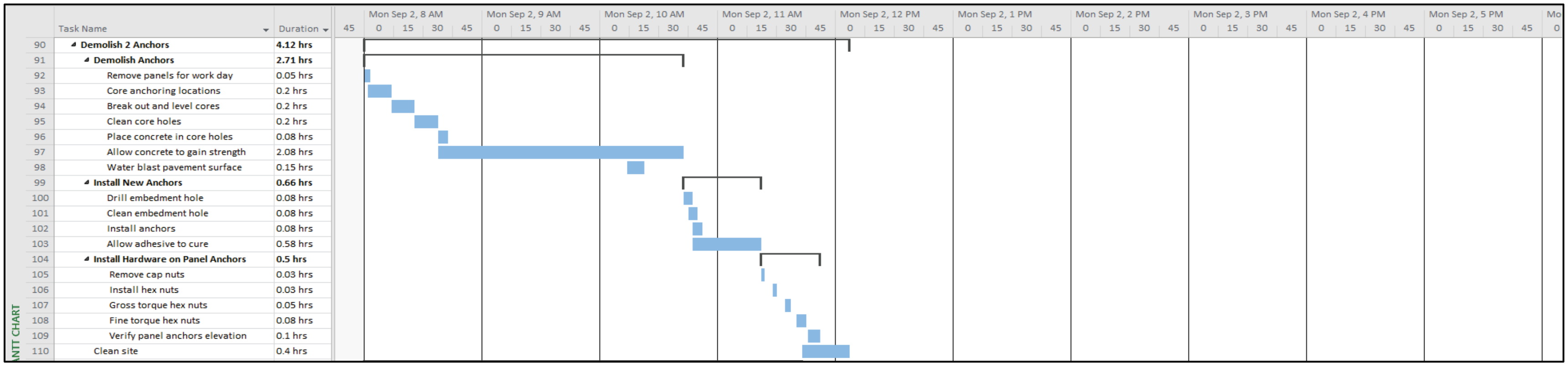

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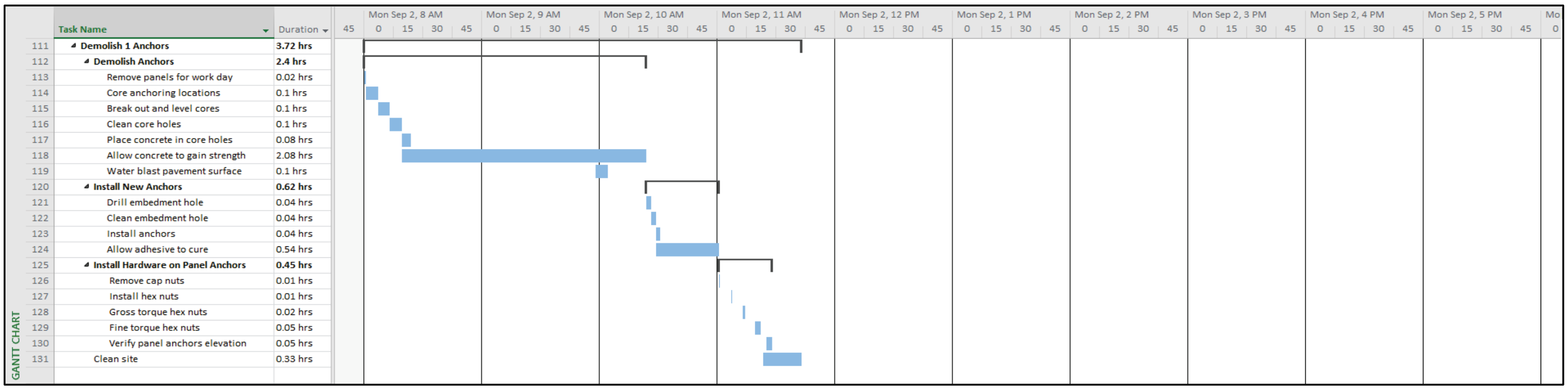

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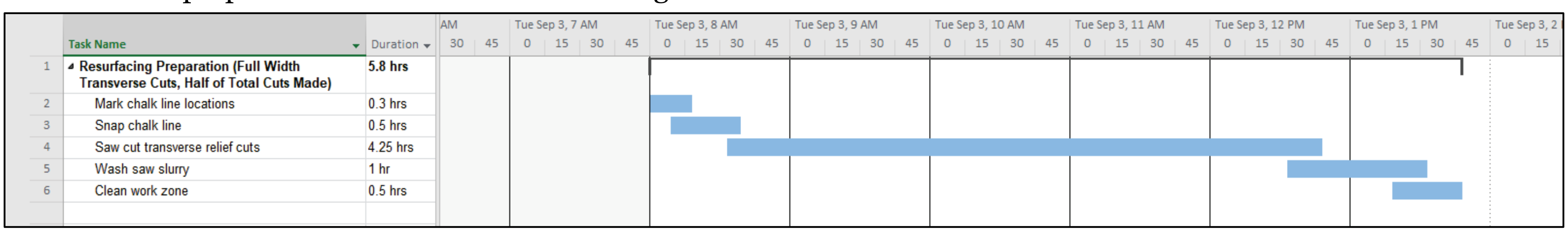
c. Demolition preparations – Transverse sawcutting



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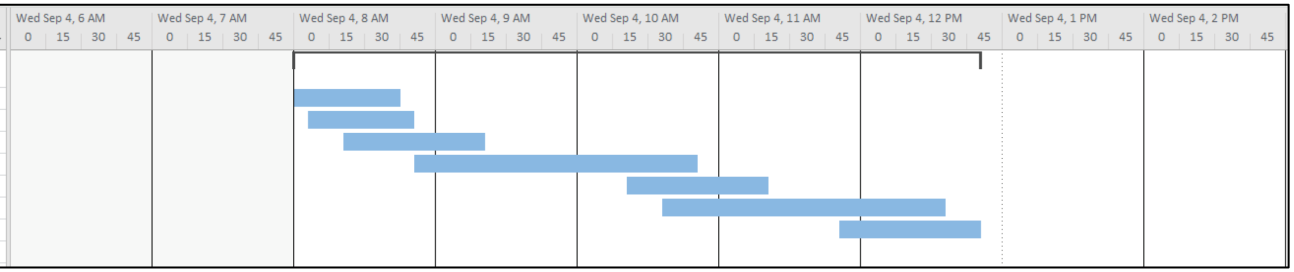
d. Demolition preparations – Longitudinal sawcutting

	Task Name	Duration
1	**Demolition Preparation (Partial Width Longitudinal Cuts, Quarter of Cuts Made)**	**4.85 hrs**
2	Remove panels	0.75 hrs
3	Mark chalk line locations	0.75 hrs
4	Snap chalk line	1 hr
5	Saw cut relief cuts	2 hrs
6	Wash saw slurry	1 hr
7	Replace panels	2 hrs
8	Clean work zone	1 hr



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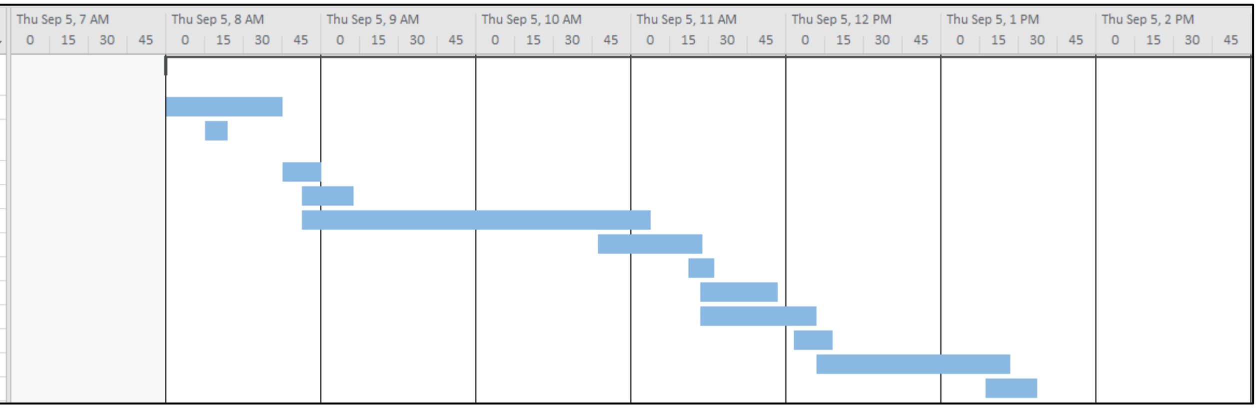
e. Surface demolition and asphalt overlaying

	Task Name	Duration
1	**AC Overlaying (Half Width, Both Sides of Paneling)**	**10.37 hrs**
2	Mill AC at foundation ends	0.75 hrs
3	Make sawcut in previously placed AC for clean construction joint (day 2 only)	0.15 hrs
4	Wet base material	0.25 hrs
5	Compact base layer	0.33 hrs
6	Chisel PCC	2.25 hrs
7	Level PCC surface	0.67 hrs
8	Vacuum patch area	0.17 hrs
9	Water blast patch area	0.5 hrs
10	Remove panels	0.75 hrs
11	Heavily air blast patch areas	0.25 hrs
12	Install steel formwork	1.25 hrs
13	Place tack coat	0.33 hrs



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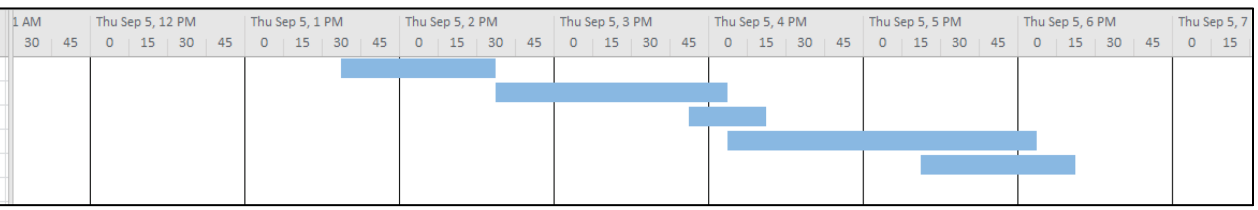
	Task Name	Duration
14	Place AC patch	1 hr
15	Watershock AC patch	1.5 hrs
16	Remove formwork	0.5 hrs
17	Reinstall panels	2 hrs
18	Clean work site	1 hr



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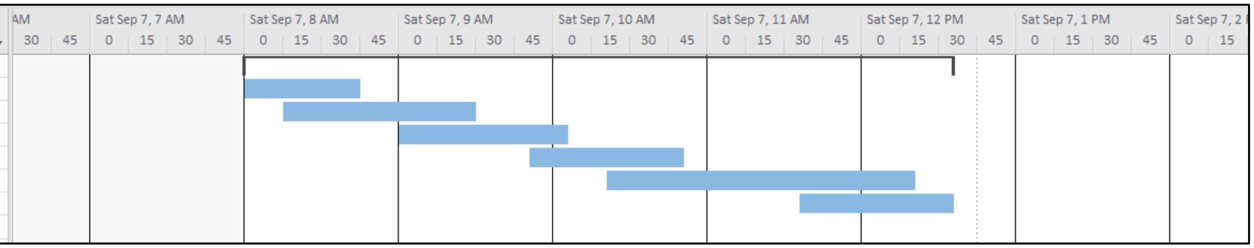
f. Drainage channel construction

	Task Name	Duration
1	Drain Channel Construction (Half Width)	4.6 hrs
2	Remove panels	0.75 hrs
3	Install saw guides	1.25 hrs
4	Cut drain channel	1.1 hrs
5	Water blast slot	1 hr
6	Reinstall panels	2 hrs
7	Clean site	1 hr



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g. Joint sealing

	Task Name	Duration
1	Joint Sealing (Full Width)	7 hrs
2	Air blast joints and anchor holes	1 hr
3	Install backer rod	3 hrs
4	Install sealant	3 hrs
5	Allow sealant to cure, begin clean up	5 hrs

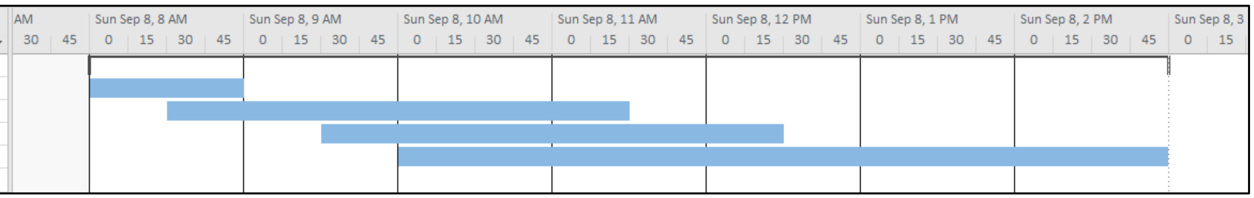

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Table 22. Optimized sequencing of required work tasks for partial retrofit of sacrificial paneling system.

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
1	1 As necessary	Demolition - Existing anchor removal	Remove panels with defective tie-down anchoring.	150 Up to 8 anchors	Per tie-down anchor replaced 8: 6.8 6: 6.3 4: 5.7 2: 4.6 1: 4.1
2			Core tie-down anchoring locations.		
3			Break out and level cores.		
4			Clean core holes.		
5			Place concrete in core holes.		
6			Allow concrete to gain strength.		
7			Water blast pavement surface.		
8			Reinstall removed panels.		
9			Install new anchor.		
10			Allow adhesive to cure.		
11			Clean site.		
12	2 Repeat as necessary across runway		Remove panels with defective panel anchoring.	Up to 4 full panels replaced per work day, intermittent	Per panel anchor replaced 24: 10.1 18: 9.1 12: 8.0 6: 7.0 2: 4.1 1: 3.7
13			Core tie-down anchoring locations.		
14			Break out and level cores.		
15			Clean core holes.		
16			Place concrete in core holes.		
17			Allow concrete to gain strength.		
18			Water blast pavement surface.		
19			Reinstall removed panels; shim as needed.		
20			Install new anchoring.		
21			Let adhesive cure.		
22			Clean site.		
23	3 Repeat 2 times	Demolition – Preparations for overlaying	Mark transverse PCC relief cut locations.	150 Cuts made are on one side of paneling	5.8
24			Saw cut transverse PCC relief cuts.		
25			Mark transverse AC patch perimeter cut locations.		
26			Saw cut transverse AC patch perimeter.		
27			Water blast slot.		
28			Clean site.		

(Sheet 1 of 2)

Task	Work Phase	Phase	Task Description	Runway Width Completed per Work Day (ft)	Projected Runway Closure Time (hr)
29	4 Repeat 4 times	Demolition – Preparations for overlaying	Remove panels.	75 Cuts made are on one side of paneling	4.9
30	4 Repeat 4 times	Demolition – Preparations for overlaying	Mark longitudinal PCC relief cut locations.	75 Cuts made are on one side of paneling	4.9
31	4 Repeat 4 times	Demolition – Preparations for overlaying	Saw cut longitudinal PCC relief cuts.	75 Cuts made are on one side of paneling	4.9
32	4 Repeat 4 times	Demolition – Preparations for overlaying	Water blast slot.	75 Cuts made are on one side of paneling	4.9
33	4 Repeat 4 times	Demolition – Preparations for overlaying	Air blast panel slot.	75 Cuts made are on one side of paneling	4.9
34	4 Repeat 4 times	Demolition – Preparations for overlaying	Replace panels.	75 Cuts made are on one side of paneling	4.9
35	4 Repeat 4 times	Demolition – Preparations for overlaying	Clean site.	75 Cuts made are on one side of paneling	4.9
36	5 Repeat 2 times	Surface demolition and AC overlay	Mill AC at PCC foundation ends.	75	10.4
37	5 Repeat 2 times	Surface demolition and AC overlay	Saw cut construction joint along previously placed AC edge (day 2 only).	75	10.4
38	5 Repeat 2 times	Surface demolition and AC overlay	Wet base material.	75	10.4
39	5 Repeat 2 times	Surface demolition and AC overlay	Compact base layer.	75	10.4
40	5 Repeat 2 times	Surface demolition and AC overlay	Break PCC surface.	75	10.4
41	5 Repeat 2 times	Surface demolition and AC overlay	Vacuum patch area.	75	10.4
42	5 Repeat 2 times	Surface demolition and AC overlay	Water blast patch area.	75	10.4
43	5 Repeat 2 times	Surface demolition and AC overlay	Remove panels.	75	10.4
44	5 Repeat 2 times	Surface demolition and AC overlay	Air blast patch area.	75	10.4
45	5 Repeat 2 times	Surface demolition and AC overlay	Install steel formwork.	75	10.4
46	5 Repeat 2 times	Surface demolition and AC overlay	Apply tack coat.	75	10.4
47	5 Repeat 2 times	Surface demolition and AC overlay	Place AC patch.	75	10.4
48	5 Repeat 2 times	Surface demolition and AC overlay	Watershock AC patch.	75	10.4
49	5 Repeat 2 times	Surface demolition and AC overlay	Remove formwork.	75	10.4
50	5 Repeat 2 times	Surface demolition and AC overlay	Reinstall panels.	75	10.4
51	5 Repeat 2 times	Surface demolition and AC overlay	Clean site.	75	10.4
52	6 Repeat 2 times	Cut drain channel	Remove panels.	75	4.6
53	6 Repeat 2 times	Cut drain channel	Install saw track.	75	4.6
54	6 Repeat 2 times	Cut drain channel	Cut drain channels.	75	4.6
55	6 Repeat 2 times	Cut drain channel	Water blast slot.	75	4.6
56	6 Repeat 2 times	Cut drain channel	Reinstall panels.	75	4.6
57	6 Repeat 2 times	Cut drain channel	Clean site.	75	4.6
58	7	Joint sealing	Air blast joints and anchor holes.	150	7.0
59	7	Joint sealing	Install backer rod.	150	7.0
60	7	Joint sealing	Install sealant.	150	7.0
61	7	Joint sealing	Allow sealant to cure, clean site.	150	7.0
					(Sheet 2 of 2)

4 Options for Performance Improvements

After developing the work planning for each of the UHMW installation options, specific work tasks issues were discussed or components were re-evaluated from Chapter 3 for improvement. Five improvements were identified to yield more efficient construction and faster installation timing to reduce runway closures.

4.1 Torque-limiting extensions

One issue affecting all pavement installation options is the speed of fixing the panels to the foundation. It is encountered both when panels are installed after new panel anchoring has been installed and when in-place panels are replaced after other work tasks are completed to prevent damage to the paneling. The anchor nuts or bolts must be torqued to a minimum value specified by AFI 32-1043, which should be less than the allowable installation torque given by the manufacturer of the anchor adhesive used.

Procedures given in these installation techniques focus on a three-part method after the panel is placed in the slot. First, the washers and the nut (or bolt for the soil anchoring option) are placed on the panel anchoring rod, and the nut is rotated enough to hold its position on the threaded rod. Second, the nut is quickly gross tightened using an impact wrench and correctly sized socket to some torque below the minimum required torque of 60 ft-lb by AFI 32-1043. Last, a torque wrench set to 60 ft-lb with a correctly sized socket is used to apply the remaining amount of required torque needed to complete the installation. This three-step procedure is applied to all panel anchoring installed and can total approximately 50 anchors per 30 ft of paneling. Figure 55 shows the tools and personnel used for this set of work tasks. A five-person team is projected to be used where two people remove the temporary setting hardware and install the washers and nuts on the threaded anchor rods, one person uses an impact wrench to quickly tighten the anchors, and two people use torque wrenches to finalize tightening and verify the minimum required torque has been achieved.

Figure 55. Tightening of panel anchoring components.

Removing temporary setting.

Gross tightening with impact hammer installing permanent hardware.

Fine tightening with torque wrench.

Finished product.

Use of the torque wrench is required to ensure the correct installation torque is achieved. The panel must be properly affixed to the pavement so it stays within its slot and does not come loose. The anchors, however, cannot be torqued beyond the allowable strength of the adhesive such that it dislodges the anchor or damages the concrete the panel must be affixed to. Use of a torque wrench achieves this level of accuracy but can be cumbersome since the ease of applying higher torques depends on the length of the tool (moment arm) and its operation for this particular work requires the operator to stoop low or be sitting on the pavement. Significant time can be taken to use the torque wrench as well. Currently, it is projected that an hour is used to grossly tighten the anchoring nut and finish the installation with the fine tightening and verification of the minimum torque for an approximately 50-anchor installation. The fine tightening task takes the majority of the time for this set of work tasks.

Use of the impact hammer is a much more attractive method since it offers a greater installation speed and torqueing power from an overhead position (over the anchor), but the amount of torque the tool to provides cannot be precisely controlled for an accurate installation. Currently, impact wrench operators are to use short bursts of the tool to apply the gross tightening of the nut, but there is no way to tell how much torque was applied. If the tool were able to quickly and accurately apply the correct torque to the nut, the need for fine tightening would not be needed, and the process could be reduced by combining the gross and fine tightening tasks into one.

One option available is to use a torque-limiting extension with the impact wrench to assist in making the tool more intelligent (Figure 56). Torque-limiting extensions are commercially available equipment typically used by auto mechanics when installing lug nuts on tires for vehicles. Multiple sized (torque-rated) extensions are available that can be selected to meet panel installation requirements. The extensions are essentially torsional springs. Once the nut is torqued to the specified torque limit listed on the extension, the extension absorbs additional torque instead of applying it to the nut.

Figure 56. Torque-limiting extension.

Due to the speed and power of the equipment, it is projected that the time needed to tighten the components will be the same as that needed for gross tightening. Total time saving for an approximately 50-anchor installation will be 30 min for a one-person impact hammer team as described with the projected work planning. Using a second person and an impact hammer/extension tool will cut the time in half, for an additional 15 min time savings. For a 10 hr work phase in which this task is completed, a total time reduction of approximately 8% is possible and will further help minimize runway closure time. Time savings will be even greater where more panels are in need of replacement after sawing work tasks in the retrofit options described.

One issue with the use of torque-limiting extensions is that they rely on a specific dynamic loading to correctly achieve the specified torque. When the torque-limiting extension flexes to signal its maximum torque has been reached, the tool resonates and causes a larger rotational deformation (response) to the critical load applied. Resonance in structural dynamics occurs when an applied dynamic loading is equal to the natural frequency of the component (Craig and Kurdila 2006). In this case, the dynamic loading is generated by the beating of the impact wrench on the extension bar. When resonance is achieved, the maximum response is generated for the applied loading. To generate the correct conditions, the correct dynamic loading must be applied by the impact wrench for the system to work. This needs to be verified, or the tool system calibrated in advance of the work to ensure the proper load can be achieved with the tools intended for use.

Calibration involves installing nuts on panel anchoring and tightening to 60 ft-lb using a standard torque wrench, followed by adjusting the power tools to meet the torque with the extension bar. If air tools are used, the air supplied to the tool can be easily adjusted by the regulator on the air compressor by trial and error to match the torqueing effort needed with testing for a standard torque wrench for verification. A standard SuPR kit will not have pneumatic impact wrenches available, but these tools should be easily procurable in USAF inventories. The large towable air compressor can be used to power the tools if the proper reducers and fittings are available and will have more than enough air storage capacity to supply the demand of two wrenches. The SuPR kit also contains a small electric air compressor that can be used as well. Some extension kits come with a recommended tool and air regulator setting that can be used as a starting point for the calibration process. Completion of this work is intended before work begins and not on-the-fly while construction activities occur on the runway unless small adjustments are made from spot checking completed anchors with a torque wrench as they are installed.

A different approach must be taken with electric impact hammer tools that are in a standard SuPR kit. Review of automotive internet forums on torque-limiting tools have shown electric tools may not be able to match the dynamic loading required. One post reported that the extension bar will not work with hand operated wrenches (Pelican Parts 2000), but this is expected since a standard wrench does not produce a dynamic loading. Others report not being able to achieve the specified torque with electric tools and achieving lower than expected torques when checked by a standard torque wrench. Electric tools are not adjustable like air tools; therefore, resonance may not be achieved to allow the tool to work as intended. Outside of developing a specialized extension to work with electric impact hammers, the only option available is to use a torque-limiting extension with a larger rating to allow the tool system to reach the necessary torque. This is not a true calibration scenario since no adjustments are made; rather, the maximum torque is measured by completing multiple installations where multiple tool/extension bar combinations are used, and the combination that best meets what is required is selected.

4.2 Formwork for full-depth PCC pavement method

Installing of the formwork and casting the UHMW paneling void for the full-depth PCC repair option was especially challenging using the formwork developed for the work. A pre-constructed, wooden-framed void-forming mold was used for its ease of construction, as shown in Figure 20. Segments of the mold were constructed with a plan area of 25 in. by 4 ft. The mold was constructed before testing began by attaching a 1/2 in. thick piece of plywood to a perimeter of 1 in. by 1 in. dimensional lumber to create the 1.5 in. tall mold. The void mold formwork was suspended over the repair void by a series of 2 in. by 4 in. by 8 ft long dimensional lumber struts with 2 in. by 4 in. wooden plates between the ends of the struts and the void mold to raise the strut off the pavement surface to allow access for concrete finishing tools. Connections between the form mold segments and struts were made with 2 in. long screws. After form erection, the form was sprayed with a concrete release agent to allow for easy demolding. Multiple coatings were needed due to the absorptive nature of the lumber. The prepared formwork was then dragged into position by hand and centered in the repair void area. Each end of the struts was to be weighted down with sand bags to resist the buoyant uplift force of the plastic concrete during placement, but no sand was present for use on site. Instead, the pieces of concrete removed from the pavement were placed over the end of the struts located at the ends and midspan of the form.

The formwork did not produce an acceptable paneling void as previously described. Failure of the formwork was attributed to improper design to fully resist the buoyant uplift forces that result from suspending the formwork in liquid (plastic) concrete. Since estimated timing of the full-depth repair option is within the 12 hr maximum closure window, a redesigned formwork package was developed for any future efforts that would be more user friendly and yield a better finished cast product. The optimal timing information provided in Table 7 and Figure 24 estimated timing assuming redesigned formwork is used; however, actual timing requirements should be determined for accuracy.

Redesigned formwork components and assembly drawings can be found in Appendix F and done in accordance with American Institute of Steel Construction (AISC 2005). Major formwork design items include the following:

- Steel formwork was used rather than wood for a variety of reasons. Most notably, steel items allowed for greater recyclability of the formwork and provided a stiffer material for use. Construction of the formwork was easier since standard structural shapes could be procured and fastened together rather than cutting multiple wood components.
- Assuming 150 lb/ft^3 unit weight for concrete, the plastic concrete exerts approximately 42.3 lb of buoyant uplift force per linear foot of form based on the volume of concrete displaced by the form.
- The formwork would continue to be modular to aid in assembly efforts and tailoring to the project at hand. Segments 5 ft in length would be used for the majority of the work and cover slab widths of multiples of 5 ft. Additional $2^1/_2$ and $3^3/_4$ ft segment lengths were also developed to allow for the installation into $12^1/_2$ and $18^3/_4$ ft slab widths to allow for a wide range of installation possibilities. The segments of formwork would be connected to one another using gusset plates and bolted together.
- The formwork continued to be suspended in the repair void using struts. A column piece was added to the base plate to correctly position the formwork elevation in the void. The base plate would be affixed to the pavement using mechanical concrete anchors once erected and

positioned in the repair void. The anchors can be quickly and easily installed and removed using SuPR kit equipment. Only small holes are drilled into the pavement for their installation, and the anchors can be cut off and ground down with an angle grinder once form demolition is completed.

- The formwork was modeled as a pinned-pinned beam with uniformly distributed loading at the center for simplicity and as a worst-case loading scenario. The form was assumed to be weightless for initial design considerations. To provide a smooth and flat void, the maximum deflection allowed by any part of the formwork was set to 0.01 in. To achieve the maximum deflection, the form must have a minimum moment of inertia of 30.4 $in.^4$. A wide flange section was selected to serve as the main structural section of the formwork to resist the uplift force on its own. A W8X10 is the smallest section that meets this requirement. The plate that formed the bottom of the panel void perimeter was modeled as a cantilevered beam with a uniformly distributed load and requires a $^3/_8$ in. thickness to meet deflection requirements. Additional steel is to be welded to the ends of the plate to form the 1.5 in. mold depth. Gusset plates will consist of two $7^1/_4 \times$ 14 in. long pieces of 0.5 in. plate steel bolted to both sides of the web of the wide flange to provide the minimum moment of inertia.
- The minimum cross-section design for a standard 5 ft segment weighs approximately 230 lb. This corresponds to a self-weight of 46 lb per linear foot of form. The configuration of the minimum required form described is sufficient to resist the buoyant force alone. Additional optimization of the formwork can be completed to lighten the cross section for a more efficient structure.
- All bolts, nuts, and mechanical wedge anchors needed use $^3/_8$ in. diameter hardware to minimize the need for different sized wrenches and sockets by the installation team.
- Air vent holes were added to the interior of the form mold to assist in releasing trapped air when placing concrete. A concrete spud vibrator should be used to fluidize the concrete under the form and ensure the trapped air is removed.
- The segments of forms developed weighed too much for two personnel to lift and position. Considerations for lifting equipment and rigging were needed to minimize personnel effort and allow for speedy installation. It is recommended that the formwork be moved with a 5,000 lb warehouse forklift with side shift/movement control using a minimum of 1,000 lb shackle and lifting sling for rigging equipment.

The shackle should have an inside diameter or width of at least 2 in. to allow for installation with the lifting tab welded to the formwork. Larger allowable loads than prospective form mold section weights were used to account for spilled concrete within the form interior and allow for some additional force to remove the formwork from the concrete if necessary.

- Both the number and lengths of the struts will be minimized to reduce congestion in the tight work area where personnel and volumetric mixer will operate. A maximum strut spacing of 10 ft was selected to best reduce the section size of strut needed. Two sets of bolt holes were provided in the top flange of the wide flange section to help with positioning struts. Struts were made 7 ft long to minimize the length required to clear the 5 ft wide repair void and additional distance from the repair void edge required for mechanical wedge anchor installation. The strut was modeled as a simple pinned-pinned beam with a center point load. A point load was used to consider the uplift force applied to the strut was that developed over a 10 ft length of formwork. A double angle was selected to provide flat surfaces for connections and provide the geometric stiffness required. The minimum section required is an L 5 in. × 3 in. × 7/16 in. Each strut will be approximately 90 lb at its lightest, and it is recommended that two personnel move each piece about the site.

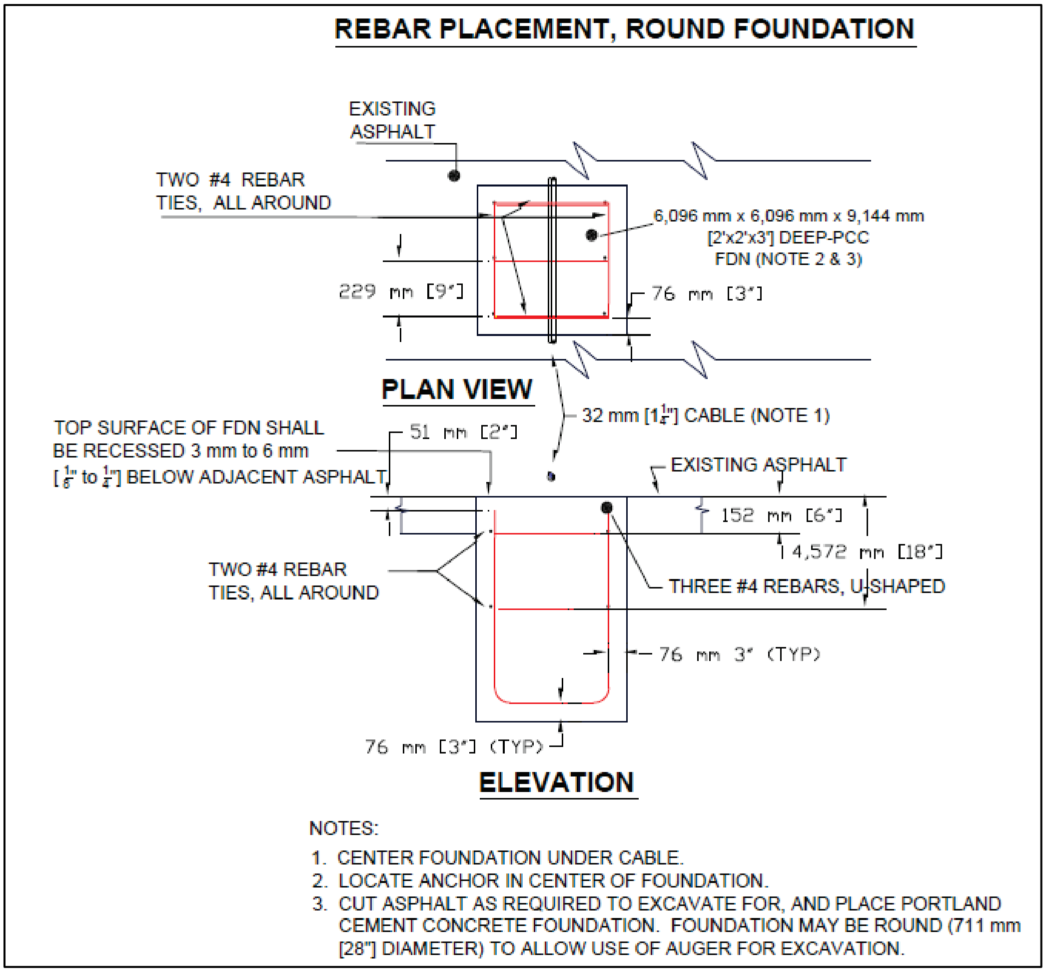
The redesigned formwork described will give the installation team a better alternative to efficiently cast the UHMW paneling void with few post-placement modifications. The formwork described should be tested before its first field use to verify its effectiveness and constructability. The testing will also produce accurate timing information and verify personnel requirements before its use is implemented.

One note to the design presented is that the formwork was designed assuming it is weightless to begin the member selection process; however, this is not true. The weight of the formwork will resist a portion to all of the buoyant uplift force, ultimately reducing the demand for the member sizes selected for the components designed. A less structurally stiff system can be developed if needed to provide a lighter structure for easier handling by personnel and reduced heavy equipment needs. Use of mechanical wedge anchors to affix the forms to the pavement is still recommended to ensure the formwork does not move out of position when concrete is placed.

4.3 Helical tie-down anchoring for soil anchoring AC method

Use of the soil anchoring method for AC pavements requires the installation of a series of small foundation elements across the runway to assist in fixing the pendant to the location. The series of concrete elements across the runway is necessary since no concrete, either slabs of pavement or a strip foundation, is present with this option as with the other options considered in this investigation. AFI 32-1043 provides drawings for either square or circular cast-in-place reinforced concrete elements that provide a location to tie a 3,300 lb rated nylon rope around the pendant (Figure 57). Either four or eight anchoring points are required across the runway, depending on the type of aircraft that is expected to operate at the airfield. The document allows the surface of the concrete to be flush with the asphalt surface as a special provision.

Figure 57. Available tie-down anchoring foundation options (Headquarters, Department of the Air Force 2012).

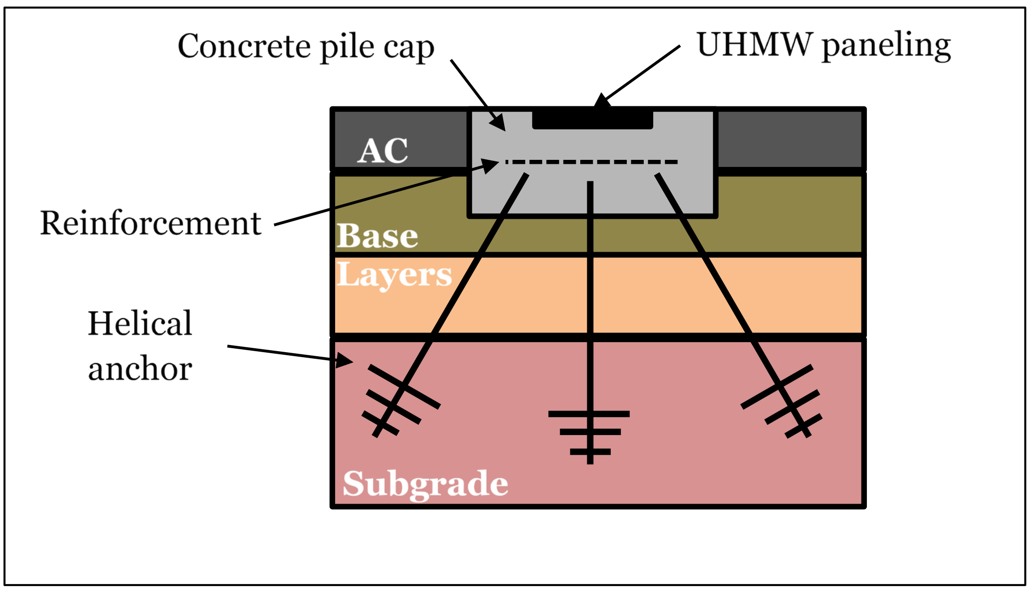


One major challenge with the foundation design is the drawings show the concrete surface elevation to be cast flush with the pavement surface. When installing with a paneling system, the thickness of the UHMW paneling must be considered. For speed and ease of installation, an augered excavation is expected to be used for the installation plan made by the CTL in the SuPR kit. The SuPR kit does not contain an augering attachment or the flight needed to bore the holes, but these items are commercially available and will easily transport in military cargo aircraft. AFI 32-1043 shows that the anchor excavation must be 28 in. in diameter to maintain the same foundation weight as the 2 ft square option. The diameter of the circle made is larger than the width of the paneling void (28 vs. 25 in.) and questions as to what to do with the paneling arose. Ultimately two options were available to construct the foundation following current guidance. After cutting the pavement to accept the larger diameter, the concrete could either be formed to accept the paneling (or a slot cut and demolished partial-depth after curing) or the excavation could be placed below the paneling. Sinking the foundation surface below the panel was the better option to minimize any spalling of the $1^1/_2$ in. slivers of concrete outside the paneling slot that remained. In both cases, cutting a larger square utility cut around the foundation would require full-depth asphalt patching to replace the pavement removed.

To minimize the need for patching after foundation placement, reducing the size of the foundation was considered. Using standard auger bit diameters distributed by the CTL manufacturer, 24 and 18 in. diameter bits were available that would allow the excavation to be within the panel slot. To maintain the same foundation weight with the smaller diameters used, the excavations would need to be deeper. Excavation depths of $4^1/_2$ and $7^1/_4$ ft would be required for the 24 and 18 in. diameter foundations, respectively. These depths are significant, and drilling of the shaft for the foundation may require additional construction considerations if the underlying soils will not support the hole made and cave in, drilling removes more material than expected, or locations that have high water tables. Caving soils may require drilling slurry or a casing be installed to help support the depth of the excavation perimeter until backfilled with concrete. These construction methods are more complex than typical methods, may require special materials and equipment not in USAF inventories, and may not allow for runway closure times less than 12 hr.

One foundation option available is using helical earth anchoring to resist the loading applied by the aircraft failing the tie-down ropes (Figure 58). Helical anchors are essentially large screws drilled into the soil that use the area of the threads to resist applied loads. Anchors can have a number of helixes and be drilled to different depths and angles to achieve the tension and shear load capacity required for tailoring to specific site geotechnical conditions. For multiple anchors installed in a group, a reinforced concrete pile cap is used to connect the anchors for group action. Commercial systems are available that use (manufacturer-specific) standard section properties. Equipment used to install anchoring includes hydraulic power packs, backhoes, CTLs, and mini-excavators using an augering-like attachment designed for helical anchoring that allows for quick drilling times. Load capacity can be empirically verified by ensuring the anchoring meets a minimum torque. Once the helical anchors are installed, a concrete pile cap encases the tops of the drilled anchors to complete the foundation. The paneling is then installed, and a rigging point like that shown in Figure 9 can be installed for rope attachment. In the concept design shown in Figure 58, a vertical and an inclined (batter) pile arrangement is required to resist both tension and shear loads, respectively.

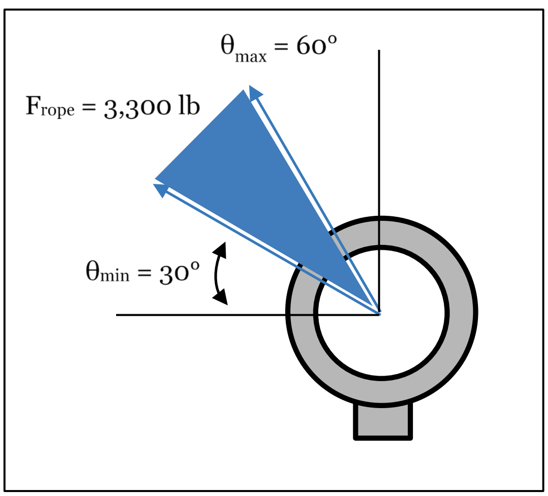
Figure 58. Prospective helical anchoring system for tie-down anchoring scenario.



A prospective preliminary design was determined for a worst-case anchoring scenario to assess the feasibility of the installation. A worst-case installation was considered to be a thin asphalt pavement on top of very weak subgrade. PCASE was used to estimate pavement layering for this scenario in which a three-layer flexible pavement system (AC - base - subbase – subgrade) with a subgrade of California Bearing Ratio of 3% is subjected to a standard USAF light-traffic pattern with Type D traffic, assuming the anchoring is installed at the runway threshold. Standard soil buoyant unit weights for typical soil materials for each layer were used for further bearing capacity reductions for saturated soils and high water tables. PCASE reported a 3 in. AC surface, with 6 in. and 29 in. of base and subbase materials, respectively, was required for the pavement.

The loading applied to the anchoring was designed to resist the break force of the nylon rope used to tie down the pendant, and the foundation is permanent and does not move when used. AFI 32-1043 reports that the rope used should be National Stock Number 4020-00-968-1356, which has a maximum break strength of 5,000 lb; however, review of typical item properties showed the specification for the rope is 3,300 lb minimum break strength. The angle the rope makes was not known when loaded, but it was assumed that the range of angle was between 30° and 60° from horizontal (Figure 59). Maximum loads for both tension and shear were estimated by trigonometry and used for design for the helical piles.

Figure 59. Estimated foundation loading.



Selection of the appropriate safety factor was critical to provide a permanent, reusable anchor that does not require repairs after use other than replacement of the damaged rope. When the arresting system is used, it is expected the aircraft will be moving very rapidly and create a short-duration ramp impulse dynamic loading as the rope is loaded to failure. Dynamic loads require more significant structural resistance since loadings are increased. Typical safety factors used in geotechnical engineering can range from 1.5 to 2 for different failure conditions of different geotechnical structures, but many of the design assumptions use static conditions. Other structures may have much greater safety factors to handle the increased loading. The increased loading can be estimated using structural dynamics models, but little is known about the dynamic load and system properties needed to perform calculations to estimate the system response. Without additional information, a safety factor of 5 was used for conservatism to ensure the anchorage was not damaged when used.

Use of the safety factor selected means that the foundation must be designed to resist large tension or shear forces (14,290 lb for the specified rope) and produce an uneconomical design. One option available is to use a lower load rated rope of similar construction and materials. The specified rope is a three strand, twisted nylon rope that is approximately 3/8 in. in diameter. Smaller diameter ropes are available that will fail at lower capacities. Similar 1/4 in. diameter rope has a minimum break strength of 1,800 lb that can be used unless the additional capacity is necessary for other loadings the rope experiences in its operation. Assuming the rope breaks at loads less than 2,000 lb, the resulting foundation design load for both tension and shear individually will reduce by 40% to 8,660 lb and ultimately allow for a more manageable foundation design.

The AB Chance (2014) technical manual was used to select the correct helical anchor components and to design a system that would resist the design loads. Components include minimum end cap dimensions; recommended anchor shaft size; and the number, size, and drilling depth of helixes required to achieve the required bearing capacity (design loads). Important design considerations and assumptions used are detailed as follows:

- Multi-helix anchors are recommended for dynamic and impact loads. High safety factors should be used.
- Guidance for reinforced pile caps was used. The manual assists in selecting the end cap of the helical anchor installed, but not selecting the dimensions of the reinforced concrete pile cap.
- The manual used covered designs for deep foundations for multi-helix anchoring. A deep foundation was considered to be three to eight times the uppermost helix diameter. To ensure the design meets this criteria, the uppermost helix must be eight times its diameter below the pile cap.

- To allow superposition of each helix in the anchor designed in bearing capacity calculations, the anchors must be spaced at least three times their diameter apart. This condition dictates a tension pull out based failure mode is designed against.
- If a round shaft is used, no skin friction along the shaft length will be considered. Square shafts wallow out the soil around the shaft and will not have skin friction available.
- Component selection will minimize the need for different, specialized components to aid in constructability. Lengths of extensions and helix diameters will revolve around common sizes available. The system will strive to be very modular and simple. The system will focus on using one size of helixes and shaft lengths to minimize the different components needed. Shorter length lead sections and short extensions with single helixes will be used to drive multiple helixes instead of selecting a single shaft with multiple helixes for greater tailoring to the design loading. Longer plain extensions will be used to drive the completed set of helixes needed to the required depth for optimal load bearing capacity. Larger helixes should be used for greater load bearing capacity per unit area for more economic designs. Items specified will focus on 3 ft long extensions with a single 12 in. helix for load bearing with 5 ft plain extensions.
- A 3 ft long, 6 in. diameter single helix on the lead section will be used to aid in constructability and driving accuracy. It is assumed that using a smaller diameter helix before larger ones will allow for easier installation initially. The bearing capacity of this helix will not be used in bearing capacity calculation since the area is fairly small compared to other standard sizes.
- Bearing capacity equations will focus on using a 12 in. pile cap for the initial design. Additional thickness may be required when the component is designed using ACI guidelines.
- The Concrete Reinforcing Steel Institute (2015) pile cap design guide was used to determine the dimensions and reinforcement requirements for the pile cap. ACI 318 (ACI 2005) requirements in building code requirements for structural concrete are used and referenced within. Rapid-setting concrete and ASTM A615 Grade 60 reinforcing steel will be used for the cap materials (ASTM 2016).

Figure 60 provides a helical anchor design based on estimated worst-case conditions described for sand and silty subgrade soils. A pile cap design is shown in Figure 61. Initial design iterations focused on using smaller diameter helixes and relying on only overburden pressure to supply load capacity; however, their smaller areas were relatively ineffective in providing load bearing capacity unless driven significantly deep. Twelve in. diameter helixes were selected to best accommodate the minimum helix spacing with available extension lengths available. Helical anchoring must be driven 27 ft deep for the load bearing 12 in. diameter helixes for adequate capacity. A ±5° tolerance is available with the assembly shown due to using the stock lengths of plain extensions.

For clay subgrade soils, only the overburden component of the bearing capacity was used for conservative design since it dominated over the cohesion terms used in the models considered. The minimum length required for clay soils is in excess of 40 ft and requires 16 in. diameter helixes to be feasible. This diameter of helix is not available in the shaft series selected. Use of a helical anchoring system may not be feasible in these situations.

One item of note is the lack of a vertical anchor, as shown in Figure 60, compared to that initially shown in Figure 58. Design efforts initially focused on a vertical anchor that resisted only tension forces and adapting the anchor for shear by rotating it and extending its length to provide the necessary shear capacity. Design guidance recommended that separate helical anchors be used for tension and shear resistance and were initially designed as such. When the pile cap was designed, guidance required that the piles be spaced 3 ft apart. For the three-anchor assembly shown in Figure 58, the plan length of the cap (longitudinal direction) would be greater than 10 ft long and require a significant volume of concrete to be placed. Since the batter piles had significant capacity to resist tension together without the vertical pile, the vertical pile was removed from the grouping to significantly reduce the pile cap length. In terms of constructing the pile cap, reducing its dimension reduces excavation and concrete backfilling work significantly and makes its construction a much more viable option in terms of projected timing.

Figure 60. Prototype helical anchoring design.

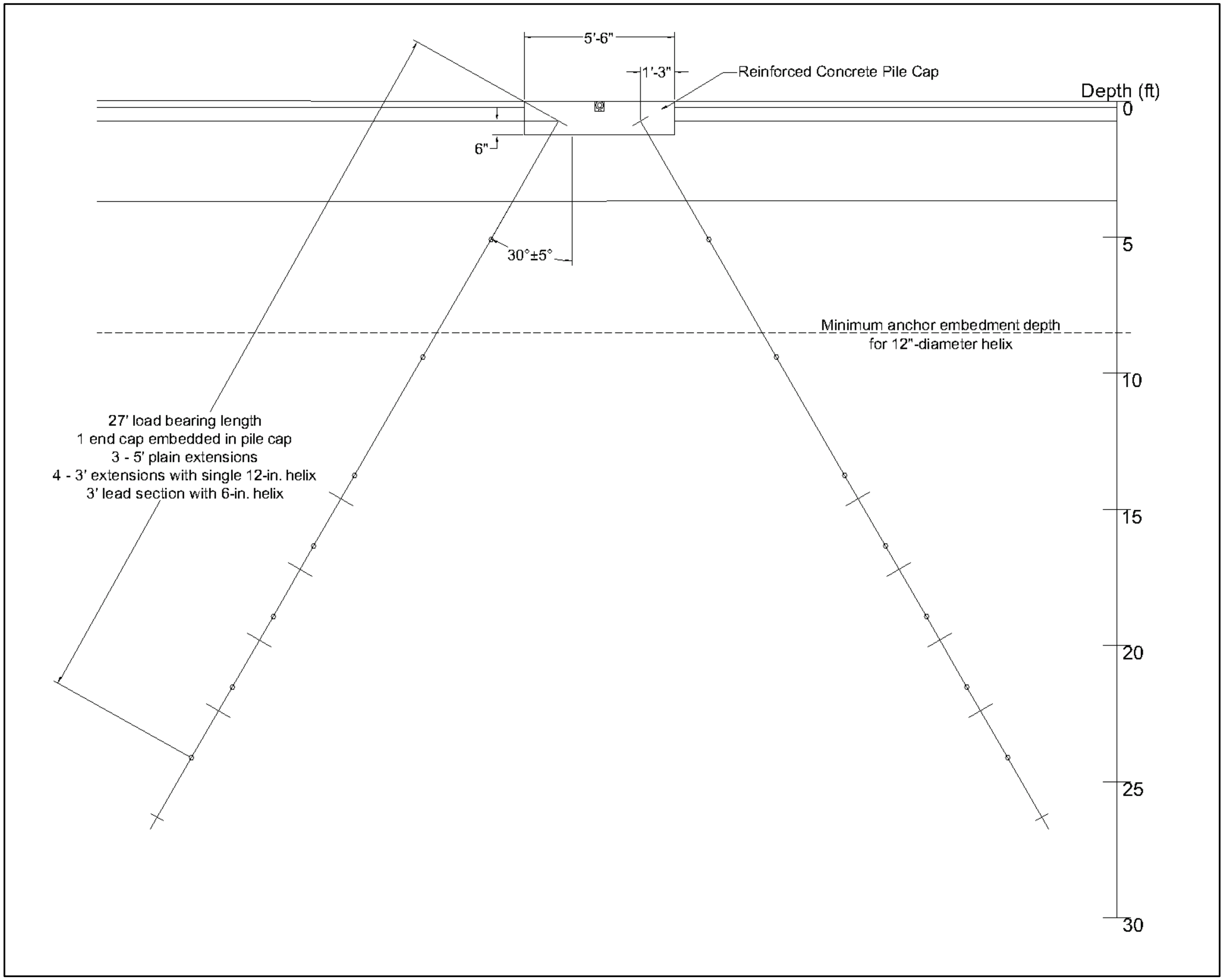
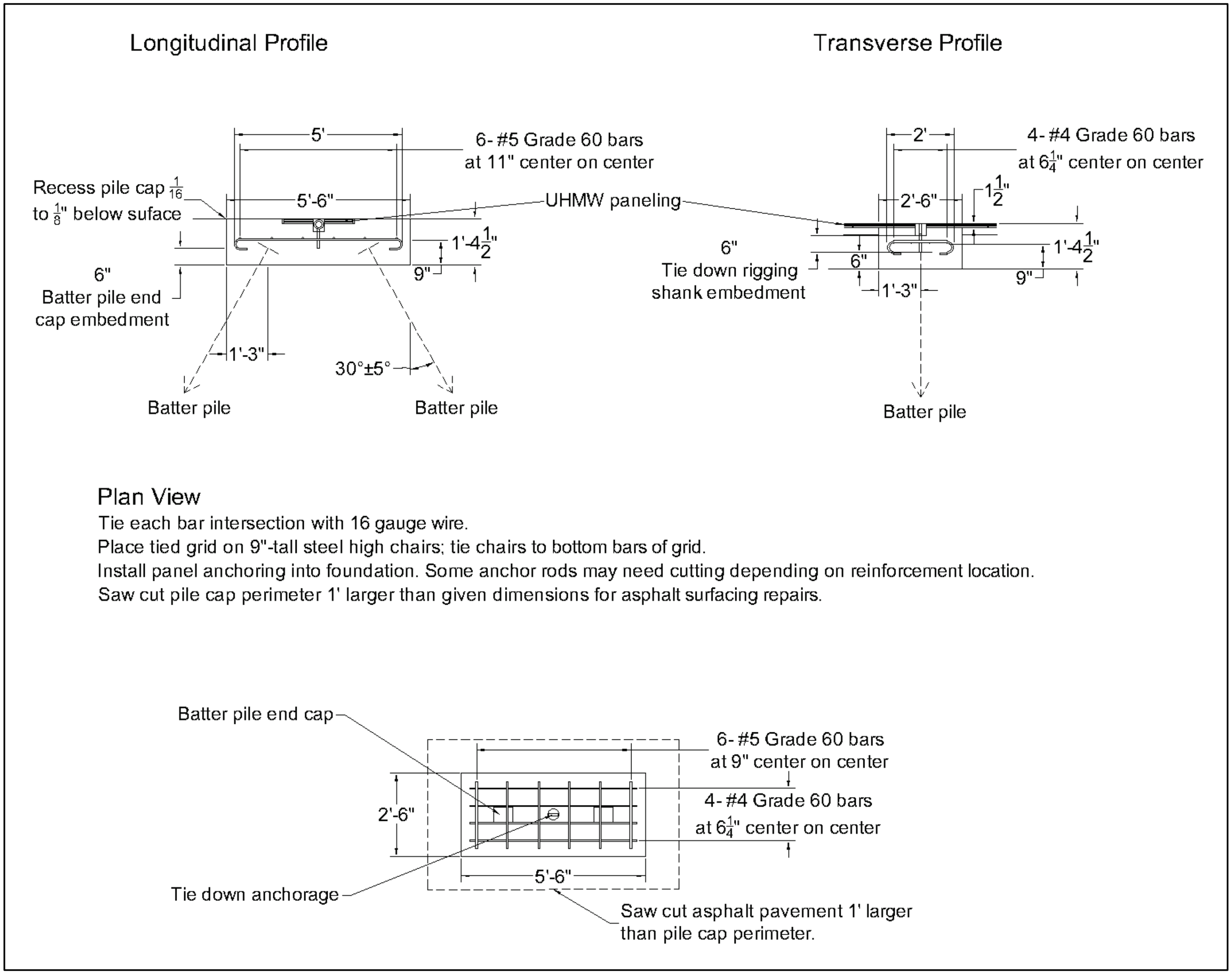


Figure 61. Pile cap dimensions and reinforcement layout for tie-down anchoring.



The design guidance used for this pile cap may not be the best choice for this particular situation, since the design loads are low compared to a more traditional foundation where it is typically applied. The design guidance was applied as best as possible but may not be truly applicable since the column (rigging point for tie-down anchoring is essentially a point) and piles (steel tube of helical anchor) were considerably smaller than the reinforced concrete, steel, or timber piles the guidance was written for. There is little shear and flexural resistance demanded by the loading on the pile cap cross section designed using the minimum values, and reinforcing steel is needed only for volume changes (by temperature and shrinking). The 15 in. thick cap is most likely overdesigned for the loading scenario described, and future efforts should focus on reducing the overall depth of the cap needed to reduce work tasks and time needed for construction. Approximately 21 ft^3 of concrete is needed for each pile cap with waste. Concrete is expected to be produced and batched using the CTL with drum mixer attachment as done with the bedding layer placement with the concrete installation methods discussed and finished with standard concrete hand tools.

A steel form was also designed to cast the paneling void across the transverse length of the pile cap that resists uplift buoyant pressure from fluid concrete. Drawings of the pile cap dimensions, reinforcement layout, and formwork can be found in Appendix G.

Tri-talon anchors within the project pile cap area should be placed when initially installing the panel to ensure the panel over the pile cap location is sufficiently affixed to the pavement until the pile cap is installed. Excavating the pavement for the pile cap will remove these anchoring points. Permanent anchor points will be required once the cap is constructed and installed using typical construction methods described in this report where a concrete element exists. The pile cap should be centered about UHMW panels with tie-down anchoring.

Estimated timing and work tasks for this work are given in Table 23. Most of the tasks are sequential, and little parallel work can be completed. It is estimated that each helical anchoring point can be placed in 7.5 to 8 hr. The helical anchor installation tools and supplies are the only major items not in USAF inventories and will need to be procured unless there is future work for an accessory kit to the SuPR kit that includes these items. All items needed are transportable by military cargo aircraft.

Table 23. Estimated work tasks and timing for prototype helical anchor.

Task	Work Description	Time (hr)	Major Equipment
Preparation work (1 day)			
1	Locate and mark pile cap locations.	1:00	Tape measure, chalk line
2	Saw cut AC surface for pile cap.	2:00	Walk-behind saw
3	Clean pavement surface.	1:00	Pressure washer, airfield vacuum truck
Anchor installation (4 or 8 days)			
4	Remove paneling in work area (3 panels).	0:05	Impact hammer
5	Demolish asphalt surface.	0:05	Backhoe, dump truck
6	Excavate pile cap void.	0:30	Backhoe, dump truck
7	Compact soil at pile cap depth.	0:10	Rammer compactor
8	Install helical anchoring.	1:00	CTL, helical anchor installation attachment with torque indicator, helical anchor components, impact hammer, open end wrench
9	Install reinforcement grid, helical anchor end caps, and panel mold.	0:15	Forklift, pre-tied rebar grid, concrete chairs, formwork, sand bags
10	Backfill pile cap with concrete.	1:30	CTL, drum mixer attachment
11	Allow concrete to cure; test and monitor concrete strength gain.	2:00	Schmitt hammer
12	Compact exposed base material.	0:15	Rammer compactor
13	Complete asphalt repair around pile cap perimeter.	0:45	Steel roller, hot mixed asphalt, asphalt placement tools
14	Shim panel and install panel anchoring.	0:10	Wooden shims, crow bar, stringline, rotary hammer drill, electric drill, air compressor, adhesive anchoring epoxy, and installation gun
15	Allow adhesive to cure.	0:40	—
16	Clean pavement.	0:30	Pressure washer, airfield vacuum truck
17	Install panel anchoring permanent hardware.	0:15	Impact hammer, torque wrench
Install tie-down anchoring (1 day)			
18	Install tie-down anchoring as described in combined PCC and AC install method	4 - 1:50 8 - 2:20	Rotory hammer drill, dry coring bit, scaling chisel and bushing bits, masonry drill bits, air compressor, electric drill, adhesive anchoring material, and installation gun

One item that should be stressed is that a geotechnical investigation should be competed to determine accurate soil properties required for the helical anchor design. Use of more accurate unit weight, water table, and cohesion information specific to the project area will greatly reduce the length of the anchoring and ensure adequate resistance. Knowledge of the bedrock depth at the project location will be significant to the design and ability to drive anchoring to the depths necessary. Anchors should be installed to the specified depths to the minimum installation torque determined in design. Field installation teams will need to ensure the selected helical anchor shaft maximum torque rating is not exceeded when installing the helical anchors.

4.4 Proper recompaction needs after installing AC foundation

One item not addressed with the work conducted for AC pavements is properly restoring the pavement layers after an excavation is made. This will be an issue for the traditional asphalt-surfaced method, any tie-down anchoring foundations, and any retrofit situation in which the concrete slab is deeper than the existing asphalt layer. As previously stated, making utility cuts into pavement soil layers can damage the soil and loosen it from its compacted state up to 3 ft into the soil from the excavation face. Over time, the soil will reduce in volume from natural compaction by its own weight (overburden of pavement layers above) or wheel loads, and a void or depression at the surface that is harmful to aircraft in need of arrestment will most likely result.

Short-term measures to mitigate the depression at the surface include sealing the construction joint between the concrete and the asphalt to minimize water infiltration that will aid post-installation volume reduction. Once deeper depressions are observed along the construction joint, localized full-depth milling and replacement of the asphalt pavement can be used to help fill the void and maintain a smooth transition between the asphalt pavement and the concrete foundation. The CTL with cold planer attachment will be used to remove the pavement for patching the full depth of the asphalt layer. The asphalt formwork shown in Figure 34 will also be required along the length of the patched area to cast the vertical face of the panel void perimeter in the correct location. Care should be taken around the perimeter of the concrete to avoid excessive spalling of the concrete edges. This work can easily be added to the current inspection procedures described in AFI 32-1043 (2012).

Longer-term measures involve correcting the loosened soil layers within the pavement structure by recompaction to the minimum required densities for the depths specified for UFC structural pavement design. With the concrete foundation(s) in place, effective recompaction of the soil can be accomplished by having proper confinement between the rigid concrete foundation and the large mass soil within the pavement structure. A terracing-like excavation is recommended in which lifts of soil are scarified, wetted, and compacted in thin lifts one terrace at a time to minimize additional damage to the pavement structure. The rigid flowable fill also provides confinement to compact successive lifts of soil against as well.

Terrace rows will be slightly wider than the width of the soil compactor roller in the SuPR kit (greater than 31 in.) to minimize the project area and allow heavy equipment to be used over hand tools for more efficient compaction. Thin lifts no greater than 6 in. will minimize cave in of the excavation walls. UFC guidance for pavement repairs recommends a maximum of 3 in. thick lifts when compacting soil layers; however, this thickness requires significantly more terraces and leads to a much larger repair. Compactive effort will be verified by nuclear density measurements and compared to Proctor laboratory test results while compacting to ensure adequate compaction is achieved. Once each terrace is completed, the prepared terrace step will be filled with rapid-setting flowable fill for quick backfilling. Once the flowable fill gains sufficient strength, recompaction of the next upper-terrace step begins. The process continues until the elevation of the asphalt concrete is reached and resurfaced. Figure 62 details the project limits of the prospective plan. After making the saw cuts needed to establish the repair boundaries, two separate construction days would be required to complete each side of the paneling. Flowable fill placement is recommended to be made by the dry placement method instead of wet to save time and reduce equipment demands.

The plan described follows good pavement repair principles; however, ultimately the repair will take much too long to complete due to the scale of the repair and will be feasible only with a significantly increased runway closure window. The main timing issue with the prospective plan is that recompaction is recommended to be conducted across the entire runway width at one time and not broken down into segments. Partial-width recompaction of the soil layers will result in re-damaging the soil layers when working successively from one side of the runway to the other, defeating the purpose of the work. Areas of the shoulder may need to be excavated to form a ramp to allow equipment access into the trench, increasing the project area and increasing restoration efforts.

The repair plan described is challenging since a large volume of good, undisturbed pavement is damaged by excavation to reach the depth of the originally damaged pavement soil. The width of the terrace was set to allow the use of the vibratory drum roller for the most efficient rolling possible with SuPR kit available equipment. Reducing the width of the terraces used helps reduce the volume of the repair made, but requires changing the equipment to work in a more confined trench. Review of commercially available trench compactors showed that a 22 in. wide drum is available by many manufacturers. For a 24 in. wide terrace, the repair volume can be reduced by a third to result in less original pavement damage from restoration efforts and less backfilling once compaction is complete. Compactive forces are also greater with many trench compactors than with the SuPR kit rollers and therefore may provide the necessary amount of compaction needed in less time (in terms of fewer passes of the compactor made to achieve the minimum compactive effort required).

Further reductions of the trench width can realistically be made to 18 in. without bracing in most soils expected, but the narrower terraces require the use of a rammer and/or plate compactors to operate (Figure 63). These items are in the SuPR kit inventory and will reduce the repair volume to a half of that shown in Figure 62, but it is expected an army of equipment will be needed to cover the trench length efficiently since the compactive effort provided by the equipment is less than that of the SuPR kit roller and typical trench compactors. Thinner 3 in. thick lifts will be necessary to meet compaction requirements with the lighter equipment, but no net time savings are expected since double the amount of compaction work will be required.

Figure 62. Prospective terracing plan for AC foundation installations with 3 ft terracing.

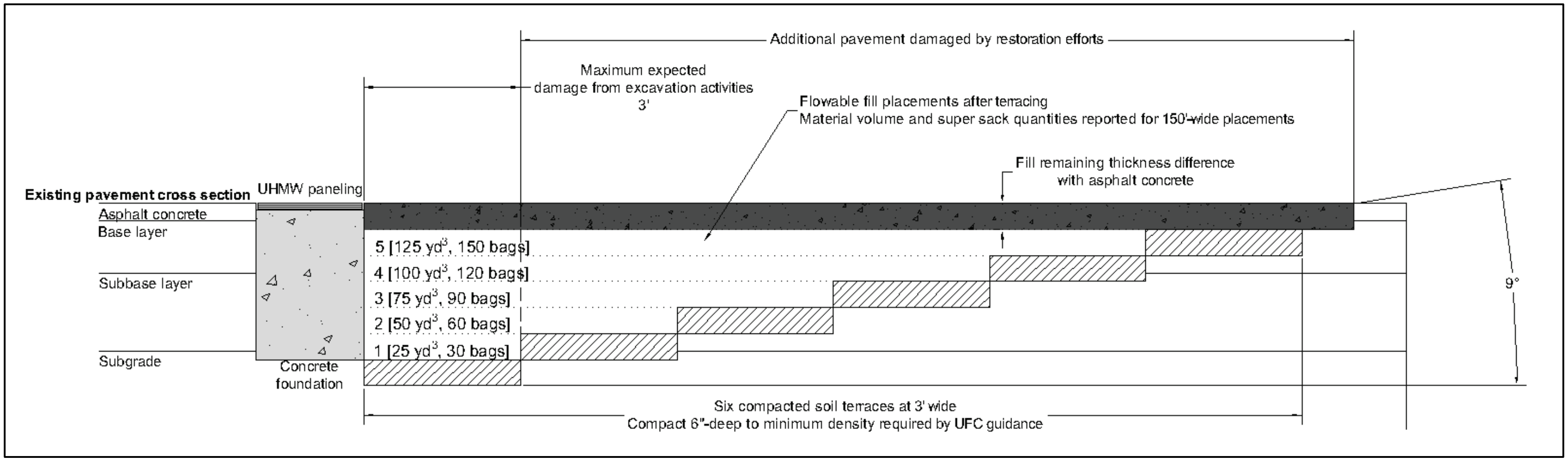
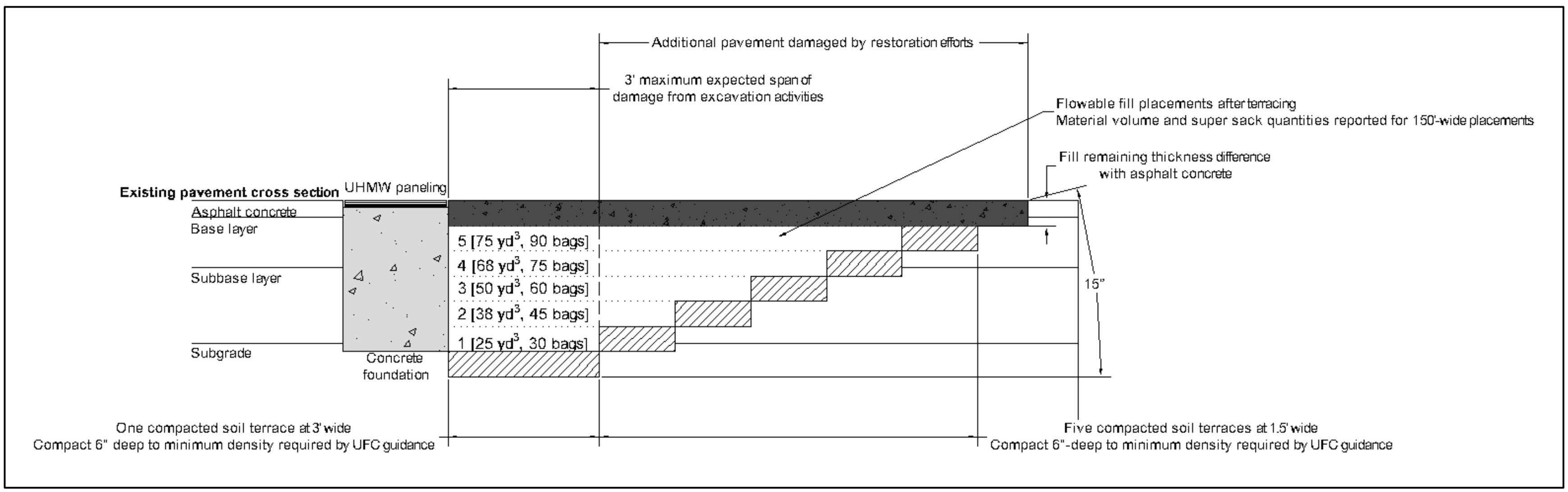


Figure 63. Prospective terracing plan for AC foundation installations with 18 in. terracing.



4.5 Mechanical anchors for UHMW panel anchoring

Another issue affecting all pavement installation options is the time lost to curing of epoxy adhesive construction materials when installing the anchoring attachment points to the foundations placed. Currently, adhesive-based anchors are used to bond the anchor hardware to the foundation. Other anchoring products that do not rely on time-dependent chemical reacting material to generate load-bearing capacity are commercially available. Mechanical based anchoring systems are available that rely on either friction or mechanical interlock to base material to resist loadings, depending on their construction. Friction is generated by expanding a component within the anchor so the anchor makes contact with the walls of the embedding hole. This is typically completed by torqueing a bolt or a nut to expand a component within the anchor. Mechanical interlock is accomplished by an anchor component embedding itself into the base material to allow for bearing. For installation into hardened concrete, mechanical interlock is accomplished by under-reaming a void for an expanding anchor component or an expanding component locally crushing concrete to create its own void (Eligehausen et al. 2006).

The main reason adhesive anchoring is used for this installation is to minimize the plan dimensions of the foundation. As mechanical anchoring is activated and expands within the embedding hole, localized internal forces that change the state of stress from the global structure are generated within the concrete. If installed closer to edges of base material, the material along the edge may not be able to resist the expansive forces and spall. Installing anchors too close to one another creates a net loading on locations between the anchors that may be greater than that applied by a single anchor. Since adhesive anchors do not create expansive loads within the concrete, they can be located closer to edges of concrete or to one another compared to mechanical anchors. The allowable load capacity can be reduced to accommodate closely spaced mechanical anchors or ones located near edges of base material by using reduction factors.

USAF matting kits contain a commercially available concrete sleeve expansion anchor, as shown in Figure 64 (Powers Fasteners, part number 6957[4]). These are the same anchors that were used for lifting out of PCC surfacing with the full-depth PCC installation method. Installation

[4] https://www.mutualscrew.com/media/refguides/power%20bolt%20sleeve%20anchors1.pdf

methods for these anchors are similar to that used for the adhesive anchoring except that no wire brushing of the drilled hole perimeter is required to remove loose material. Drill bit sizes are also smaller and require a $^{3}/_{4}$ in. diameter bit instead of the $^{7}/_{8}$ in. diameter bit used for the adhesive anchoring. The inner diameter of the anchor drilling jig would need to be reduced to accommodate the smaller drill bit. Once the anchor is driven into the foundation, the anchor can be immediately tightened to complete installation. Since some work tasks used with adhesive anchoring are not needed and no curing period is required, use of the expansion anchors as paneling anchors can reduce the overall time to install paneling by approximately 90 min for 30 ft of paneling. The anchors are also reusable and will allow for UHMW paneling replacement as needed over time.

Figure 64. Concrete expansion anchoring in USAF inventories.

Review of the technical product information provided by the manufacturer shows that the anchors have maximum load capacity when spaced at least 14 in. from one another (center on center) and have 50% of their capacity when spaced 7 in. from one another when the anchor is embedded 7 in. into the base material. The anchors have their maximum load capacity when set at least 9 in. from the concrete edges and 70% of their shear capacity when spaced at least $6^{1}/_{2}$ in. from the edge (tension capacity for $6^{1}/_{2}$ in. is approximately 85%). Considering these dimensions to provide an anchoring scenario with maximum clamping capabilities from the anchors, the edge spacing requirement poses the most difficulty. The dimensions of current paneling configurations provide 4 in. of edge clearance for anchors installed along the slab perimeter and approximately $8^1/_2$ in. spacing for anchors between individual panels. Assuming shear loadings on the anchors are minimal and only tension capacity is needed to clamp the panels to the pavement, the net load capacity of an anchor is 42% of that which meets critical dimensions. Moving the panel anchoring to 6 in. from the edges of the panel will allow for approximately 75% net load capacity compared to an anchor that meets critical dimensions. Movement of the panel hole locations towards the interior of the panel may not be beneficial to the paneling system in case the panels warp and curl. Warping and curling may raise the panel corners above the pavement surface and not allow for a smooth surface to arrest aircraft. Additional information for the required loading that installed panels experience is needed to determine whether current paneling hole locations would be sufficient to use with mechanical anchoring products.

Due to the eyebolt construction of the tie-down anchoring proposed, expansion anchoring is not applicable and still requires adhesive anchoring to be used. However, additional time reductions are possible by moving all tie-down anchoring work activities to a separate work day. This will allow the adhesive curing to occur at one time and minimize time lost to installing individual anchors.

5 Conclusions and Recommendations

The ERDC evaluated different expedient installation methods to construct UHMW paneling systems at AASs. Timed trial testing was used to acquire timing information to develop optimized work task sequencing to predict more accurate necessary runway closure times to complete all required tasks. This report details the required work tasks, their projected times to complete, and major supplies and equipment used for both new asphalt- and concrete-surfaced pavement installations. Corrective actions required to retrofit a defective or noncompliant paneling system are also discussed. Select work tasks completed or components to the paneling system for which improvements can be made to allow for more efficient, greater constructability and/or quicker installations are discussed. Conclusions from the evaluation efforts and recommendations for future work and improvements to the work tasks are summarized in the next section.

5.1 Conclusions

- ADR technologies can be used to quickly install a new UHMW paneling system or when retrofitting an existing noncompliant or damaged system in runway pavements.
- A standard SuPR kit contains many of the items, both supplies and equipment, necessary to complete the work tasks required to install a UHMW paneling system in both PCC and AC surfaced runways. Some items required are not in a standard SuPR kit but are in USAF inventories and should be added for future procurements. All items needed can be delivered to a project location using C-130 aircraft.
- Breaking down the required work tasks into different groups or smaller lengths can allow for efficient planning to meet mission objectives and minimize runway closures. Many work phases described within this report can be completed in fewer than 12 hr, but most cannot be completed in fewer than 6 hr. Work tasks that involve removal of the pavement take significant time to restore the surface to allow for aircraft operations after daily work activities and require the daily project area to be reduced to a fraction of the total runway width.
- Many of the necessary work tasks are sequential and do not allow for parallelization by overlapping tasks for greater reductions in time.
- Curing of cementitious and epoxy adhesive materials to a minimum strength penalizes the installation work the most out of all tasks considered since most work tasks cannot continue until a minimum

material strength is achieved to prevent damaging the installed items. Use of rapid-setting materials is critical for UHMW paneling installations to meet the desired closure requirements in expedient scenarios. Manufacturer data sheets must be reviewed and strength-gain information must be verified to ensure materials will meet mission objectives.

- Strength gains of cementitious and epoxy adhesives will be affected by the environmental conditions at the time of placement. Construction activities should be completed in moderate temperatures to prevent timing differences for cold weather or the need to apply hot weather construction guidance. Adhesive anchoring should be installed when anchors are dry to ensure full-load capacity.
- Monitoring strength gains of in situ construction materials can help reduce the overall time required for curing from that projected in the proposed timing by allowing work to continue once the in situ structure components are ready to proceed.
- Sawing preparation work phases can be broken down into phases for which fewer than 6 hr are required to complete work across the 150 ft runway. This work can be completed before pavement demolition efforts begin. The walk-behind saw should be used for multiple short cuts while the floor saw should be used for fewer, long cuts.
- Limiting the daily project area where pavement materials are removed to approximately 30 ft assists in keeping the maximum closure time below 12 hr and keeps the overall installation duration short. Shorter lengths of pavement may be completed but may not significantly reduce the daily closure time needed due to the time lost to curing materials. The overall project duration will also increase since less work can be completed per work event. Larger placements or greater numbers of anchor installations per work day are more efficient at reducing time lost to curing.
- Demolition of the panel slot partial depth by chiseling or by milling with the cold planer attachment with CTL in the SuPR kit is estimated to take the same amount of time.
- Reusing noncompliant PCC slabs within an asphalt-surfaced runway can assist in reducing the amount of demolition work required to restore the runway pavement.
- Joint sealing efforts considered with this work involve standard UHMW paneling for which, other than cleaning and using standard silicone based materials, the edges of the joints are not prepared before sealing. If additional preparation activities are required or perimeter

grooving is added to the UHMW panel perimeter to increase sealant bond, the proposed work tasks and timing information should be modified to accommodate any differences in the construction tasks.
- Restoring the density of underlying soil layers disturbed by excavation tasks within an asphalt pavement system is not efficiently completed with any work plan developed with this study. Soil greater than 6 in. deep and up 3 ft away from concrete placed will not be restored to the minimum required densities given in UFC pavement design guidance.

5.2 Recommendations

- For new UHMW paneling system installations, the traditional partial-depth method for PCC surfaces and the traditional AC foundation method with rapid-setting materials modifications are recommended for field use.
- Options to retrofit portions of or an entire noncompliant or defective existing paneling system are available. All work relies on recycling the existing foundation element to minimize demolition efforts. Additional statements may be required in AFI 32-1043 to allow for recycled concrete slabs to be used to be compliant with current UFC pavement definitions. USAF guidance on testing anchoring points should be used for partial retrofit scenarios to ensure all anchors can be recycled if the same panel configuration is used.
- Appendicies A through E contains instruction manuals for the selected installation methods, along with equipment and supply needs and prospective personnel tasks. Work task scheduling is also repeated in the manuals to be a stand-alone document.
- The prototype tie-down anchoring presented should be considered for future installations. A larger hole is required in the UHMW paneling to accommodate the head of the eye bolt.
- It is recommended that the work tasks and procedures discussed in the instruction manuals be practiced and thoroughly discussed before implemented in the field to ensure all parties involved understand their work assignments and to minimize delays in the tight work scheduling.
- Use of the torque-limiting extensions should be considered for future use to allow for quicker installations. Use of torque-limiting extensions can be applied to all installation methods developed in this work.
- The tri-talon micropiling option for the asphalt-surfaced pavements has potential to be a viable construction method; however, performance of the tri-talon anchors to affix UHMW panels to airfield

pavements for aircraft loadings is unknown. The trafficking performance of this anchoring method should be further investigated.

- If the tri-talon micropiling option is considered for future testing, considerations for thinner pile caps for the prospective tie-down anchoring using helical soil anchors should also be made. The helical anchoring system can be an easier to construct and is less invasive to the existing pavement structure. The dimensions of the pile cap can be potentially reduced in all directions for a more compact anchorage structure.
- Use of mechanical concrete anchors for airfield matting installations should be investigated further to reduce installation components that require curing. Mechanical anchors require similar preparation work as adhesive anchoring, except that no curing is necessary. Time saving from the use of mechanical anchoring is projected to be at least 30 min. Long-term trafficking performance of permanent mechanical anchoring should be tested to verify applicability.
- Work phases in which pavement is demolished should be limited to approximately 30 ft to ensure the maximum closure time can be met. Work should be terminated at the prospective joints for concrete slabs and UHMW panels.
- Additional analysis is required to determine the extent soil layers are disturbed after excavation activities to assess the need for recompaction adjacent to the paneling system. Short-term corrective measures of crack sealing the interface and full-depth patching may help mitigate small deficiencies, but deeper and or significantly loosened soil will not be corrected and will continue to require monitoring and possible maintenance.

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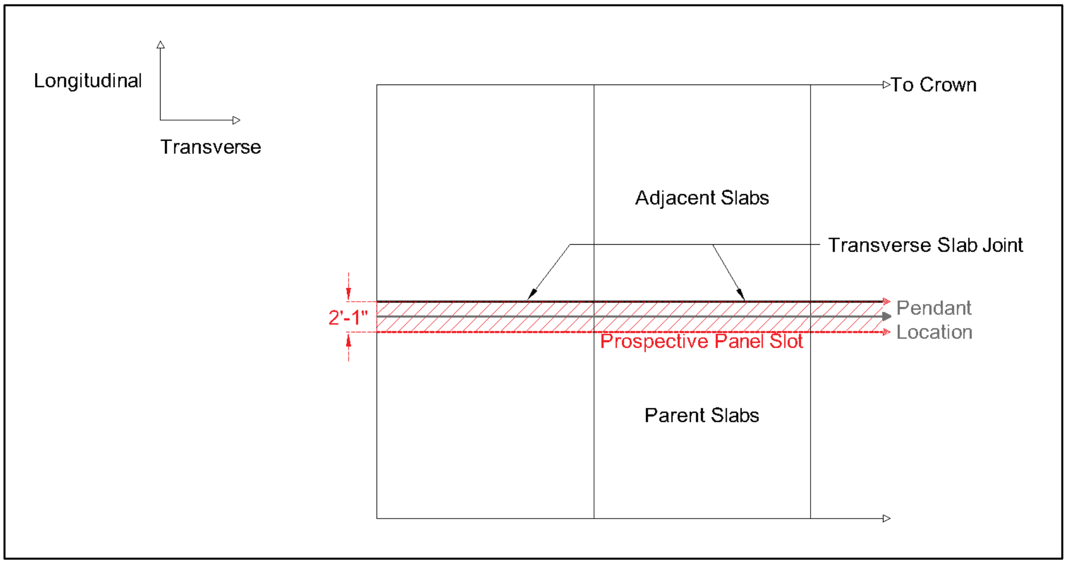
Appendix A: Expedient AAS-UHMW Panel Installation Methods - Partial-Depth Installation for New Portland Cement Concrete (PCC) Pavement Construction

This installation manual follows the traditional method for installing UHMW panels in existing PCC pavements given in AFI 32-1043 (AF 2012). Materials, equipment, installation techniques, and work phasing were modified to allow for efficient and optimal installation following the runway closure criteria given. The existing pavement is the foundation for the anchoring points required. A grid of relief cuts is made to assist in the removal and to control the depth of the pavement surface material removed for the panel slot. Concrete within the panel slot is demolished, and a long, partial-depth patch is made to provide a smooth surface on which to place panels. Threaded anchorage points are installed, and the panels are installed. Anchorage points for the tie-down ropes are also cut and hardware installed while the UHMW panels are installed. Joint sealing is completed as a separate activity once all panels across the runway are installed. Personnel requirements for each task and supplies and equipment needs for the work are provided. Estimated durations of the required work tasks and their scheduling are provided in Figure A-32 at the end of this appendix.

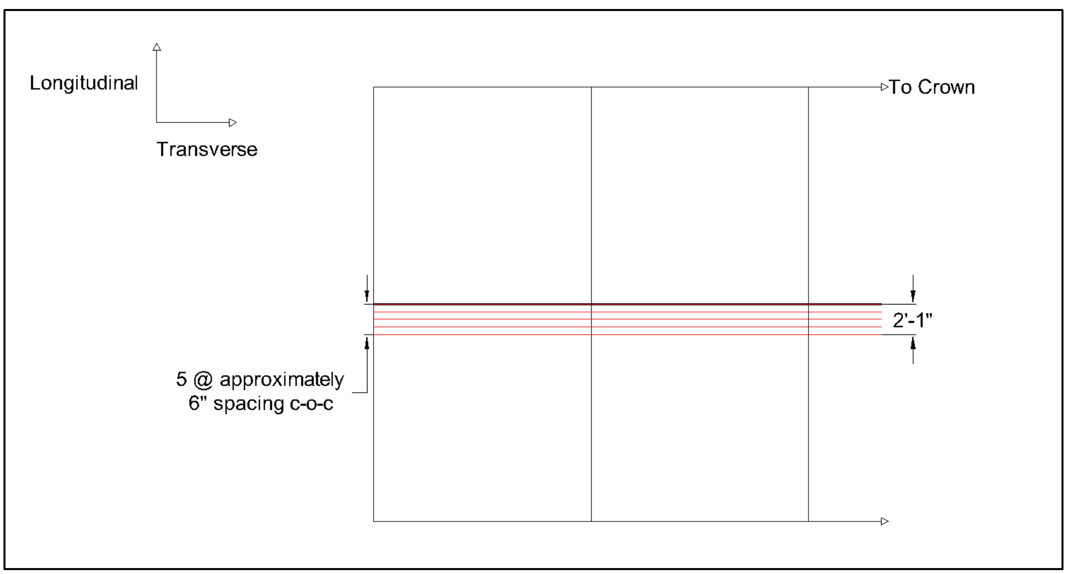
1. Initial demolition
   a. Transverse sawcutting (1 work day, 4.8 hr)
      (1) See Tables A-1 and A-2 for projected equipment, supply, and personnel needs before conducting work.
      (2) Locate the panel installation location (Figure A-1). Panel installation is expected to be at a transverse slab edge to minimize damage to the pavement.

Figure A-1. Typical project location.



(3) Mark saw-cut locations on the pavement (Figure A-2).
   (a) Lay out saw-cut locations using a tape measure and lumber crayon. Marks should be spaced approximately 6 in. apart. Make sets of marks every 30 ft transversely across the runway (four total sets).
   (b) Make additional marks to indicate cutting at the slab joint. Caulk lines may not be needed.

Figure A-2. Transverse saw cut locations.



(c) Use water-resistant chalk to snap a chalk line between the corresponding parallel marks.
   i. Use two, three-person teams: one operates the tool, one holds the free end of the string line, and one snaps the line. Multiple snaps of the line may be needed to produce a solid, observable line.
   ii. Complete all lines longitudinally within a set of crayon marks before moving transversely across the runway. This will allow the saws to start before all lines are made.

(4) Begin sawcutting with the large floor saws using 18 in. saw blades.
   (a) Allow ample time for the chalking crew to snap lines before starting sawing efforts. Chalk will not stick and stain the concrete surface if wet.
   (b) Cut to a depth of 3½ in. minimum (Figure A-3). Minimize cutting deeper than 4 in.
   (c) The spotter should use a floor broom to clear saw slurry. Cleaners should lightly spray water over the work area as sawing is completed to rinse the surface and allow the saw team to see chalk lines as needed. Use a less aggressive spray nozzle if available to prevent chalk line removal (Figure A-4).
   (d) If multiple saws are used at one time, stagger saw start times and cuts made to allow for continuous cutting. Scheduling shown uses one large walk-behind saw as provided in a standard SuPR kit.

(5) Water blast the cut area and surrounding pavement with a pressure washer to remove saw slurry and debris. Start at the pavement crown and work towards the shoulder (Figure A-5).

(6) Finalize site cleanup and exit the runway. The pavement surface should look similar to that shown in Figure A-6 after completion.

Figure A-3. Making transverse cuts.

Figure A-4. Lightly rinsing the surface while sawing.

Figure A-5. Waterblasting saw slurry.

Figure A-6. Completed transverse cuts.

Table A-1. Personnel needs and tasks for transverse sawing activity.

Description	Task	Quantity
Marker	Mark locations for chalk lines	2
Chalk line team	Make chalklines	6 (2 teams of 3)
Equipment operator	Operate floor saw	1
Spotter	Assist with aligning saw	1
Hose tender	Move and maintain water truck and hose	1
Cleaner	Pressure wash and clean pavement	2
Equipment operator	Operate airfield sweeper truck	1

Table A-2. Equipment and supplies needs for transverse sawing activity.

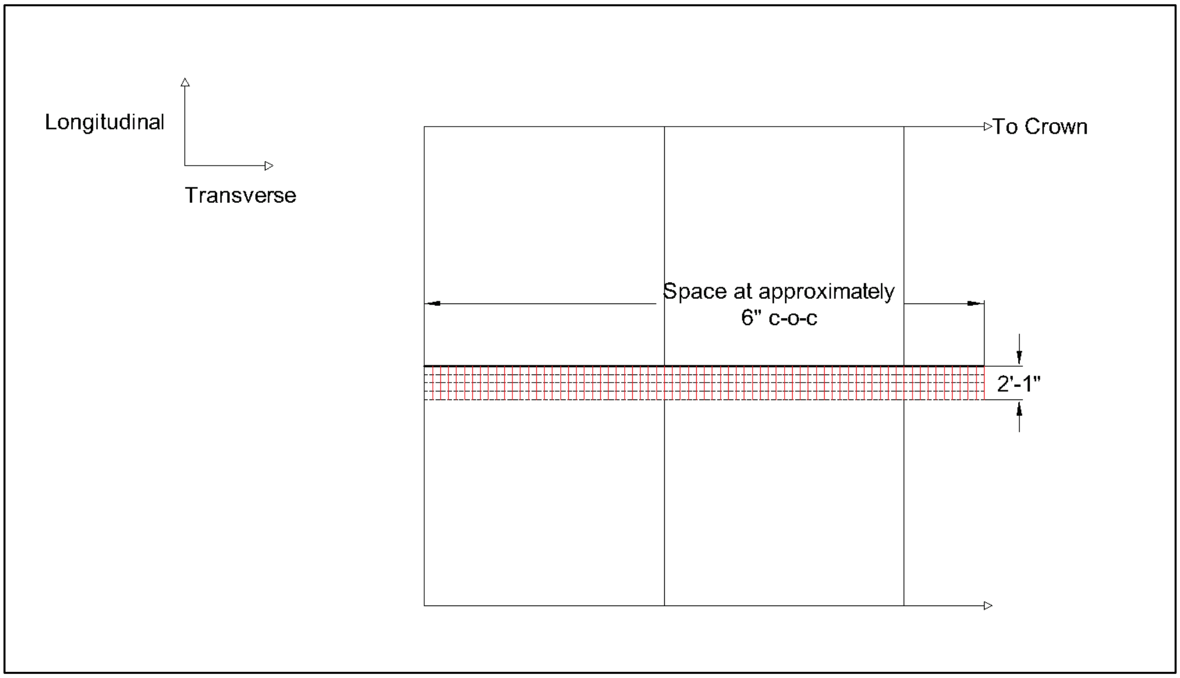
Equipment	
Item	**Quantity**
Measuring tape	2
Chalk line tool	2
Floor saw	1
Push broom	2
Squeegee	2
Water truck, 1000-gal minimum	1
Water hoses, ¾ in. diameter by 50 ft long	6
Pressure washer	2
Airfield sweeper truck	1
Supplies	
Item	**Quantity**
Water-resistant chalk, bottle	1
Lumber crayons, each	4
18 in. diameter concrete saw blade	2

Italicized items are not included in a Standard USAF SuPR Kit.

b. Longitudinal Sawcutting (2 work days, 5.3 hr total each work day)
   (1) See Tables A-3 and A-4 for projected equipment, supply, and personnel needs before conducting work.
   (2) Mark sawcut locations on the pavement.
      (a) Layout sawcuts to make using a tape measure and lumber crayon (Figure A-7). Marks should be spaced approximately 6 in. apart.

(b) Make additional marks to indicate cutting at the slab joint. Caulk lines *may not be needed*.

Figure A-7. Longitudinal cut locations.



(c) Use water-resistant chalk to snap a chalk line between the corresponding parallel marks.
   i. Use two, two-person teams: one operates the tool, and one holds the free end and snaps the line.
   ii. Work transversely starting at the shoulders. This will allow the saws to start before all lines are made.

(3) Begin sawcutting with the small walk-behind saws using 18 in. saw blades.
   (a) Allow ample time for the chalking crew to snap lines before starting sawing efforts. Chalk will not stick and stain the concrete surface if wet.
   (b) Cut to a depth of 3½ in. minimum (Figure A-8). Minimize cutting deeper than 4 in.
   (c) Minimize overcutting (saw kerfs) of concrete outside the panel void. Stop the cuts short of the panel slot edge to prevent overcutting.
   (d) Lightly spray water over the work area to rinse the surface and allow the saw team to see chalk lines as needed. Use a

less aggressive spray nozzle if available to prevent chalkline removal.

(e) If multiple saws are used at one time, spread saws across the work area to minimize the need to move the saws long distances and allow for continuous cutting.

i. Scheduling shown uses two saws.

ii. If one saw is used, two work days are required. Make the appropriate number of marks required for the area per work day. This slightly reduces the time spent out of the runway but increases the number of work days required.

(4) Water blast the cut area and surrounding pavement with a pressure washer to remove saw slurry and debris. Start at the pavement crown and work towards the shoulder.

(5) Finalize site cleanup and exit the runway. The pavement surface should look similar to that shown in Figure A-9 after completion.

Figure A-8. Making longitudinal cuts.

Figure A-9. Completed transverse and longitudinal cuts.

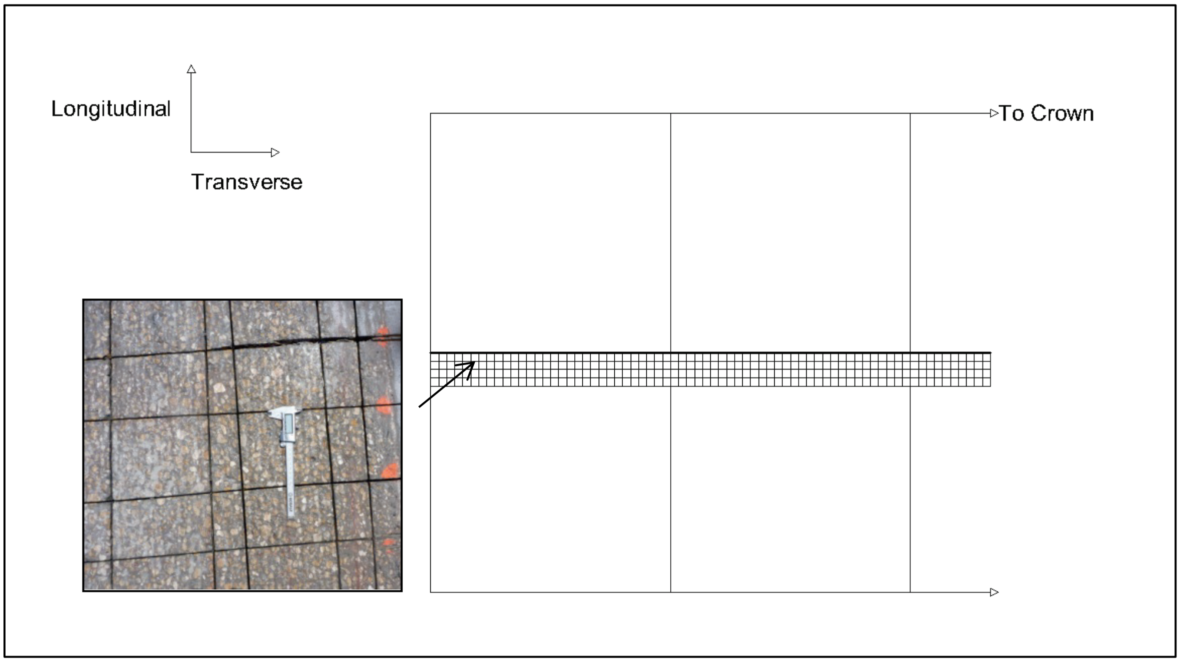


Table A-3. Personnel needs and tasks for longitudinal sawing activity.

Description	Task	Quantity
Markers	Mark locations for chalk lines	2
Chalk line team	Make chalk lines	4 (2 teams of 2)
Equipment operators	Operate floor saw	2
Hose tender	Move and maintain water truck and hoses	1
Cleaners	Pressure wash and clean pavement	2
Equipment operator	Operate airfield sweeper truck	1

Table A-4. Equipment and supply needs for longitudinal sawing activity.

Equipment	
Item	**Quantity**
Measuring tape	2
Chalk line tool	2
Walk-behind saw	2
Push broom	2
Squeegee	2
Water truck	1
Water hoses, ¾ in. diameter x 50 ft long	8
Pressure washer	2
Airfield sweeper truck	*1*
Supplies	
Item	**Quantity**
Water-resistant chalk, bottle	1
Lumber crayons, each	4
18 in. diameter concrete saw blade	2

Italicized items are not included in a Standard USAF SuPR Kit.

2. Demolition and panel installation (5 work days, 11.0 hr total each day)

Install panels across approximately two to three full slabs per work day. Start on one edge of the runway and work across the runway transversely. Install the correct sequence of panels following the drawings in AFI 32-1043 for the existing slab dimensions (combination of full and half panels as well as full panels with tie-down anchoring points).

a. See Tables A-5 and A-6 for projected equipment, supply, and personnel needs before conducting work.
b. Demolish concrete within panel slot area.
   (1) Remove the first panel adjacent to the panel slot to prevent damaging any installed panels.
   (2) Chisel the panel slot area to a minimum depth of 3½ in (Figure A-10).
      (a) Use light jackhammers (less than 30 lb) to prevent damage to underlying pavement.

(b) Use two jackhammer teams of two personnel each.
   i. One person operates the jackhammer, and the other removes the debris generated. Team members switch jobs as needed.
   ii. Start each team on opposing ends of the slot area to be prepared for the work day and work to the interior of the void.
   iii. Operate the jackhammer such that it impacts at the depth of the relief cuts made at a 30° to 45° angle from horizontal. This will allow the pre-cut concrete to pop off as individual square piece units. Operating the jackhammer more vertically than recommended chips the units into multiple small pieces that take more time to remove, make debris clearing efforts more extensive, and potentially remove more material than required.

(c) Remove medium and large pieces of debris by hand and deposit them into a front end loader or backhoe bucket. Empty bucket in a dump truck as needed. The equipment operator should help remove debris with the jackhammer team and sweep up the smaller debris with a push broom during any idle time.

c. Mill the bottom surface of the panel slot area using the compact track loader and cold planer attachment (Figure A-11).
   (1) The goal is to take out the high spots while some low spots may be present. Mill the surface approximately ¼ in. so that the average elevation difference between before and after demolition is greater than 3⅝ in. and the majority of the large high peaks are removed.
   (2) Set one of the skis on the cold planer to 3¾ in. and zero the other ski. This will allow the cold planer to use existing pavement as a stable guide to control the cutting depth.
   (3) Position the cold planer such that the ski set to 3¾ in. rides along the pavement surface. Begin milling and ensure the ski remains parallel to the pavement surface.
      (a) Make two passes with the CTL, one on each side of the repair void.
      (b) Focus on the center 23 in. width to prevent damaging the slot edges. Significantly damaged edges (medium- and high-severity joint and corner spalls) will require partial depth repairs at the conclusion of the work day.

(4) The spotter should sweep debris out of the CTL track areas to provide maximum traction to the vehicle. A backpack blower may also be used to clean larger amounts of debris; however, more extensive project area cleaning with the airfield sweeper truck will be needed at the end of the work day.
(5) Do not overwork the milling head. Travel at a speed that efficiently removes material.

Figure A-10. Chiseling concrete within the repair void.

Figure A-11. Milling the panel slot.

d. Remove all the smaller debris within the slot void. Straddle the airfield vacuum truck over the void and vacuum the surface. At least two passes of the vacuum truck should be conducted.
e. Fine tune the slot depth to remove the high spots along the perimeter.
   (1) Use the depth guide tool to verify the minimum slot depth of $3^5/_8$ in. was achieved (Figure A-12). Mark any high locations with a lumber crayon.
   (2) Use the jackhammers or other hand tools to demolish the areas where the milling machine cannot reach along the slot perimeter and any high points as marked.

Figure A-12. Checking the slot depth.

f. Clean the slot area.
   (1) Water blast the concrete surface to remove any loose material at the surface.
   (2) Remove all the smaller debris remaining within the repair void. Straddle the airfield vacuum truck over the void and vacuum the surface at least twice.
   (3) Heavily air blast the surface until a saturated surface dry (SSD) condition has been achieved and all standing water has been removed. Do not try to dry the surface completely.
g. Place a thin bead of caulk along the slab joints to seal the cracks.
   (1) Start at the shoulder side of the void and work to the interior.

(2) Use a putty knife to smear the compound over and into the joint if it is difficult to place a continuous bead over the rough surface to ensure the joint becomes sealed. Remove excess material at the surface and outside the vicinity of the crack.

h. Place the bedding layer.

(1) Prepare a batching station approximately 30 ft away from the repair area to allow ample space to work and to operate equipment. Station a water truck and towable/transportable dumpster near the batching station to assist with concrete mixer cleaning. Place pallets of concrete components in the batching area for easy access.

(2) Place the appropriate bonding agent for the pavement repair material used on the concrete surface. If water is used, this work task is not required if the panel slot surface is still in SSD condition after air blasting. Lightly apply additional water if the surface becomes dry and air blast before continuing with placing the bedding layer. Monitor surface moisture while bedding layer is placed and lightly apply more water as necessary.

(3) A compact track loader with concrete mixing drum is the preferred method of mixing and transport due to the quantity of material made. Batch material such that no more than 50% of the total drum volume is used.

(4) Have a four-person batching team prepare concrete for the bedding layer (Figure A-13).

(a) One person will operate the CTL, two people will handle adding dry materials to the drum, and one will handle measuring batch water and washing out the drum. A fifth person may be needed to batch aggregates or admixture materials if used on site.

(b) Have a trash disposal container available to dispose of spent concrete packaging.

(c) Have batch team prepare materials for each load while mixer is delivering material to the panel area for quick reloading.

Figure A-13. Batching concrete with CTL.

(5) Batch material following manufacturer directions.
  (a) Use an approved cementitious pavement repair material for permanent runway or temporary crater repairs.
  (b) Use manufacturer or typical guidance for hot or cold weather placements to mitigate changes in set time. Some recommended mitigation techniques include
    i. Hot weather: Replace mixing water with chilled or ice water; use a retarding admixture.
    ii. Cold weather: Keep materials warm until used; use warmed water.
  (c) The panel slot will require approximately 16.3 ft^3 of material with a conservative amount of waste (two-slab installation, 15 ft wide slabs and 25% waste). Assuming typical prepackaged products yield 0.4 ft^3, approximately 40 units will be required for each work day. Ensure enough material for an additional two full CTL deliveries is available in case deeper than expected repairs are encountered.
  (d) Mix the concrete at the batch site for at least 2 min once all components are added. Mix materials at a speed and angle that allow for complete incorporation of the materials but minimize splatter and material loss from the drum. Rotating the drum back and forth, if allowed by the equipment, can help mix all components together efficiently.
  (e) Continue agitating the material slowly while delivering the material.

(6) Have a three-person finishing team construct the bedding layer (Figure A-14).

(a) Two people will screed and trowel the concrete; one person will direct material placement, move concrete as needed, and maintain site cleanliness.

(b) Place material from the shoulder to runway interior. Use a square shovel to block and prevent concrete splatter.

(c) Screed the surface of the concrete to a depth of $1^{5}/_{8}$ in. below the pavement surface. Pass the screed multiple times to remove excess material. Start the screed over previously placed areas to provide smooth transitions between placements.

(d) Float and trowel the surface to make it flush and smooth. Work fast and efficiently to ensure the material does not set up before work is complete.

(e) Remove excess material at the end of the placement and deposit it into an empty bucket for removal.

Figure A-14. Placing and finishing the bedding material.

(7) Wash out the drum and equipment at an approved location close to the site. A portable wash-out station consisting of a small, water-tight dumpster is recommended so that washing out can be accomplished in the vicinity of the site without any environmental issues. The container can be emptied at an approved site after the work day.

i. Allow the concrete to gain at least 2,500 psi of compressive strength before continuing with work activities within the panel slot. The estimated time to reach this strength is approximately 90 min at 70°F but refer to the manufacturer's provided information. Use a nondestructive Schmitt hammer testing device to monitor strength gain.

j. Arrange the panels near their prospective installation locations in the correct order within the slab (Figure A-15). See AFI 32-1043 for the correct panel sequence for the width for the slabs and tie-down anchoring needed. Ensure locations that require tie-down anchoring receive the correct panel type. Place panels approximately 5 ft away from the slot area to allow work to continue.

Figure A-15. Arranging panels.

k. Reestablish joints at existing locations within the bedding layer (Figure A-16).

(1) Use the handheld cut-off saw for longitudinal cuts.

(2) Use the walk-behind saw for the edge joint cut.

(3) Cut joints to 4½ in. in depth minimum. Do not cut deeper than 40% of the slab height to prevent cutting any ties or dowels.
(4) Air blast each cut after completion.

Figure A-16. Joint cutting.

l. Clean the vertical faces of the slot perimeter with an angle grinder and a wire cup brush (Figure A-17).

Figure A-17. Cleaning slot perimeter.

m. Inspect the depth of the panel slot. Ensure the surface is smooth and level so the panels lie correctly in the slot once completed.
(1) Begin verifying the surface while the concrete is gaining strength. Mark locations that require leveling with a lumber crayon.
(2) Level locations with a small handheld pneumatic scabbler, handheld angle grinder with masonry disk, or demolition

hammer/light jackhammer with a bushing bit after the surface reaches 2,500 psi compressive strength (Figure A-18). Other appropriate equipment may be used if available.

(3) Verify the final surface elevation in any areas modified. Repeat as necessary.

Figure A-18. Final leveling of the panel slot.

n. Air blast the panel slot to remove all small debris.
o. Cut water drain slots in panel depth (Figure A-19).
   (1) Use the walk-behind saw with two 18 in. diameter saw blades butted together.
   (2) Cut two slots transversely in the bedding layer ½ in. deep. Use the panel void vertical faces as guides. Ensure the cuts are not within 6 in. of the panel slot vertical face to avoid panel anchoring locations.
   (3) Connect previously cut drain slots from previously installed panels as best as possible. Do not damage any existing anchors.

Figure A-19. Cutting drain slots.

p. Water blast the panel slot.
q. Vacuum the repair area. Straddle the airfield vacuum truck over the void and vacuum the surface at least twice.
r. Heavily air blast the panel slot.
s. Place and install panels
    (1) Place and arrange panels in the slot.
    (2) Shim panels into position using wooden wedges (Figure A-20).
        (a) Arrange panels such that approximately ½ in. joints are between the slot vertical faces and between each panel.
        (b) Draw a stringline across the top of the panels. Pick a convenient location/point to assist in aligning the panels. Tangent to the panel anchoring holes is a good location to use as reference. Use masonry nails to fix the string line to the selected location.
        (c) Use wrecking bars to help move panels and add shims as needed to prevent movement.
        (d) Do not break shims after installation. Shims will be removed after anchoring is installed.

(e) Ensure the panels are solidly locked into position before moving forward with work tasks. Use wrecking bars to help move panels and add shims as needed.

Figure A-20. Aligning panels within the slot.

(3) Install panel anchoring (Figure A-21)

(a) Drill holes into the concrete foundation using appropriately sized masonry drill bit and hammer drill. Use the panel anchoring drill guide to ensure a vertical cut made to the correct depth. Use two drillers for increased speed, one on each side of the panel transversely.

(b) Clean the anchoring holes following the adhesive manufacturer's directions. Typical cleaning procedures include air blasting, wire brushing, and another round of air blasting to remove all loose material. Personnel requirements could include one airman and one brush cleaner or one airman, one brush cleaner, and one airman. A three-person team requires an additional air compressor, hose, and blow gun than listed in the equipment requirements.

(c) Any holes that cannot be drilled full depth from embedded steel located within the concrete should be marked. Steel within the concrete may be encountered if the concrete is reinforced and/or ties or dowels are present. The masonry drill bits will not cut through the steel. These locations will require a shortened anchor.

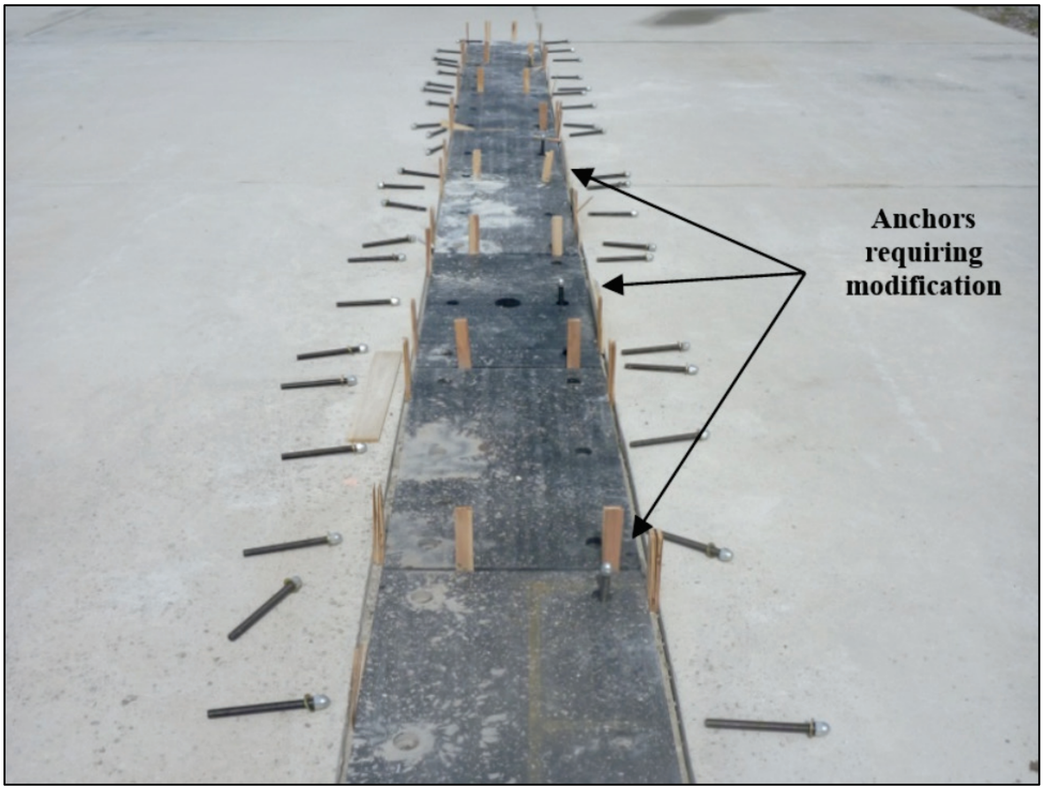
Figure A-21. Anchor hole production line.

(d) Set out and prepare each anchor for installation (Figure A-22).

i. Anchors should be prepared with setting hardware and washers assembled before placement.

ii. Set out any tie-down anchoring needed. Locate the center of the anchoring hole and mark its location with a lumber crayon.

Figure A-22. Layout anchors.



iii. Anchors requiring shortening should be trimmed with a portable band saw to an appropriate length where the threaded rod is recessed below the panel surface (Figure A-23). Length determination includes the following:
   (i) Place anchor in the indicated hole requiring modification. Install the washer and hex nut on the rod.
   (ii) Twist the nut down within the countersunk hole to mark the maximum anchor length. Rotate the anchor an additional two turns to provide a void for adhesive at the hole depth.
   (iii) Remove the anchor without moving the hex nut. Cut the portion of the rod that extended above the panel surface flush with the top of the nut with the band saw.
   (iv) Remove the nut and replace on the uncut end of the anchor.

Figure A-23. Trimming a panel anchor.

(e) Install anchoring hardware in each hole (Figure A-24).

i. AFI 32-1043 describes the use of prepackaged adhesive packets for this task. Ensure the correct amount (or combination of packets if applicable) of adhesive is placed in the hole. Follow all manufacturer directions to correctly measure and use adhesive.

ii. Bulk adhesive cartridges that use a mixing tube to premix adhesive before entering the drilled holes are highly recommended to ensure all adhesive is properly mixed at the correct ratio. Large cartridges with pneumatic handheld dispensing equipment are recommended to minimize time lost to changing cartridges.

iii. Ensure enough adhesive is used to embed the anchor. Adjust the air regulator such that adhesive is deposited without leaving air voids but is allowed to flow fast enough to install all anchors in a timely fashion without clogging.

iv. The proper amount of adhesive has been dispensed when the adhesive is level with the bottom surface of the panel slot when the anchor is installed. Use the first couple of holes to determine the amount of adhesive needed by counting the time the trigger is held.

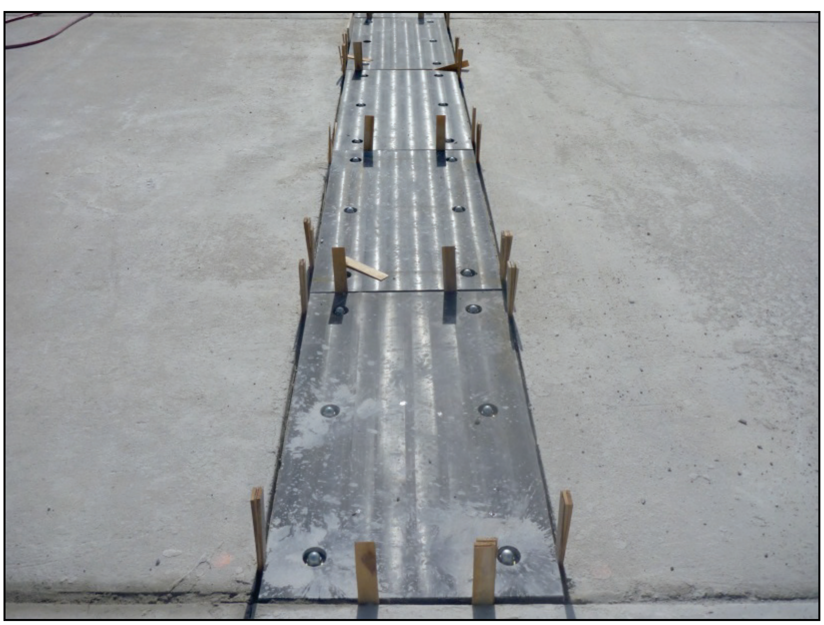
v. Clean any excess adhesive that enters the countersunk area with a paper towel before it hardens.

vi. Rotate the anchor back and forth while in the hole to ensure adhesive completely surrounds the anchor thread.

vii. An off-site trial of this work is highly recommended to determine the proper equipment settings and the filling times.
viii. Cool or heat adhesive to modify setting times as needed in extreme weather conditions.
ix. After all anchors are installed, the surface of the paneling should look similar to that shown in Figure A-25.

Figure A-24. Anchor installation.

Figure A-25. After all anchors are installed.



(4) Install tie-down anchoring (if present in panel arrangement installed on work day, Figure A-26).

(a) Once the drillers are complete, they can begin constructing the tie-down anchoring. One driller makes the small partial depth core for the anchoring eye, and the other makes the embedding hole deeper into the concrete foundation for the anchor shank.

(b) The first driller must change drill bits to the dry coring bit. Center the core bit in the tie-down anchor hole and cut to a depth of 3 in. Make one continuous cut if possible. Removing the core bit at any time in the process requires the hole to be cleaned before continuing to prevent clogging and to allow for additional cutting.

(c) The dry core bit used in hammer mode should demolish the majority of the cored material while used. If material is still present, use a chisel or bushing bit to level the bottom of the core.

(d) Air blast the core hole.

(e) Drill the tie-down anchor embedment hole. Use the tie-down anchoring drill guide to ensure a vertical cut made to the correct depth.

(5) Clean the anchoring hole following the adhesive manufacturer's directions.

(6) Install the tie-down anchor into the hole. Ensure the eye is aligned in the longitudinal direction.

Figure A-26. Tie-down anchorage installation.

t. Allow the adhesive to cure to full strength. This is temperature dependent; colder temperatures and base material (concrete foundation) require additional time than warmer environments. Do not activate the anchor until the cure time has been met.

u. Begin any cleanup efforts that do not disturb the anchoring adhesive. Remove the wooden wedges from the panels towards the end of the cure period.

v. Once adhesive has cured, install the hardware on the panel anchoring (Figure A-27).

(1) Remove the setting hardware and install the hex nut on each anchor stud. Use a $1^1/_8$ in. socket and an impact hammer/ratchet to aid in removal.
(2) Gross torque the hex nut on the panel anchoring with an impact wrench. A couple of short bursts are needed to spin the nut hand tight and begin torqueing the nut. Do not over torque the hex nuts.
(3) Fine torque the hex nuts on the panel anchoring with a torque wrench set to 60 ft-lbs.

Figure A-27. Permanent hardware installation.

w. Verify the final anchor head elevations. Grind off any anchors that stick above the panel with an angle grinder. Use care so that the panel is not damaged (Figure A-28).

Figure A-28. Grinding an anchor head flush with the panel surface.

x. Finalize site cleanup and sweep project area. Exit the runway. The surface of the paneling should look similar to that shown in Figure A-29 at the conclusion of the work day.

Figure A-29. Panel installation complete.

Table A-5. Personnel needs and tasks for demolition and panel installation activities.

Description	Task	Quantity
Complete Demolition		
Demolisher	Jackhammer concrete, remove large debris pieces, level panel surface	4 (2 teams of 2)
Equipment operator	Transport construction debris, clean small debris, operate CTL	1
	Operate vacuum sweeper truck	
Equipment operator / Spotter	Transport construction debris, clean small debris, assist with cold milling	1
Bedding Layer Placement		
Equipment operator	Concrete delivery	1
Concrete batchers	Prepare and measure materials for concrete, washe out concrete mixer	3
Concrete finishers	Install caulk, place and finish concrete, sawcut joints and drain channel	3
Cleaner	Maintain site cleanliness, brush slot faces	1
Final Bedding Layer Leveling		
Demolisher	Jackhammer concrete, remove large debris pieces, level panel surface	4 (2 teams of 2)
Cleaner	Maintain site cleanliness, brush slot faces	1
Anchorage Installation		
Installer	Place and shim panels	4
Driller	Drill anchor holes	2
Cleaner	Clean anchor holes	2-3
Adhesive installer	Arrange and lay out anchors, trim anchors as needed, install anchors, assist adhesive dispenser	2
Adhesive dispenser	Install anchors	1
Everyone begins cleaning the site once complete		
Hardware Installation		
Installer	Remove temporary and place permanent hardware	2
	Tighten nuts	3
	Verify all anchors are recessed below panel surface, grind anchors that require recessing	1
Cleaner	Collect removed temporary hardware	1

Table A-6. Equipment and supply needs for demolition and panel installation activities.

Equipment	
Item	**Quantity**
Impact hammer	2
1 1/8 in. socket	4
Jackhammer, 30 lb max, with bits	2
Air hose, ¾ in. diameter x 50 ft	2
Air compressor, 100 cfm minimum	1
Backhoe or front end loaded	1
Dump truck	1
Shovel, square	2
Wrecking/pry bar, 36 in. long	2
Push broom	2
CTL	1
18 in. cold planer attachment for CTL	1
Backpack blower	1
Airfield vacuum truck	1
Depth guide tool, 3⁵⁄₈ in. deep	2
Handheld scabbler	2
Angle grinder	2
Demolition hammer/hammer drill, with bits	1
Pressure washer	1
Water truck	1
Water hose	2
Putty knife, ½ in., flexible	2
Hopper/dumpster	2
Concrete mixer attachment for CTL	1
Knife	2
Concrete float, magnesium	3
Concrete trowel, steel	3
Depth tool guide/screed, 1⁵⁄₈ in. deep	4
Cut-off saw	1

Equipment	
Item	**Quantity**
Walk-behind saw	1
18 in. concrete saw blade	3
Hammer/maul	3
Rotary hammer drill	2
Small air compressor lance	2
Small air compressor hose, 3/8 in. diameter	6
Small air compressor, 4 gal minimum, 2 outlets	2
5,000 W generator	2
Electric drill, 6 A	2
Portable band saw	1
Extension cords, 50 ft	8
Setting hardware	75
*Epoxy adhesive dispensing gun, pneumatic**	1
Panel anchor alignment tool	2
Dry core barrel	1
Tie-down anchor alignment tool	1
Torque wrench, ½ in. drive, 100 ft-lb capacity	2
Supplies	
Item	**Quantity/ work day**
Lumber crayon	4
4½ in. diameter masonry stone	10
Caulk compound, 14 oz container	4
Rapid-setting concrete, 0.4 ft^3 yield*	50
Sponge	2
Bucket, 5 gal	10
Measuring cup, 1 gal capacity	2
Steel cup brush	2
Wooden shims, 3/8 in. thick	600
Stringline	1

Equipment	
Item	Quantity
Masonry nail, 3 in., box	1
*Masonry drill bit, 7/8 in. diameter**	4
*Wire brushes for anchoring adhesive**	*
Threaded rod, steel, ¾ in.-10 diameter x 10 in. long	*
¾ in. washer, SAE, steel	*
Hex nut, ¾ in., steel	*
4 ½ in. diameter steel stone	10
Epoxy adhesive	5
*Additional mixing tubes for epoxy adhesive**	12
Shop towels, box/roll	6
Eyebolt	8

* Varies by existing slab and prospective panel arrangement.
Italicized items are not included in a Standard USAF SuPR Kit.

3. Joint sealing (1 work day, 7.0 hr)
   a. See Tables A-7 and A-8 for projected equipment, supply, and personnel needs before conducting work.
   b. Schedule a day when the weather will accommodate sealant placement.
   c. Air blast the panel joints and anchor holes.
   d. Install backer rod in all panel joints (Figure A-30).
      (1) Approximately 400 linear feet of backer rod is required.
      (2) For ½ in. wide joints and use of silicone based joint sealants, the backer rod should be placed ¼ in. below the panel surface.
      (3) Start with placing the long transverse pieces, follow with by the shorter longitudinal pieces.
      (4) Install longitudinal pieces from the runway interior to the shoulders.

Figure A-30. Backer rod installed.

e. Install silicone sealant following manufacturer's directions (Figure A-31).
   (1) If a priming material is required, apply material before backer rod is placed.
   (2) Installation of sealant with pneumatic applicator guns using large cartridges is recommended. Adjust regulator to appropriate pressure for best installation. Provide a recess of approximately 1/8 in. below the panel surface.
   (3) Begin at the runway interior and work towards the shoulders. This will allow the sealant at the center portion of the runway to have the maximum amount of time to cure.

Figure A-31. Joint sealant installation.

f. Allow sealant to cure to tack free. Finalize site cleanup and exit the runway.

Table A-7. Personnel needs and tasks for joint sealing activity.

Description	Task	Quantity
Installer	Place backer rod	4 (2 teams of 2)
Sealant dispenser	Place sealant	2
Dispenser assistant	Assist sealant dispensers and maintain site cleanliness	1

Table A-8. Equipment and supply needs for joint sealing activity.

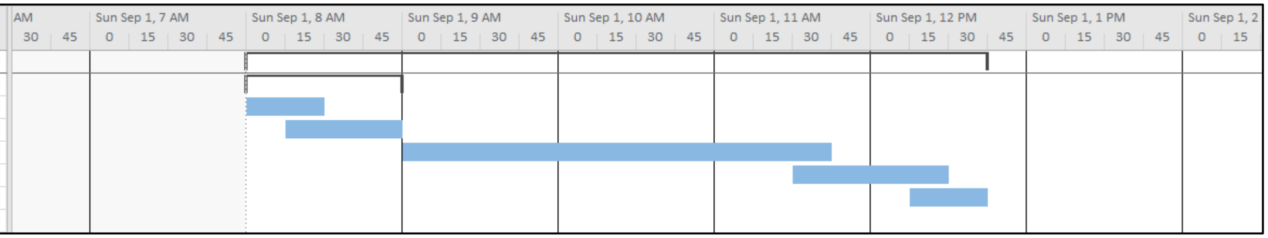
Equipment	
Item	**Quantity**
Small air compressor lance	2
Backer rod installation tool	2
Air compressor, 4 gal	1
Air hose, $^{3}/_{8}$ in. diameter x 50 ft long	4
5,000 W generator	1
Sealant dispenser, for 29 oz cartridges, pneumatic	2
Supplies	
Item	**Task**
Backer rod, HDPE closed cell, ¾ in. diameter	1 box (500 ft minimum)
Silicone sealant, airfield grade, 29 oz cartridge	42

Italicized items are not included in a Standard USAF SuPR Kit.

Figure A-32. Project phasing expedient UHMW-PE panel installation – PCC pavement.

1. Initial demolition - transverse sawcutting

	Task Name	Duration
1	**Initial Demolition (full width, transverse)**	**4.75 hrs**
2	Mark Sawcut Perimeter	**1 hr**
3	Mark chalk line locations	0.5 hrs
4	Snap chalk line	0.75 hrs
5	Saw cut perimeter and relief cuts	2.75 hrs
6	Wash saw slurry	1 hr
7	Clean work zone	0.5 hrs



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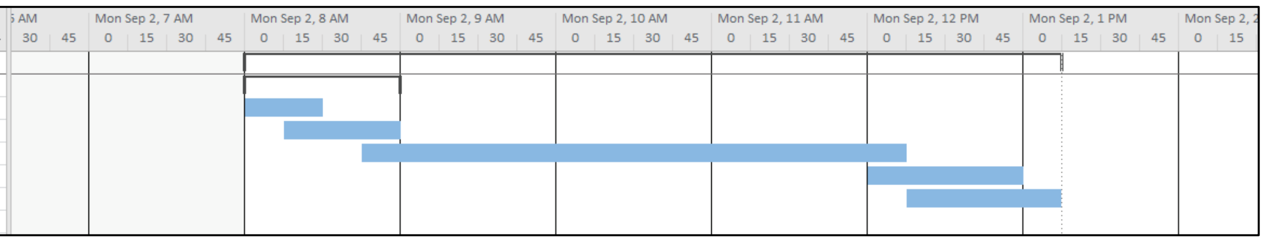
2. Initial demolition - longitudinal sawcutting

	Task Name	Duration
1	**Initial Demolition (half width, longitudinal)**	**5.25 hrs**
2	**Mark Sawcuts**	1 hr
3	Mark chalk line locations	0.5 hrs
4	Snap chalk line	0.75 hrs
5	Saw cut relief cuts	3.5 hrs
6	Wash saw slurry	1 hr
7	Clean work zone	1 hr



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3. Demolition and panel installation

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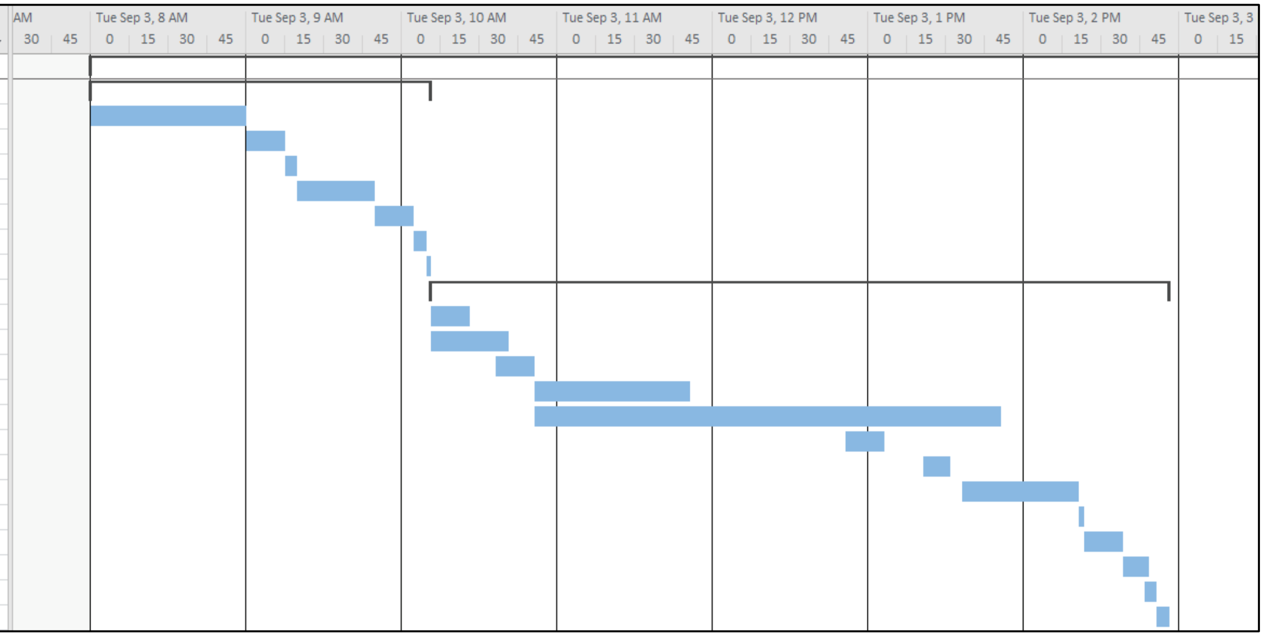
	Task Name	Duration
1	**Demolition and Panel Installation**	**10.99 hrs**
2	**Complete Demolition**	**2.19 hrs**
3	Remove material with light jackhammers	1 hr
4	Mill high points in slot	0.25 hrs
5	Vacuum the slot area	0.08 hrs
6	Perform final slot inspection	0.5 hrs
7	Water blast slot	0.25 hrs
8	Vacuum slot area	0.08 hrs
9	Air blast slot area	0.03 hrs
10	**Bedding Layer Placement**	**4.75 hrs**
11	Caulk slab edge joints	0.25 hrs
12	Allow caulk to set up	0.5 hrs
13	Apply bonding agent	0.25 hrs
14	Place bedding layer	1 hr
15	Allow concrete to gain strength	3 hrs
16	Reestablish joints	0.25 hrs
17	Clean slot perimeter	0.17 hrs
18	Perform final slot inspection	0.75 hrs
19	Air blast slot	0.03 hrs
20	Cut water drain holes	0.25 hrs
21	Water blast completed slot	0.17 hrs
22	Vacuum slot area	0.08 hrs
23	Air blast completed slot	0.08 hrs



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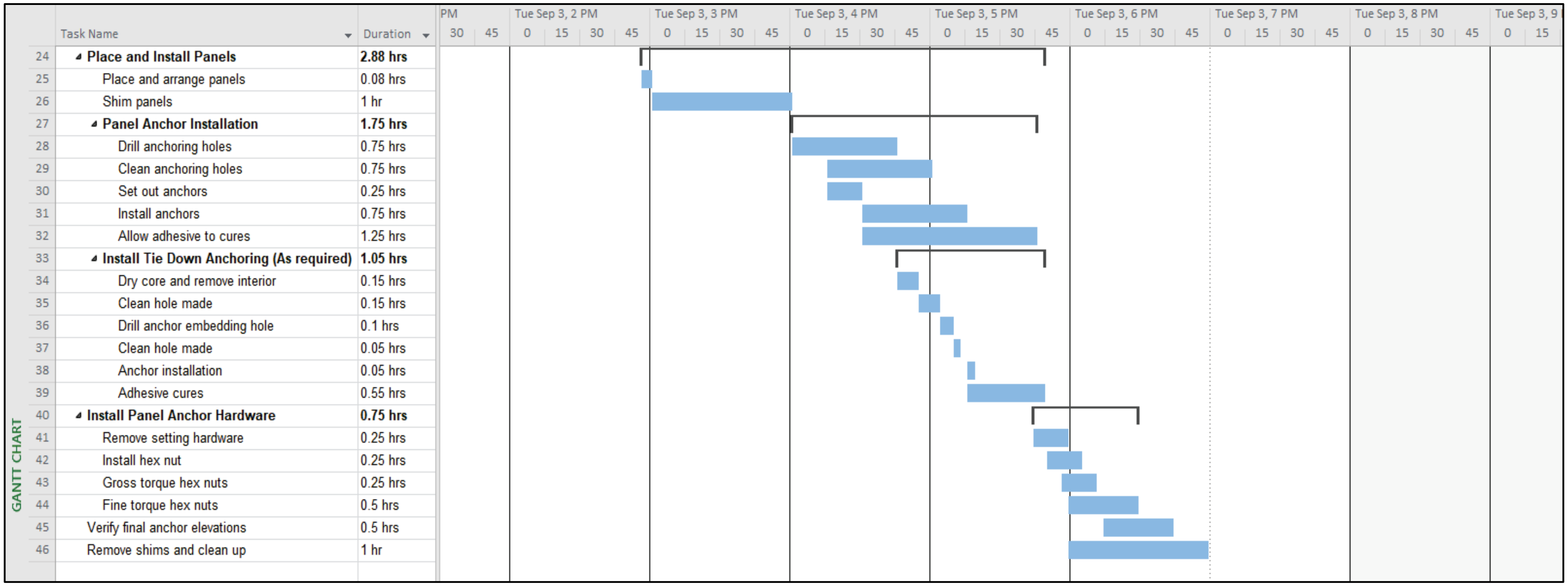

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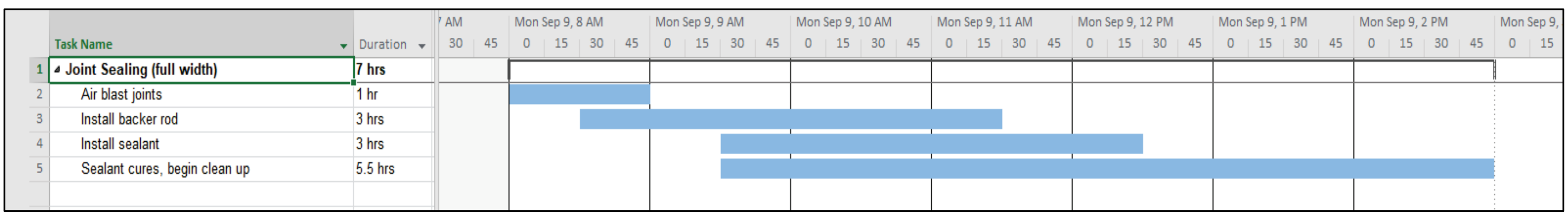
4. Joint sealing



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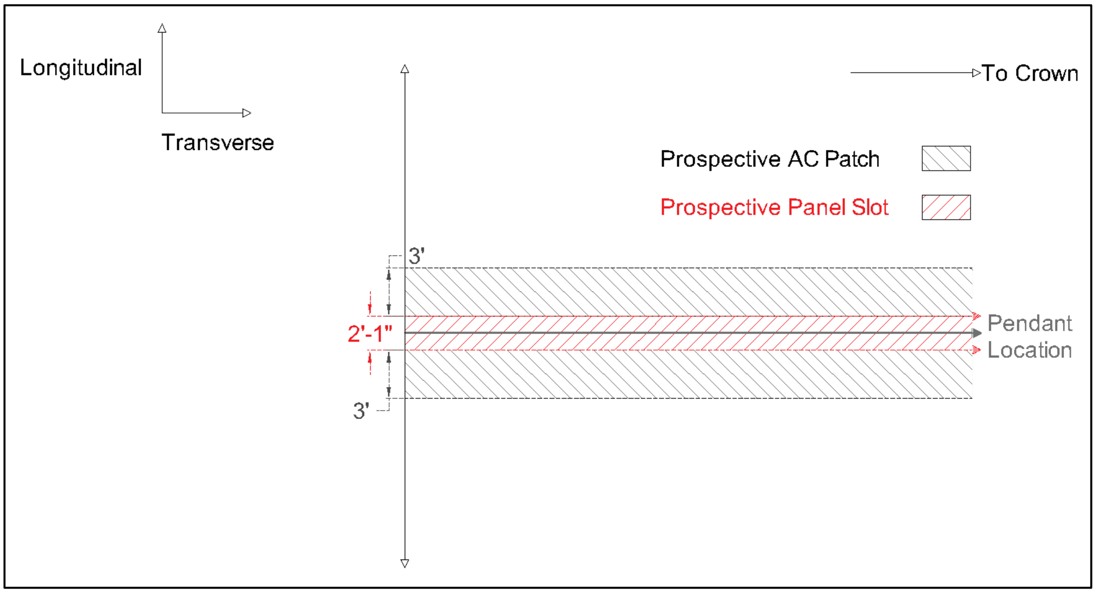
Appendix B: Expedient AAS-UHMW Panel Installation Methods - Full-Depth Installation for New Asphalt Concrete (AC) Pavement Construction

This installation manual follows the traditional method for installing UHMW panels in existing AC pavements given in AFI 32-1043 (Department of the Air Force 2012). Materials, equipment, installation techniques, and work phasing were modified to allow for efficient and optimal installation. A 3 ft deep trench is excavated across the runway for the anchoring foundation. A 12 in. layer of rapid-setting flowable fill is placed on the subgrade followed by a 22 in. lift of concrete. The surface of the concrete is smoothed to accept the UHMW panels not requiring a separate bedding layer. Threaded anchorage points are put in, and the panels are installed. Anchorage points for the tie-down ropes are also cut and hardware installed during UHMW panel installation. A 3 ft wide, full-depth asphalt patch is placed along the concrete foundation to allow access for recompaction of the soil disturbed along the vertical face of the foundation during excavation and to ensure that a quality joint is created. Joint sealing is completed as a separate activity once all panels across the runway are installed. Personnel requirements for each task and supplies and equipment needs for the work are provided. Estimated durations of the required work tasks and their scheduling are provided in Figure B-31 at the end of this appendix.

1. Initial demolition
    a. See Tables B-1 and B-2 for projected equipment, supply, and personnel needs before conducting work.
    b. Transverse sawcutting (1 work day, 4.0 hr)
        (1) Locate the panel installation location (Figure B-1).

Figure B-1. Typical project location.



(2) Mark sawcut locations on the pavement.
    (a) Lay out sawcut locations using a tape measure and a lumber crayon. Make sets of marks every 30 ft transversely across the runway. Make marks for the slot and patch extents.
    (b) Snap water resistant chalk lines between the corresponding parallel marks made with water resistant chalk (Figure B-2).
        i. Use two, three-person teams: one operates the tool, one holds the free end of the string line, and one snaps the line. Multiple snaps of the line may be needed to produce a solid, observable line.
        ii. Complete all lines longitudinally within a set of crayon marks before moving transversely across the runway. This will allow the saws to start before all lines are made.
    (c) Snap chalk lines longitudinally at every 30 ft perpendicular to the chalk lines made.

Figure B-2. Snapping chalklines.

(3) Begin full-depth sawcutting with the large floor saws using 18 in. saw blades (Figure B-3).
   (a) Allow ample time for the chalking crew to snap lines before starting sawing efforts. Chalk will not stick and stain the concrete surface if wet.
   (b) A larger diameter saw blade may be needed depending on the asphalt pavement thickness encountered. Use multiple saw blades of increasing diameter to cut deeper surface pavement to assist with making straight cuts. For a cut depth of 6 in., 9 in., or 15 in., use a 18 in., 24 in., or 36 in. diameter blade, respectively.
   (c) The spotter should use a floor broom to clear saw slurry. Cleaners should lightly spray water over the work area as sawing is completed to rinse the surface and allow the saw team to see chalk lines as needed. Use a less aggressive spray nozzle if available to prevent chalk line removal.
   (d) If multiple saws are used at one time, stagger saw start times and cuts made to allow for continuous cutting. Scheduling shown uses one saw.

Figure B-3. Making transverse cuts.

(4) Use the cutoff saw or walk-behind saw to make the longitudinal saw cuts every 30 ft across the runway (Figure B-4). Cuts deeper than 3 in. will require the walk-behind saw be used.

Figure B-4. Making longitudinal cuts.

(5) Water blast the cut area and surrounding pavement with a pressure washer to remove saw slurry and debris (Figure B-5). Start at the pavement crown and work towards the shoulder.

Figure B-5. Waterblasting saw slurry.

(6) Finalize site cleanup and exit the runway.

Table B-1. Personnel needs and tasks for transverse sawing activity.

Description	Task	Quantity
Marker	Mark locations for chalk lines	2
Chalk line team	Make chalk lines	6 (2 teams of 3)
Equipment operator	Operate floor saw	1
Spotter	Assist with aligning saw	1
Hose tender	Move and maintain water truck and hose	1
Cleaner	Pressure wash and clean pavement	2
Equipment operator	Operate airfield sweeper truck	1

Table B-2. Equipment and supply needs for transverse sawing activity.

Equipment	
Item	**Quantity**
Measuring tape, 2 ft	2
Chalk line tool	2
Floor saw	1
Push broom	2
Squeegee	2
Water truck	1
Water hoses, ¾ in. diameter by 50 ft long	6
Pressure washer	2
Airfield sweeper truck	1
Supplies	
Item	**Quantity**
Water resistant chalk, bottle	1
Lumber crayons, each	4
18 in. diameter concrete saw blade	2

Items in italic font are items not found in a standard USAF SuPR kit.

2. Demolition and Panel Installation (5 work days, 11.2 hr total each day)

Install panels across 30 ft of runway width per work day. Start on one edge of the runway and work across the runway transversely. Install the correct sequence of panels, following the drawings in AFI 32-1043 needed for the tie-down anchoring.

a. See Tables B-4 and B-5 for projected equipment, supply, and personnel needs before conducting work.
b. Demolish AC pavement within panel slot area (Figure B-6).
   (1) Remove the first panel adjacent to the panel slot to prevent damaging any installed panels (if any panels were previously installed).
   (2) Remove the asphalt concrete surface.
      (a) Use a backhoe or small excavator with an 18 in. wide bucket to rip and remove the asphalt from within the panel slot area. Place material to the side of the repair for removal.

(b) Use a small jackhammer to demolish the asphalt within 1 ft of the ends of the panel slot area to minimize damaging the existing pavement of previously placed panel foundation.

(c) Use the CTL to remove the demolished asphalt pavement and deposit it into a dump truck.

(d) Trim any uneven portions of the remaining asphalt concrete with a cutoff saw (Figure B-7).

c. Remove soil sublayers to 36 in. below the pavement surface (Figure B-8).

(1) Remove the soil within the panel slot area with a backhoe or a small excavator.

(2) Some handwork will be required at the ends of the trench and to square the sides of excavation.

(3) Monitor excavation depth over time to verify required depth is achieved.

(4) Use the CTL or backhoe to dispose of removed soil and deposit it into a dump truck.

d. Backfill the trench with a flowable fill base.

(1) Pre-position supersacks of flowable fill near the project area for use with the forklift. Allow ample space to operate equipment and allow personnel to work.

(a) The panel slot will require approximately 65 ft^3 of material with a conservative amount of waste (30 ft long and 25% waste). Assuming a typical supersack yields approximately 27 ft^3, approximately four units will be required for each work day.

(b) Remove plastic wrapping and prepare lifting loops.

(c) Have an additional supersack of material on hand in case the excavation is wider than expected. Do not remove plastic wrap until needed.

(2) There are two options for placing the flowable fill using typical ADR procedures: the wet method and the dry method.

(a) The wet method uses the simplified volumetric mixer to batch and mix dry materials and water together before placement. The dry method involves placing dry material directly into the excavation and adding a specific amount of water on top of the placed dry material that percolates through the dry material for hydration of the entire mass placed.

(b) If two volumetric concrete mixers are available, the flowable fill can be placed by using the wet method or the dry method. The wet method is expected to take longer for material placement than the dry method since the material production/placement rate is much less; however, the wet method produces a better mixed and ultimately much more consistent material that will gain strength much faster since water does not need to percolate through the loose material.

(c) If only one volumetric concrete mixer is available, the flowable fill must be placed using the dry method to allow for the mixer to be used to batch the concrete surfacing (Figure B-9). Project phasing and this instruction manual use the dry method to provide accelerated installation times to meet mission objectives.

Figure B-6. Pavement surface removal.

Figure B-7. Trimming the remaining pavement.

Figure B-8. Sublayer material removal.

(3) Make marks in the vertical faces of the soil 24 in. below the pavement surface around the perimeter of the trench.
(4) Place layers of flowable fill by emptying individual supersacks within the trench to the 24 in. marks made.

(a) Collect and place material from a supersack within the excavation. Center an extendable boom forklift 3 ft from the end of the trench.
(b) Cut the bottom of the bag and distribute material by moving the forklift boom back and forth (Figure B-9). Keep the supersack low to the pavement to minimize dust.

Figure B-9. Placing flowable fill (dry method).

(c) Rake and level the surface of the material placed.
(d) Add water to the trench.
   i. Determine the flow rate of a water truck distributing water out its rear hose before the project begins. Calibration of the truck's flow rate consists of measuring the amount of time it takes to fill a 5 gal bucket at a constant engine speed (rpm). Determine and mark the height required to dispense a true volume of 5 gal within the bucket. The total (completely filled) total bucket volume will be greater than 5 gal (Figure B-10).

$$Flow\ rate = \frac{5\ (gallons)}{Time\ to\ fill\ (\text{seconds})}$$

   ii. Determine the total amount of water required to add to the placed flowable fill. For dry placed flowable fill, material is approximately batched at 0.0133 gal/lb of dry material. For standard 3,000 lb supersacks, approximately 40 gal are required.

$$Total\ Water = \#\ of\ supersacks\ used \times Supersack\ weight\ (lb) \times \frac{40\ gal}{3000\ lb}$$

iii. Determine the amount of time to distribute water from the water truck.

$$Time\ to\ run\ water\ (seconds) = \frac{Total\ water}{Flow\ rate}$$

Figure B-10. Calibrating the water discharged from a water truck.

iv. Add water to the trench for the amount of time calculated. Lightly spray water over the flowable fill area.

(e) Poke a grid of holes into the flowable fill layer to aid uniform water percolation through the lift of material. A 5 ft long piece of #5 rebar works well for this task. Center two holes longitudinally every foot transversely.

(f) Repeat steps 2 through 5 until the material within the trench reaches the 24 in. depth marks made earlier. Begin placing additional layers once all the water on the surface has soaked into the dry material.

(g) Smooth the surface of the flowable fill with rakes once all material is placed.

(5) Notable differences in the wet vs. dry backfilling methods are as follows:

(a) A volumetric concrete mixer is used with the wet method. Position the mixer approximately 4 ± 1 ft from the trench edge, but do not get close enough to cause the trench to cave in. Place material from the shoulder to the interior of the runway. Ensure the mixer hopper stays at least approximately one-quarter full to ensure a consistent product is produced.

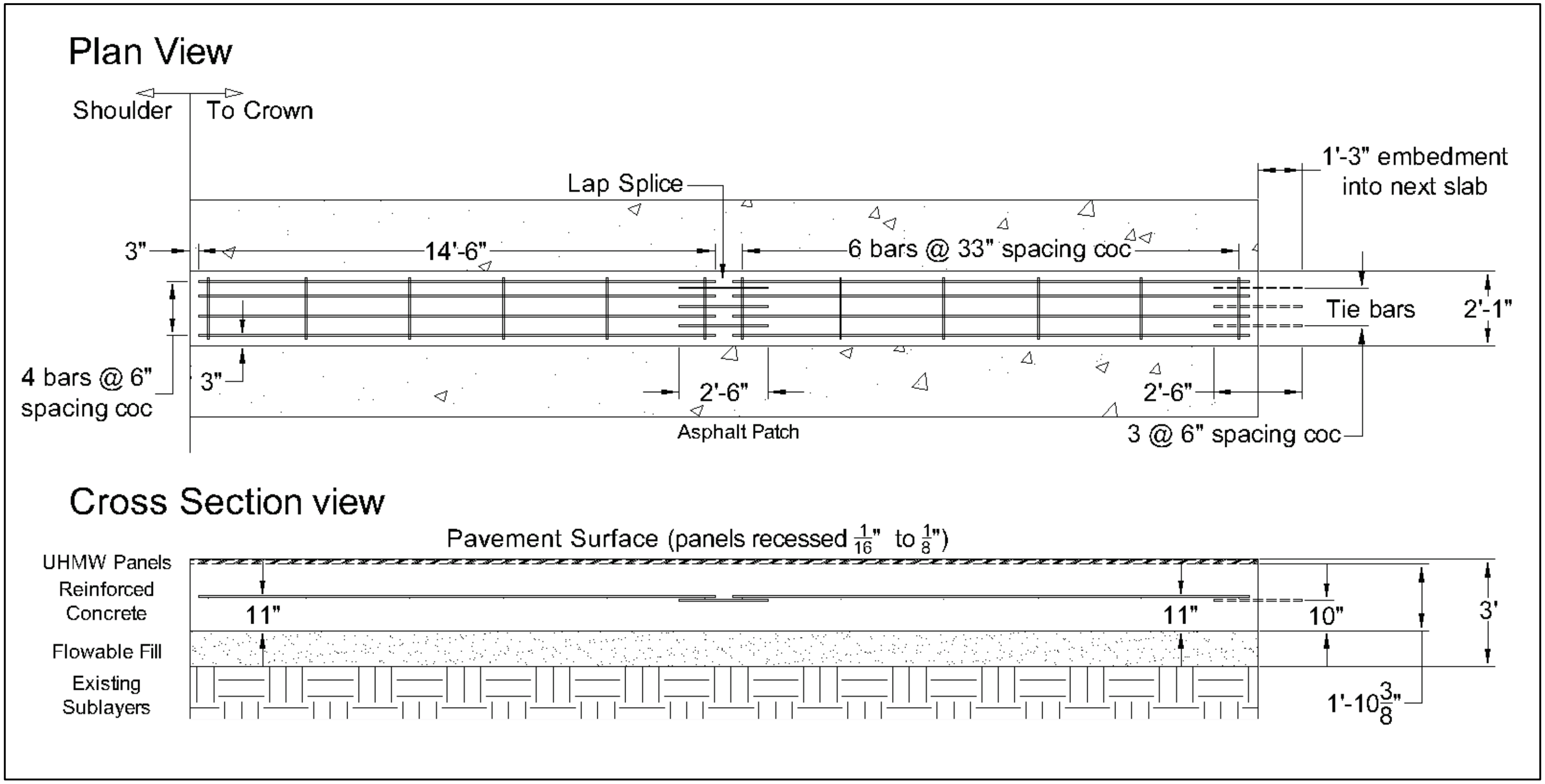
(b) More water is used to batch flowable fill with the wet method. Approximately 70 gal of water per supersack is used for making flowable fill by the wet method. Material should have a flowability of 10 ± 1 in. by ASTM D6103.

(c) The fluid consistency of the wet mixed material makes it self-leveling and matching the cross-slope of the pavement will be difficult. The material will require tailoring by hand tools before the material sets to match the cross-slope of the pavement structure for drainage.

e. Allow the flowable fill to gain strength before continuing work within the excavation. The recommended strength to allow foot traffic for future reinforcement installation and concrete placement without damaging the flowable fill layer is 10 psi by ASTM D6133.

f. Place the reinforcement grid in the trench (Figure B-11). It is recommended to assemble all necessary reinforcement grids before the project begins.

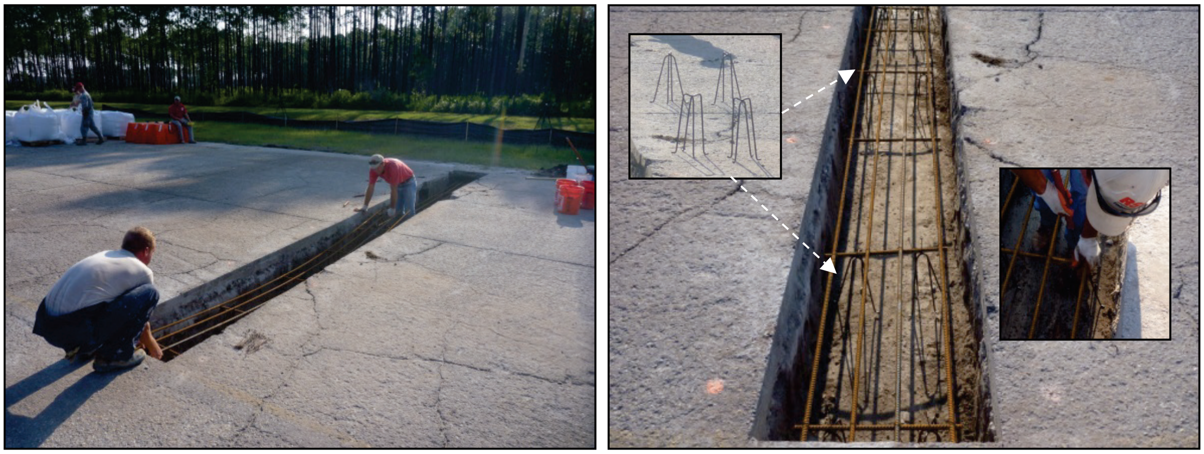
Figure B-11. Reinforcement layout and dimensions.



(1) Install tie bars to the existing concrete foundation placed previously (work days 3 through 6 only). Tie bars will hold the multiple slabs placed transversely together.
   (a) Remove and level any seriously irregular portions of the previously installed concrete with the cutoff saw or jackhammer with chisel or bushing bit. Do not try to level the area perfectly, but enough to have a fairly vertical joint.
   (b) Locate the installation locations and mark the locations with a lumber crayon.
   (c) Drill holes at the marked locations with the hammer drill and appropriately sized masonry bit to a depth of 15 in. Clean the holes as required by the epoxy adhesive manufacturer.
   (d) Inject the holes with epoxy adhesive and install the #5 reinforcement ties. Ensure enough adhesive is used to fully embed the tie. Rotate the tie in the hole to ensure the entire tie length is coated with adhesive.
   (e) Install a grout retention ring over the reinforcement to prevent adhesive from flowing out of the hole.
   (f) Clean any remaining soil residue from the concrete surface with a wire brush or an angle grinder with a wire brush attachment.

(2) Place the reinforcement grid on a network of steel high chairs that set the grid approximately at the mid-height of the constructed slab (Figure B-12).
   (a) Use a minimum of 12 chairs per grid installed. Additional chairs may be needed to prevent the grid from sagging.
   (b) Place transverse reinforcement on top of chairs.
   (c) Tie all chairs to the reinforcement.

Figure B-12. Reinforcement grids placed on chairs.



(3) Add lap splices to successive placements of reinforcement grids after placement within the trench. Center and tie the short segments of reinforcement to the placed grids to prevent movement, as shown in Figure B-11.

(4) Tie the reinforcement grid to the ties to prevent movement.

g. Backfill the trench with rapid-setting concrete (Figure B-13).

(1) Use a four-person concrete production team. One drives the truck that pulls the mixer, one operates the forklift that fills the mixer, one assists the forklift operator with bags and monitors the hopper material, and one operates the mixer controls at the rear.

(2) Pre-position supersacks of concrete near the project area for use with the forklift. Allow ample space to operate equipment and allow personnel to work.

(3) The panel slot will require approximately 150 ft^3 of material with a conservative amount of waste (30 ft long and 25% waste). Assuming a typical supersack yields approximately 25 ft^3, approximately six units will be required for each work day.

(4) Spray the volumetric mixer auger and chute on the outside and inside with concrete release agent using a pump sprayer. Hand tools can also be sprayed for easier cleanup.

(5) Ensure both mix water tanks are filled with water. Also, add citric acid to the water tanks as a retarding admixture to increase working time during hot weather. Recommended citric acid dosing rates are shown in Table B-3.

Table B-3. Citric acid dosing rate information.

Ambient Temperature ($^{\circ}$F)	Dosage (lbs per 50-gal of mix water)
Below 75	0
75-80	1
80-85	2
85 and above	3

(6) Remove plastic wrapping and find/prepare lifting loops.
(7) Position the volumetric mixer approximately 4 ± 1 ft from the trench edge, but do not get close enough to cause the trench to cave in. Place material from the shoulder to the interior of the runway.
(8) Ensure the mixer hopper stays fairly full to ensure a consistent product is produced. An additional two supersacks must be added to the hopper as material is placed to allow the mixer to correctly produce material at the correct water to powder mixing rates, but these will ultimately be wasted as unused material.

Figure B-13. Placing rapid setting concrete.

(9) Have a five-person finishing team construct the bedding layer.
   (a) The rapid-setting concrete used is self-consolidating due to its fluid consistence. No vibration is required.
   (b) Four people will screed and trowel the concrete, and one person will direct material placement, move concrete as needed, and maintain site cleanliness.
   (c) Place material from the shoulder to the runway interior. Use a square shovel to block and prevent concrete splatter.
   (d) Screed the surface of the concrete to a depth of 1 5/8 in. below the pavement surface. Pass the screed multiple times to remove excess material and deposit into material low areas. Start the screed over previously placed areas to provide smooth transitions between placements.
   (e) Float and trowel the surface to make it flush and smooth. Allow the concrete to stiffen up slightly before working to allow for efficient finishing since the placed concrete will be self-leveling in nature.
   (f) Work quickly and efficiently to ensure the material does not set up before work is complete. Remove excess material at the end of the placement and deposit into an empty bucket for removal.

h. Allow the concrete to gain at least 2,500 psi of compressive strength before continuing with work activities within the panel slot. The estimated time to reach this strength is approximately 90 min at 70°F, but refer to the manufacturer's provided information. Use a nondestructive Schmitt hammer testing device to monitor strength gain.

i. Arrange the panels near their prospective installation locations in the correct order within the slab (Figure B-14).
   (1) See AFI 32-1043 for the correct panel sequence to ensure the panels with tie-down anchoring holes are positioned correctly.
   (2) Place panels approximate 5 ft away from the slot area to allow work to continue.

Figure B-14. Arranging panels.

j. Inspect the depth of the panel slot. Ensure the surface is smooth and level so the panels lie correctly in the slot once completed (Figure B-15).
   (1) Begin verifying the surface while the concrete is gaining strength. Mark locations that require leveling with a lumber crayon.
   (2) Level locations with a small hand scabbler, handheld angle grinder with masonry disk, or demolition hammer/light jackhammer with a bushing bit after the surface reaches 2,500 psi compressive strength. Other appropriate equipment may be used if available.
   (3) Verify the final surface elevation in any areas modified.
   (4) Repeat steps 1 through 3 as needed.

Figure B-15. Final leveling of the panel slot.

k. Cut water drain slots in panel depth (Figure B-16).
   (1) Use the walk-behind saw with two 18 in. diameter saw blades butted together.
   (2) Cut two slots transversely in the bedding layer ½ in. deep. Use the panel void vertical faces as guides. Ensure the cuts are not within 6 in. of the panel slot vertical face to avoid panel anchoring locations.
   (3) Connect previously cut drain slots from previously installed panels as best as possible. Do not damage any existing anchors.
l. Water blast the panel slot.
m. Vacuum the repair area. Straddle the airfield vacuum truck over the void and vacuum the surface at least twice.
n. Heavily air blast the panel slot.

Figure B-16. Cutting drain slots.

o. Place and install panels.
   (1) Place panels in the slot.
   (2) Shim panels into position using wooden wedges (Figure B-17).
      (a) Arrange panels such that approximately ½ in. transverse joints are between the slot vertical faces and between each panel.
      (b) Draw a stringline across the top of the panels. Pick a convenient location/point to assist in aligning the panels. Tangent to the panel anchoring holes is a good location to use as reference. Use masonry nails to fix the string line to the selected location.
      (c) Use wrecking bars to help move panels and add shims as needed to prevent movement. Be careful not to leave impressions or gouges in the joint with the wrecking bar.
      (d) Do not break shims after installation. Shims will be removed after anchoring is installed and cured.

(e) Ensure the panels are solidly locked into position before moving forward with work tasks.

Figure B-17. Aligning panels within the slot.

(3) Install panel anchoring (Figure B-18).
   (a) Drill holes into the concrete foundation using appropriately sized masonry drill bit and hammer drill. Use the panel anchoring drill guide to ensure a vertical cut is made to the correct depth. Use two drills for increased speed, one on each side of the panel transversely.
   (b) Clean the anchoring holes following the adhesive manufacturer's directions. Typical cleaning procedures include air blasting, wire brushing, and another round of air blasting to remove all loose material. Personnel requirements could include one air blasting operator, one brush cleaner or one blasting operator, one brush cleaner, and one blasting operator. A three-person team requires an additional air compressor, hose, and blow gun than listed in the equipment requirements.
   (c) Any holes that cannot be drilled their full depth from encountering embedded steel located within the concrete should be marked. Steel within the concrete may be encountered if the concrete is reinforced and/or ties or dowels are present. The masonry drill bits will not cut through the steel. These locations will require a shortened anchor.
   (d) Set out and prepare each anchor for installation (Figure B-19).
      i. Anchors should be prepared with setting hardware and washers assembled before placement.
      ii. Set out any tie-down anchoring needed. Locate the center of the anchoring hole and mark its location with a lumber crayon.
      iii. Anchors requiring shortening should be trimmed with a portable band saw to an appropriate length to recess the rod below the panel surface (Figure B-20). To determine rod length needs, perform the following:
         (i) Place anchor in the indicated hole requiring modification. Install the washer and hex nut on the rod.
         (ii) Twist the nut down within the countersunk hole to mark the maximum anchor length. Rotate the anchor

an additional two turns to provide a void for adhesive at the hole depth.

(iii) Remove the anchor without moving the hex nut. Cut the portion of the rod that extended above the panel surface flush with the top of the nut with the band saw.

(iv) Remove the nut and replace it on the uncut end of the anchor.

Figure B-18. Anchor hole production line.

Figure B-19. Layout anchors.

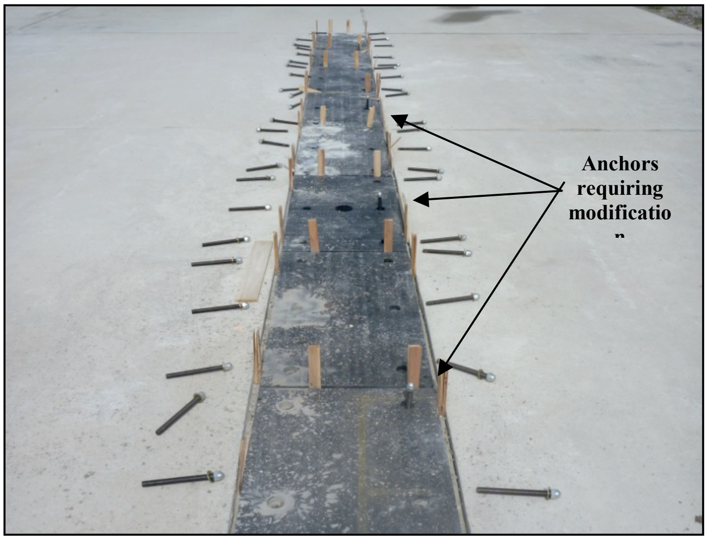


Figure B-20. Trimming a panel anchor.

(e) Install anchoring hardware in each hole.

i. AFI 32-1043 describes the use of prepackaged adhesive packets for this task. Ensure the correct amount (or combination of packets if applicable) of adhesive is placed in each hole. Follow all manufacturer directions to correctly measure and use adhesive.

ii. Bulk adhesive cartridges that use a mixing tube to premix adhesive before entering the drilled holes are highly recommended to ensure all adhesive is properly mixed at the correct ratio (Figure B-21). Large cartridges with pneumatic handheld dispensing equipment are recommended to minimize time lost to changing cartridges. An off-site trial of this work is highly recommended to determine the proper equipment settings the filling times.

(i) Ensure enough adhesive is used to embed the anchor. Adjust the air regulator such that adhesive is deposited without leaving air voids but is allowed to flow expeditiously enough to install all anchors in a timely fashion without clogging.

(ii) The proper amount of adhesive has been dispensed when the adhesive is level with the bottom surface of the panel slot when the anchor is installed. Use the first few holes to determine the amount of adhesive needed.

(iii) Clean any excess adhesive that enters the countersunk area with a paper towel before it hardens.

(iv) Rotate the anchor back and forth while in the hole to ensure adhesive completely surrounds the anchor thread.

(v) Cool or heat adhesive to modify setting times as needed in extreme weather conditions.

(vi) After all anchors are installed, the surface of the paneling should look similar to that shown in Figure B-22.

Figure B-21. Anchor installation.

Figure B-22. After all anchors are installed.

(4) Install tie-down anchoring (if present in panel arrangement installed on work day, Figure B-23).
   (a) Once the drilling is complete, preparations for tie-down anchoring can begin. One drill operator makes the small partial depth core for the anchoring eye, and the other makes the embedding hole deeper into the concrete foundation for the anchor shank.
   (b) The first drill operator must change drill bits to the dry coring bit. Center the core bit in the tie-down anchor hole and cut to a depth of 3 in. Make one continuous cut if possible. Removing the core bit at any time in the process requires the hole to be cleaned before continuing to prevent clogging and allow for additional cutting.
   (c) The dry core bit used in hammer mode should demolish the majority of the cored material while used. If material is still present, use a chisel or bushing bit to level the bottom of the core.
   (d) Air blast the core hole.
   (e) Drill the tie-down anchor embedment hole. Use the tie-down anchoring drill guide to ensure a vertical cut made to the correct depth.

(f) Clean the anchoring hole following the adhesive manufacturer's directions.
(g) Install the tie-down anchor into the hole. Ensure the eye is aligned in the longitudinal direction.

p. Allow the adhesive to cure to full strength. This is temperature dependent; colder temperatures and base material (concrete foundation) require more set time than warmer temperatures. Do not activate the anchor until the cure time has been met.
q. Begin any cleanup efforts that do not disturb the anchoring adhesive. Remove the wooden wedges from the panels near the end of the cure period.
r. Once the adhesive has cured, install the hardware on the panel anchoring (Figure B-24).
   (1) Remove the setting hardware and install a hex nut on each anchor stud. Use a $1^1/_8$ in. socket and an impact hammer/ratchet to aid in removal.
   (2) Gross torque the hex nut on the panel anchoring with an impact wrench. Two short bursts are needed to spin the nut hand tight and begin torqueing the nut. Do not over torque the hex nuts.
   (3) Fine torque the hex nuts on the panel anchoring with a torque wrench set to 60 ft-lb.
s. Verify the final anchor head elevations. Grind off any anchors that stick above the panel with an angle grinder (Figure B-25). Be careful not to damage the panel.
t. Finalize site cleanup and sweep project area. Exit the runway. The surface of the paneling should look similar to that shown in Figure B-26 at the conclusion of the work day.

Figure B-23. Tie-down anchorage installation.

Figure B-24. Permanent hardware installation.

Figure B-25. Grinding anchor head flush with the panel surface.

Figure B-26. Panel installation complete.

Table B-4. Personnel needs and tasks for demolition and panel installation activities.

Description	Task	Quantity
Demolition and Excavation		
Equipment operators	Operate CTL and backhoe, transports construction debris	2
Spotter/cleaner	Transport construction debris, clean small debris, fine tune trench dimensions with hand tools	2
Flowable Fill Placement		
Equipment operators	Drive forklift	1
	Operate water truck and dispense water	1
Spotter	Remove shrinkwrap, open supersacks, dispense dry material	1
Spreaders	Level flowable fill to correct elevation, make percolation holes	3
Concrete Placement		
Equipment operators	Tow volumetric mixer, clean out mixer after placement	1
	Operate volumetric mixer, clean out mixer after placement	1
	Operate forklift	1
	Operate airfield sweeper truck	1
Operator assistant	Remove shrinkwrap for supersacks, assists with loading mixer	1
Concrete finishers	Screed and finish concrete	5
Demolisher	Jackhammer concrete, remove large debris pieces, level panel surface, install reinforcement, install reinforcement ties	4 (2 teams of 2)
Cleaner	Maintain site cleanliness, air blast slot area	1

Anchorage Installation		
Panel installer	Place and shim panels	4
Driller	Drill anchor holes	2
Cleaner	Clean anchor holes	2-3
Adhesive installer	Arranges and lays out anchors, trims anchors as needed, installs anchors, assists adhesive dispenser	2
Adhesive dispenser	Install anchors	1
Everyone begins cleaning the site once complete		
Hardware Installation		
Installer	Remove temporary and places permanent hardware	2
Cleaner	Collect removed temporary hardware	1
Fitter	Tighten nuts	3
Validator	Verifie all anchors are recessed below panel surface, grind anchors that require recessing	1

Table B-5. Equipment and supply needs for demolition and panel installation activities.

Equipment	
Item	**Quantity**
CTL	1
Cold planer attachment, 18 in. wide	1
Airfield sweeper truck	1
Water truck, 500-gal minimum	1
Impact hammer	2
1$^{1}/_{8}$ in. socket	4
5,000 W generator	2
Backhoe or small excavator	1
Jackhammer, 40 lb max, with bits	1
Air hose, ¾ in. diameter x 50 ft	1
Air compressor, 100 cfm minimum	1
CTL with bucket	1
Cutoff saw with concrete blade	1
Dump truck	1
Measuring tape, 25 ft	1
Shovel, square	2
Shovel, round	2

Equipment	
Item	**Quantity**
Concrete rake	2
Sand rakes	3
Wrecking/pry bar	2
Push broom	2
Rebar, #5 x 5 ft long	2
Telehandler forklift, 6 kip capacity minimum	1
Volumetric concrete mixer	1-2
Backpack sprayer	1
Airfield vacuum truck	1
Rebar tying tool	2
Handheld scabbler	2
Angle grinder	2
Demolition hammer/hammer drill, with bits	1
Knife	2
Concrete float, magnesium	3
Concrete trowel, steel	3
Depth tool guide/screed, 1 $^5/_8$ in. deep	4
Walk-behind saw	1
18 in. concrete saw blade	3
Pressure washer	1
Water hose	2
Hammer/maul	3
Rotary hammer drill	2
Small air compressor lance	2
Small air compressor hose, 3/8 in. diameter	6
Small air compressor, 4 gal minimum, two outlets	2
Hammer drill	2
Portable band saw	1
Extension cords, 50 ft	8
Setting hardware	50
*Epoxy adhesive dispensing gun, pneumatic**	1

Equipment	
Item	**Quantity**
Electric drill, 6-A	1
Panel anchor alignment tool	2
Dry core barrel, 4½ in. diameter	1
Tie down anchor alignment tool	1
Torque wrench, ½ in. drive, 100 ft-lb capacity	2
Supplies	
Item	**Quantity/ work day**
#5 steel reinforcement, 20 ft	9
Rebar ties, 16 gauge, 8 in. long	100
Lumber crayon	4*
High chairs, 11 in. tall	12
Grout retention ring, ⅝ in. inner diameter	3
4 ½ in.diameter masonry stone	10*
Rapid setting flowable fill, 3000 lb	5
Rapid setting concrete, 3000 lb	8
Citric acid, anhydrous powder form, 50 lb	1
Concrete release agent, 5 gal	1
Bucket, 5 gal	5
Measuring cup, 1 gal capacity	2
Steel brush attachment for angle grinder	2*
Wooden shims, ⅜ in. thick	600*
Stringline	1*
Masonry nail, 3 in., box	1*
Masonry drill bit, 1⅛ in. diameter	4*
Masonry drill bit, ⅞ in. diameter	2*
Wire brushes for 1 in. diameter anchoring pieces	2*
Wire brushes for ¾ in. diameter anchoring pieces	4*
Threaded rod, steel, ¾ in.10 diameter x 10 in. long	48
¾ in. washer, SAE, steel	48
Hex hut, ¾ in., steel	48
4½ in. diameter steel stone	10*

Equipment	
Item	Quantity
Epoxy adhesive, 28 oz_f cartridge	4
Additional mixing tubes for epoxy adhesive	2
Shop towels, box/roll	6
Tie-down anchoring eyebolt	4 or 8**

* Total quantity needed for all work days.

** Varies by existing slab and prospective panel arrangement.
Items in italic font are items not found in a standard USAF SuPR kit.

3. AC patching (4 work days, 6.2 hr per day, half width on one side of installed panels per day)
   a. See Tables B-6 and B-7 for projected equipment, supply, and personnel needs before conducting work.
   b. Mill the asphalt pavement between the sawcuts and foundation full depth with the CTL with cold planer attachment (Figure B-27).
      (1) Make passes in 1 in. increments. At least two passes per cut depth will be required. Maintain approximately 1 in. away from the edges to prevent damaging materials outside the boundaries.
      (2) Set one of the skis on the cold planer 1 in. deeper the other ski after the first pass is made. This will allow the cold planer to use existing pavement as a stable guide to control the cutting depth.
      (3) Have the airfield sweeper truck vacuum the patch slot after each pass of the CTL.
      (4) Complete milling on both sides of the panels before moving forward.
      (5) After milling is complete on each side, use a demolition hammer to remove the unmilled portions within the slot perimeter.

Figure B-27. Milling the panel slot.

c. Wet the exposed base material with water to prepare for compaction. Apply approximately 1 gal/yd^2 evenly across the base material.
d. Remove the UHMW panels within the milled area from the runway.
e. Compact the surface of the base layer with the steel wheel roller. Vibrate the soil to aid in compaction. Be careful not to over roll and damage the aggregates.
f. Install steel asphalt formwork to the panel anchoring.
   (1) Install while the roller operates but in completed compacted areas.
   (2) Apply form release oil to the steel to assist in form removal.
   (3) Use an impact wrench to quickly tighten the forms to the concrete. Use a quick burst to prevent over tightening and damaging the anchorage points.
g. Apply tack material to perimeter of asphalt surfaces. Asphalt binder is recommended to prevent the need for water base emulsion products to break. Use a locally available material that best matches the grade of the existing asphalt concrete.
h. Place asphalt and compact with the steel roller (Figure B-28).
   (1) Place material within the patch. Grossly fill low spots and level high areas by hand but minimize handwork to prevent segregation. Place loose material 1 in. higher than needed to account for compaction. Distribute enough loose material to provide 1 to 2 in. of head while screeding with the CTL.
   (2) Roll loosely placed asphalt with the steel wheel roller. Follow guidance on ADR asphalt placement and materials.

(3) Monitor density with a nuclear density gage to ensure efficient compaction is met. Continue rolling as needed.

i. Watershock the overlay surface to accelerate cooling the asphalt placed.

(1) Distribute water over the surface of the asphalt overlay to help the material cool and gain strength. This can be done intermittently by hand (Figure B-29) or continuously by using a lawn sprinkler.

(a) Use of a cart-mounted lawn sprinkler is recommended for continuous cooling.

(b) When the lawn sprinkler is used, set up the sprinkler and water truck towards the runway crown end of the overlay and allow the water to flow to the shoulder. Set up equipment such that it lies on cool pavement and the water sprayed lands at 1 ft from the start of the overlay.

(c) Place sandbags over the cart wheels to prevent movement.

(d) Two systems will be required for overlaid areas at the pavement crown.

(2) Monitor the surface temperature of the overlay with an infrared thermometer at 5 min intervals. Take measurements in at least six random locations across the fresh patch.

(3) Stop cooling once surface reaches 125°F or is similar to surrounding pavement.

j. Remove the steel formwork once the steel is safe to touch with gloves.

k. Replace the panels.

l. Finish cleaning the project area.

Table B-6. Personnel needs and tasks for AC patching activities.

Description	Task	Quantity
Milling		
Equipment operator	Operate CTL	1
	Operate airfield sweeper truck	1
Spotter	Guide CTL while milling, set milling head ski height	1
Base Recompaction		
Equipment operator	Drive water truck, apply water	1
	Operate plate compactor	1
Installer	Remove panels, collect hardware, install formwork	6 (2 groups of 3)
AC Placement		
Equipment operator	Deliver asphalt	1
	Operate CTL	1
	Operate roller compactor	1
	Operate water truck, watershock asphalt	1
	Operate airfield sweeper truck	1
Spotter	Guide CTL while screeding, set screed height	1
Paver	Apply tack material, place AC	4
Panel Reinstallation		
Installer	Remove formwork, reinstall panels	6 (2 groups of 3)
	Tighten nuts with torque wrench	2

Figure B-28. Asphalt placement.

Table B-7. Equipment and supply needs for AC patching activities.

Equipment	
Item	**Quantity**
CTL	1
Cold planer attachment, 18 in. wide	1
Airfield sweeper truck	1
Push broom	1
Demolition hammer, with bits	1
Extension cord, 50 ft	1
Generator, 3,000 W	1
Water truck, 1,000 gal minimum	1
Steel wheel vibratory compactor, CB14 or equivalent	1
Impact hammer	2
1 1/8 in. socket	2
5,000 W generator	1
Wrecking/pry bar	2
Custom steel formwork	*
Roofing brush	2
Asphalt screed attachment	1
Measuring tape, 25 ft	1
Shovel, square	2
Asphalt rake/lute	2
Water hose	4
Water sprinkler, wheeled	2
Sand bag, 25 lb	2
Infrared temperature gun	1
Torque wrench, ½ in. drive, 100 ft-lb capacity	2
Supplies	
Item	**Quantity/ work day**
Hot asphalt binder, gal	8
Hot mixed asphalt, airfield grade, ton	14**

* Varies by prospective panel dimensions.

** Assumes 4 in. deep patch is made with 25% waste.

Italicized items are not included in a Standard USAF Suprkit.

4. Joint sealing (1 work day, 7.0 hr)
   a. See Tables B-8 and B-9 for projected equipment, supply, and personnel needs before conducting work.
   b. Schedule a day when the weather will accommodate sealant placement.
   c. Air blast the panel joints and anchor holes.
   d. Install backer rod in all panel joints (Figure B-29).
      (1) There are approximately 400 linear feet in total.
      (2) For ½ in. wide joints and use of silicone-based joint sealants, the backer rod should be placed ¼ in. below the panel surface.
      (3) Start with placing the long transverse pieces, follow with the shorter longitudinal pieces.
      (4) Install longitudinal pieces from the runway interior to the shoulders.

Figure B-29. Backer rod installation.

e. Install silicone sealant following manufacturer's directions (Figure B-30).
   (1) If a priming material is required, apply material before backer rod is placed.
   (2) Installation of sealant with pneumatic applicator guns using large cartridges is recommended. Adjust regulator to appropriate pressure for best installation. Provide a recess of approximately 1/8 in. below the panel surface.
   (3) Begin at the runway interior and work towards the shoulders. This will allow the sealant at the center portion of the runway to have the maximum amount of time to cure.
f. Allow sealant to cure to tack free. Finalize site cleanup and exit the runway.

Figure B-30. Joint sealant installation.

Table B-8. Personnel needs and tasks for longitudinal sawing activity.

Description	Task	Quantity
Installer	Place backer rod	4 (2 teams of 2)
Sealant dispenser	Place sealant	2
Dispenser assistant	Assist sealant dispensers, maintain site cleanliness	1

Table B-9. Equipment and supply needs for joint sealing activity.

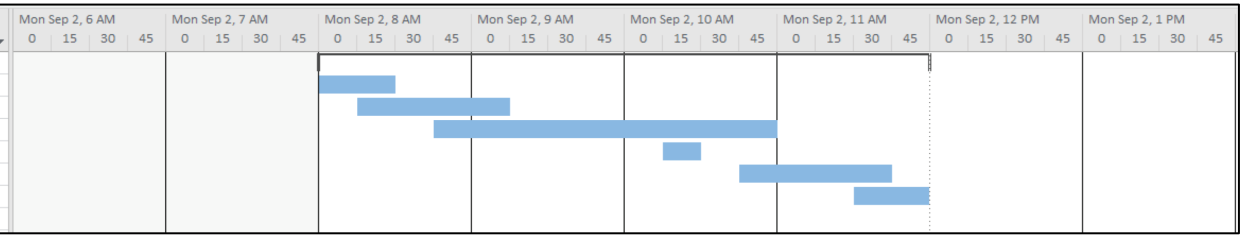
Equipment	
Item	**Quantity**
Backer rod installation tool	2
Air compressor, 4 gal	1
Air hose, 3/8 in. diameter x 50 ft long	4
5,000 W generator	1
Sealant dispenser, for 29 oz_f cartridges, pneumatic	2
Supplies	
Item	**Task**
Backer rod, HDPE closed cell, ¾ in. diameter	1 box (500 ft minimum)
Silicone sealant, airfield grade, 29 oz_f cartridge	42

Italicized items are not included in a Standard USAF SuPR Kit.

Figure B-31. Project Phasing Expedient UHMW-PE Panel Installation – AC Pavement.

1. Initial demolition

	Task Name	Duration
1	**Initial Demolition (full width)**	**4 hrs**
2	Mark sawcut perimeter	0.5 hrs
3	Snap chalk lines	1 hr
4	Saw cut all transverse cuts	2.25 hrs
5	Saw cut all longitudinal cuts	0.25 hrs
6	Wash saw slurry	1 hr
7	Finish clean up	0.5 hrs



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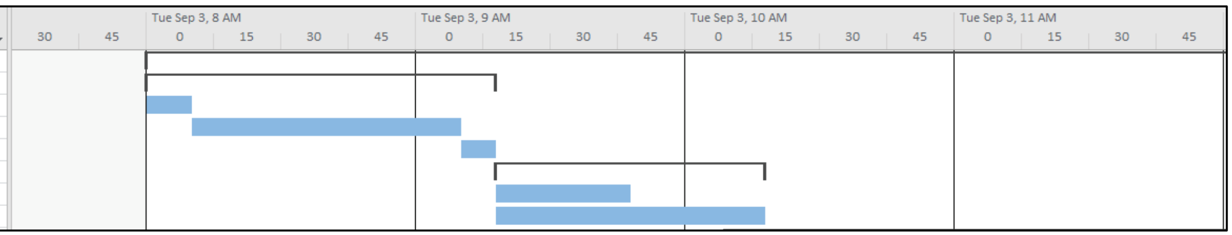
2. Initial demolition – Demolition and Panel Installation

	Task Name	Duration
1	**Demolition and Panel Installation (Partial width)**	**10.83 hrs**
2	**Demolition and Excavation**	**1.3 hrs**
3	Remove surface with backhoe	0.17 hrs
4	Remove sublayer soil	1 hr
5	Compact bottom of trench	0.13 hrs
6	**Backfilling Base**	**1 hr**
7	Place rapid setting flowable fill	0.5 hrs
8	Allow flowable fill to gain strength	1 hr



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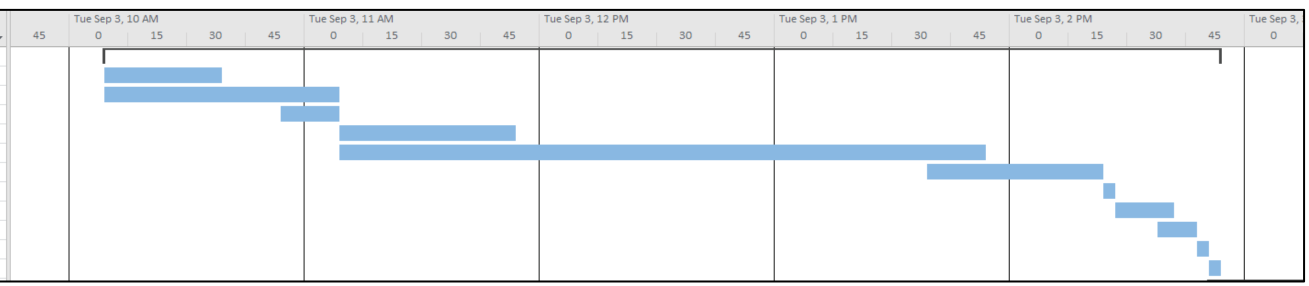
	Task Name	Duration
9	**Concrete Foundation Placement**	**4.75 hrs**
10	Install tie bars (as needed)	0.5 hrs
11	Allow adhesive to cure (if tie bars are installed)	1 hr
12	Install reinforcement grid	0.25 hrs
13	Place rapid setting concrete	0.75 hrs
14	Allow concrete to gain strength	2.75 hrs
15	Perform final slot inspection	0.75 hrs
16	Air blast slot	0.05 hrs
17	Cut water drain holes	0.25 hrs
18	Water blast completed slot	0.17 hrs
19	Vacuum slot area	0.05 hrs
20	Air blast completed slot	0.05 hrs



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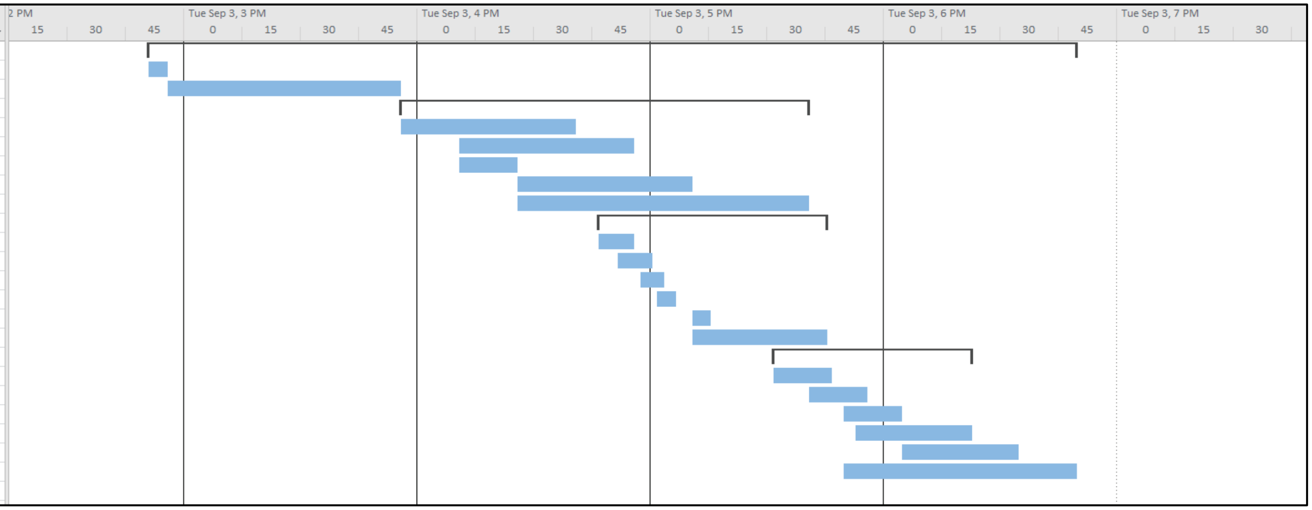
	Task Name	Duration
21	◢ **Place and Install Panels**	**3.98 hrs**
22	Place and arrange panels	0.08 hrs
23	Shim panels	1 hr
24	◢ **Panel anchor installation**	**1.75 hrs**
25	Drill anchoring holes	0.75 hrs
26	Clean anchoring holes	0.75 hrs
27	Set out anchors	0.25 hrs
28	Install hardware	0.75 hrs
29	Allow adhesive to cure	1.25 hrs
30	◢ **Install Tie Down Anchoring (As required)**	**0.98 hrs**
31	Dry core and remove interior	0.15 hrs
32	Clean hole made	0.15 hrs
33	Drill anchor embedding hole	0.1 hrs
34	Clean hole made	0.08 hrs
35	Install tie down anchor	0.08 hrs
36	Allow adhesive to cure	0.58 hrs
37	◢ **Install Panel Anchor Hardware**	**0.85 hrs**
38	Remove setting hardware	0.25 hrs
39	Install hex nuts	0.25 hrs
40	Gross torque hex nuts	0.25 hrs
41	Fine torque hex nuts	0.5 hrs
42	Verify final anchor elevations	0.5 hrs
43	Finish cleanup	1 hr



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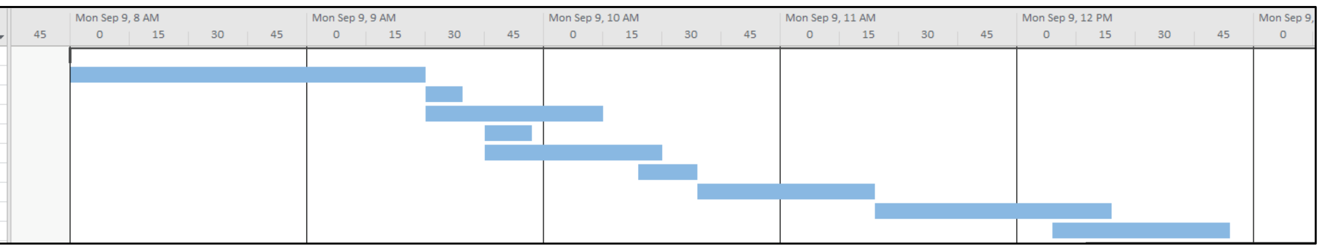
3. Demolition and panel installation

	Task Name	Duration
1	◢ **AC Patching (Half width, one side of panel)**	**6.2 hrs**
2	Mill AC	1.5 hrs
3	Wet base	0.16 hrs
4	Remove panels	0.75 hrs
5	Compact base	0.2 hrs
6	Install steel formwork	0.75 hrs
7	Apply AC binder tack material	0.25 hrs
8	Place and compact AC	0.75 hrs
9	Watershock AC and allow pavement to cool	1 hr
10	Remove steel formwork	0.75 hrs



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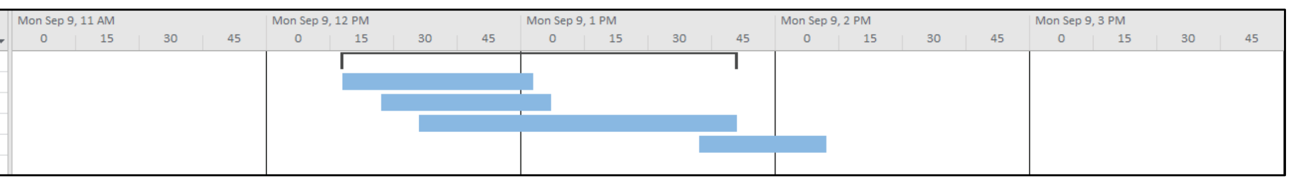
	Task Name	Duration
11	◢ Replace panels	1.55 hrs
12	Install panels and hex nuts	0.75 hrs
13	Gross torque hex nuts	0.67 hrs
14	Fine torque hex nuts	1.25 hrs
15	Clean work zone	0.5 hrs



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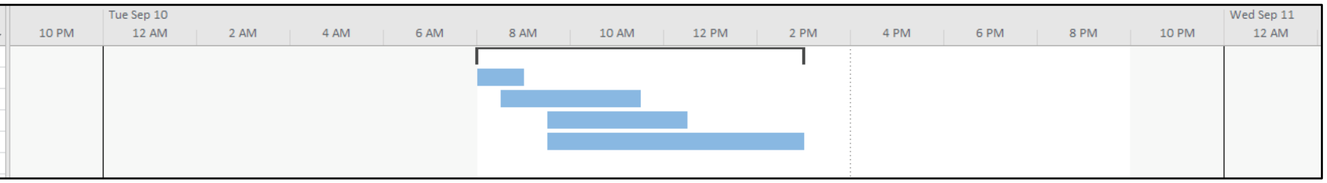
4. Joint sealing

	Task Name	Duration
1	Joint Sealing (full width)	7 hrs
2	Air blast joints and anchor holes	1 hr
3	Install backer rod	3 hrs
4	Install sealant	3 hrs
5	Allow sealant to cure, clean site	5.5 hrs



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Appendix C: Expedient AAS-UHMW Panel Installation Methods - Full Retrofit of an Existing PCC Foundation on an AC Runway

This plan assumes the current AAS paneling system is unusable and a new system must be reconstructed at the same location. The anchoring is removed, and the surface is backfilled with rapid-setting concrete to allow for aircraft operations during the phased construction effort. The surface of the concrete foundation is removed to allow for an AC overlay that brings the AAS system back into compliance with AFI 32-1043 and UFC 3-260-01 requirements by removing the deficiency of a change in pavement type within ±200 ft of the arrester pendant. The overlaid concrete becomes the foundation required for the panel and pendant tie-down anchorage points. A new panel slot is constructed, and new anchorage points are installed following the typical AFI 32-1043 installation process. All joints are sealed at the conclusion of the work. Eastimated durations of the required work tasks and their scheduling are provided in Figure C-33 at the end of this appendix.

1. Initial demolition — remove tie-down anchoring (1 work day, up to 5.8 hrs for eight anchors)
   a. See Tables C-1 and C-2 for projected equipment, supply, and personnel needs before conducting work.
   b. Remove panels with tie-down anchoring.
      (1) Use an impact hammer to remove the panel anchoring nut from each panel.
      (2) Collect nuts and washers removed and save for later use.
      (3) Remove the UHMW panel from its position.
         (a) Use a wrecking bar to help pry and lift one end of the panel up so it can be lifted by hand. Be careful not to damage the panel.
         (b) Place the panel to the side of the location from which it was removed.
         (c) Use a putty knife to remove any joint sealant and backer rod from the panel (perimeter and anchoring holes) and from the portion of the panel void perimeter from which the panel was

removed. Clean the washers and nuts removed from the panel anchoring.

c. Drill a partial-depth core around each tie-down anchor.
   (1) Center the core bit over the center of the tie-down anchor.
   (2) Cut to a depth of at least 10 in. measured from the depth of the panel slot.
d. Remove the material within the cored perimeter.
   (1) Use a wrecking bar to pry the material and break it free from its base.
   (2) If prying does not work, the material will need to be demolished with power equipment. Use a demolition hammer or light jackhammer to break out the material. Be careful not to damage the surrounding pavement.
   (3) Level the depth of the core using a bushing bit on the demolition hammer or a jackhammer to create a smooth surface.
   (4) Remove large debris by hand. Use a vacuum to help remove small debris material from the depth of the core.
e. Thoroughly clean the perimeter of each cored void.
   (1) Scrub the void surfaces with a stiff bristled brush to remove saw slurry and fine particles.
   (2) Generously rinse the void surfaces with water.
   (3) Use the vacuum to remove the dirty water from the cored void. Remove water to the full depth of the core and clean the bottom.
   (4) Repeat this cleaning process two more times.
   (5) Air blast the cleaned void when complete.
f. Place rapid-setting concrete.
   (1) Start batching material once multiple voids are cleaned, and the entire unit batched can be utilized at one time.
   (2) Batch material following manufacturer directions. Products without aggregate extensions will require aggregates to be added. Most prepackaged products will yield enough material to fill cored voids with some waste. Use an approved cementitious pavement repair material for permanent runway repairs.
   (3) For 4 in. diameter cores, typical prepackaged materials will fill four repairs with some waste (assumes product yields 0.4 ft^3).
   (4) Place material in each void. Strike off each repair at the surface of the concrete to remove excess material. Float and trowel the surface to make it flush and smooth with the panel slot depth surface. No texturing is needed.

g. Allow the concrete placed to gain strength. Ensure at least 2,500 psi of compressive strength is achieved before carrying on with work activities within the panel slot. Estimated time is approximately 90 min at 70°F, but refer to the manufacturer's provided information. Use a nondestructive Schmitt hammer testing device to monitor strength gain.
h. Water blast the panel slot and surrounding pavement with a pressure washer to remove saw slurry and debris. Start at the pavement crown and work towards the shoulder.
i. Removed panels can be installed once their areas are completely water blasted.
   (1) Position the panel to align the anchoring studs through the holes. Provide approximately ½ in. joints between the panels and the surrounding pavement.
   (2) Replace the washers and nuts on the anchoring studs.
   (3) Gross tighten the nuts using an impact hammer.
   (4) Fine tighten the nuts using a torque wrench set to 60 ft-lbs.
j. Do not replace joint sealant at this time. All joint sealant will be reinstalled at the conclusion of the project.
k. Finalize site cleanup and exit the runway.

Table C-1. Personnel needs and tasks for tie-down anchoring removal activity.

Description	Task	Quantity
Installer	Remove and install panels, operate generator	2
Demolisher	Remove anchoring equipment and concrete	
Equipment operator	Operate core rig	1
Spotter	Assist with aligning core rig, move and maintain electrical cords as needed	1
Equipment operator/hose tender	Move and maintain water truck and hose	1
Cleaner	Clean core voids, pressure wash and clean pavement	2
Concrete batcher	Make and distribute concrete	2
Concrete finisher	Place and finish concrete	1
Equipment operator	Operate airfield sweeper truck	1

Table C-2. Equipment and supply needs for tie-down anchoring activity.

Equipment	
Item	**Quantity**
Impact hammer	1
$1^1/_8$ in. socket	3
Electric generator, 5000 W minimum	2
Electric extension cord, 25 ft minimum, 15 A rated	4
Putty knife, 1 in. blade	2
Wrecking bar, 36 in.	1
Core rig	1
Water truck, 1000 gal min	1
Water hose, ¾ in. diameter by 50 ft long	6
Engineer hammer/maul, 3 lb	1
Demolition or jack hammer, 40 lb max	1
Variety of bits for demolition hammer	-
Scaling chisel, 3 in.	1
Cold chisel, 1 in.	1
Moil point	1
Slotting tool	1
Bushing bit	1
Air compressor, 100 cfm minimum*	1
Air hose, ¾ in. diameter, 50 ft*	1
Wet/dry vacuum, 5 hp min, with accessory tools	1
Steel wire brush	2
Plastic bucket, 5 gal	10
Small air compressor lance	1
Small air compressor hose, $^3/_8$ in. diameter, 50 ft	1
Small air compressor, 4 gal minimum, electric	1
Electric drill, 6-A min**	1
Magnesium concrete float	1
Steel concrete trowel	1
Torque wrench, 100 ft-lb capacity	2
Push broom	1
Squeegee	1

Equipment	
Pressure washer	2
Airfield sweeper truck	1
Supplies	
Item	**Quantity**
Diamond core barrel, 12 in. long min., 4 in. inner diameter	2
Measuring cup, 1 gal capacity	2
Paddle mixer bit**	2
Rapid-setting concrete mix, approximately 50 lb per unit	3

* Required only if pneumatic jackhammer is used.
** Other acceptable handheld concrete mixer may be used.
Italicized items are not included in a Standard USAF SuPR kit.

2. Initial demolition - Remove panel anchoring (10–20 work days, 6.6 hr total per day for two panels, 9.0 hr total for four panels)
   a. See Tables C-3 and C-4 for projected equipment, supply, and personnel needs before conducting work.
   b. Remove panels.
      (1) Approximately four panels will be demolished per work day to accomplish this task within the time requirements given. Assuming 40 panels across a 150 ft runway, this work event will take 10 work days. If fewer than four panels are completed per work day to better accommodate allowable runway closure needs, additional work days will be needed. Remove at least one panel from the next adjacent section to prevent damage to the panel and ensure a flush repair.
      (2) Use an impact hammer to remove the panel anchoring nut from each panel.
      (3) Collect nuts and washers removed and save for later use.
      (4) Remove the UHMW panel from its position.
         (a) Use a wrecking bar to help pry and lift one end of the panel up so it can be lifted by hand. Be careful not to damage the panel.
         (b) Place the panel to the side of the location from which it was removed.
         (c) Use a putty knife to remove any joint sealant and backer rod from the panel (perimeter and anchoring holes) and from the portion of the panel void perimeter from which the panel was

removed. Clean the washers and nuts removed from the panel anchoring.

c. Partial depth core around each panel anchor.
   (1) Center the core bit over the center of the tie-down anchor.
   (2) Cut to a depth of at least 10 in. measured from the depth of the panel slot.
d. Remove the material within the cored perimeter.
   (1) Use a wrecking bar to pry the material and break it free from its base.
   (2) If prying does not work, the material will need to be demolished with power equipment. Use a demolition hammer or light jackhammer to chisel out the material. Be careful not to damage the surrounding pavement.
   (3) Level the depth of the core using a bushing bit on the demolition hammer or jackhammer to create a smooth surface.
   (4) Use a vacuum to help remove debris material from the depth of the core.
e. Thoroughly clean the perimeter of each cored void.
   (1) Scrub the void surfaces with a stiff bristled brush to remove saw slurry and fine particles.
   (2) Generously rinse the void surfaces with water.
   (3) Use the vacuum to remove the dirty water from the cored void. Remove water to the full depth of the core and clean the bottom.
   (4) Repeat this cleaning process two more times.
   (5) Air blast the cleaned void when complete.
f. Place rapid-setting concrete in panel slot void.
   (1) Start batching material once air blasting removes standing water. A CTL with concrete mixing drum is the preferred method of mixing and transport due to the larger quantity of material made and large discharge point area.
   (2) Batch material following manufacturer directions. Products without aggregate extensions will require aggregates to be added. Most prepackaged products will yield enough material to fill four cored voids with some waste. The panel slot will require 7.1 ft^3 of material with waste. Assuming typical prepackaged products yield 0.4 ft^3, approximately 18 units will be required for each work day for this task. Have an additional set of units available during work to ensure enough material is provided for work.

(3) Wash out the drum at an approved location close to the site. A portable wash-out station consisting of a small, watertight dumpster is recommended so that washing out can be accomplished in the vicinity of the site without any environmental issues and additional extensive cleanup of the site at the conclusion of the work day. The container can be emptied at an approved site after the work day.

(4) Place material from shoulder side to crown side. Focus on filling the anchoring voids first before filling the panel slot void to prevent a single monolithic placement. Screed the surface to remove excess material. Float and trowel the surface to make it flush and smooth with the existing pavement. Provide texturing with a light broom finish.

g. Allow the concrete placed to gain strength. Ensure at least 2,500 psi of compressive strength is achieved before carrying on with work activities around the panel. Estimated time is approximately 90 min at 70°F but refer to the manufacturer's provided information. Use a nondestructive Schmitt hammer testing device to monitor strength gain.

h. Sawcut and remove the excess rapid-setting concrete placed in the vicinity of the extra panel removed to ensure a flush repair and prevent damage to said panel. Dispose of debris.

i. Water blast the panel slot and surrounding pavement with a pressure washer to remove saw slurry and debris. Start at the pavement crown and work towards the shoulder.

j. Reinstall any paneling outside the project area that was removed to prevent damage.

k. Finalize site cleanup and exit the runway.

l. Continue with next work phases once all panels are removed and the panel slot is backfilled with concrete.

Table C-3. Personnel needs and tasks for panel anchoring removal activity.

Description	Task	Quantity
Installer	Remove and install panels, operate generator, cut concrete	2
Demolisher	Remove anchoring equipment and concrete	
Equipment operator	Operate core rig	1
Spotter	Assist with aligning core rig, move and maintain electrical cords as needed	1
Cleaner	Clean core voids, pressure wash and clean pavement	2-3
Concrete batcher	Produce concrete	2
Concrete finisher	Place and finish concrete	3
Equipment operator	Operate CTL to make and transport concrete, operate airfield sweeper truck	1
	Move and maintain water truck, manage water hoses	1

Table C-4. Equipment and supply needs for panel anchoring activity.

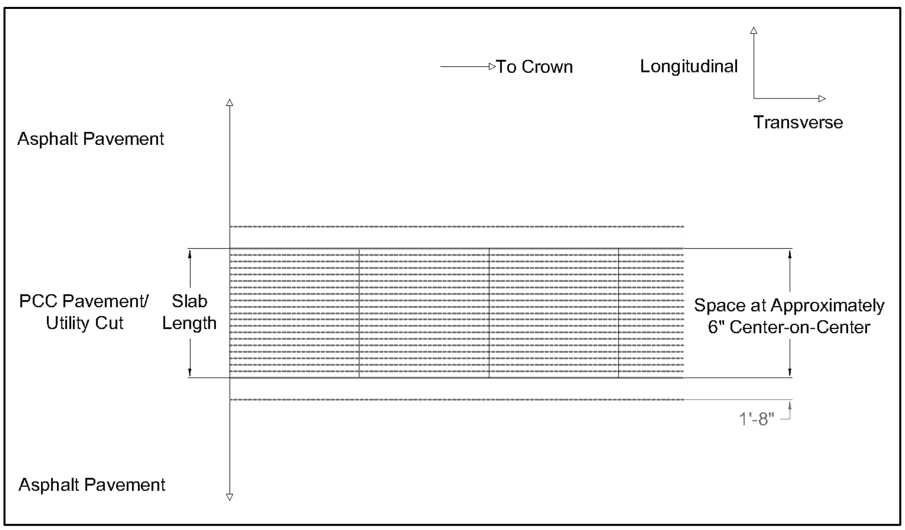
Equipment	
Item	**Quantity**
Impact hammer	1
1 1/8 in. socket	3
Electric generator, 5000 W minimum	2
Electric extension cord, 25 ft minimum, 15 A rated	4
Putty knife, 1 in. blade	2
Wrecking bar, 36 in.	1
Core rig	1
Water truck, 1000 gal min	1
Water hoses, ¾ in. diameter by 50 ft long	6
Engineer hammer/maul, 3 lb	1
Demolition or jack hammer, 40 lb max	1
Variety of bits for demolition hammer	-
Scaling chisel, 3 in.	1
Cold chisel, 1 in.	1
Moil point	1
Slotting tool	1
Bushing bit	1

Equipment	
Item	**Quantity**
Air compressor, 100 cfm minimum*	1
Air hose, ¾ in. diameter, 50 ft*	1
Wet/dry vacuum, 5 hp min, with accessory tools	1
Steel wire brush	2
Plastic bucket, 5 gal	10
Small air compressor lance	1
Small air compressor hose, 3/8 in. diameter, 50 ft	1
Small air compressor, 4 gal minimum, electric	1
Compact track loader	1
Concrete mixer attachment for CTL, 6 ft³ min	1
Hopper/dumpster, 3000 lb capacity, 2 yd³ capacity	1
Magnesium concrete float	2
Steel concrete trowel	2
Concrete hand screed, 3 ft long	1
Gas powered cutoff saw	1
Ppush broom	1
Squeegee	1
Pressure washer	2
Airfield sweeper truck	1
Supplies	
Item	**Quantity**
Diamond core barrel, 12 in. long min, 4 in. inner diameter	2
Measuring cup, 1 gal capacity	2
18 in. diamond saw blade	1
Rapid-setting concrete mix, approximately 50 lb, per work day	24

* Required only if pneumatic jackhammer is used.
** Other acceptable handheld concrete mixer may be used.
Italicized items are not included in a Standard USAF SuPR kit.

3. Demolition preparation - Transverse sawcutting (2 work days, 5.6 hr daily)
   a. See Tables C-5 and C-6 for projected equipment, supply, and personnel needs before conducting work.
   b. Mark sawcut locations on the pavement across half the runway width (Figure C-1).
      (1) Lay out sawcut locations using a tape measure and lumber crayon. Marks should be spaced approximately 6 in. apart. Make sets of marks every 25 ft transversely across the runway (four total sets).
      (2) Make additional marks for cuts 20 in. off each AC/PCC construction joint.

Figure C-1. Transverse sawcutting locations.



      (3) Snap a chalk line between the corresponding parallel marks made with water-resistant chalk.
         (a) Use two, three man teams: one operates the tool, one holds the free end, and one snaps the line.
         (b) Complete all lines longitudinally within a set of crayon marks before moving transversely across the runway. This will allow the saws to start before all lines are made.
   c. Begin sawcutting with the large floor saws using 18 in. saw blades.
      (1) Allow ample time for the chalking crew to snap lines before starting sawing efforts. Chalk will not stick and stain the concrete surface if wet.
      (2) Cut to a depth of 3¾ in. minimum for cuts within the PCC pavement (Figure C-2). Cut the AC pavement its full depth.

Figure C-2. Making transverse cuts with the floor saw.

(3) Have pressure washers lightly clean the surface to see chalk lines as needed (Figure C-3). Use a less aggressive spray nozzle if available.

Figure C-3. Lightly rinsing the surface while sawing.

(4) If multiple saws are used at one time, stagger saw start times and cuts made to allow for continuous cutting.
   (a) Scheduling shown uses one saw. Only half the marks drawn will be needed per work day.
   (b) If two saws are used, 1 work day is required. All the transverse marks are required for this per work day. Make the appropriate number of marks are required the area per work day. Have as many marking teams as sawing teams used.

d. Water blast the cut area and surrounding pavement with a pressure washer to remove saw slurry and debris (Figure C-4). Start at the pavement crown and work towards the shoulder.

Figure C-4. Waterblasting saw slurry.

e. Vacuum the project area with the airfield sweeper truck.
f. Finalize site cleanup and exit the runway.

Table C-5. Personnel needs and tasks for transverse sawing activity.

Description	Task	Quantity
Marker	Mark locations for chalk lines	2
Chalk line team	Make chalk lines	6 (2 teams of 3)
Equipment operator	Operate floor saw	1
Spotter	Assist with aligning saw	1
Hose tender	Move and maintain water truck and hose	1
Cleaner	Pressure wash and clean pavement	2
Equipment operator	Operate airfield sweeper truck	1

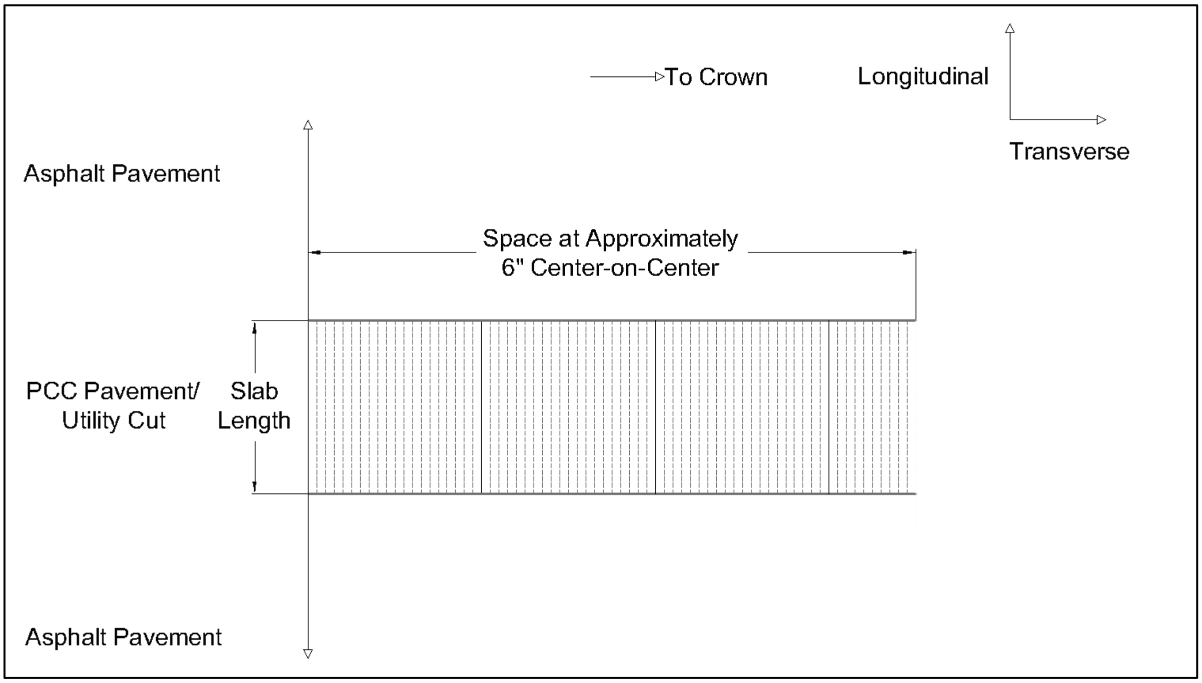
Table C-6. Equipment and supply needs for transverse sawing activity.

Equipment	
Item	**Quantity**
Measuring tape	2
Chalk line tool	2
Floor saw	1
Push broom	2
Squeegee	2
Water truck, 1000 gal minimum	1
Water hoses, ¾ in. diameter by 50 ft long	6
Pressure washer	2
Airfield sweeper truck	1
Supplies	
Item	**Quantity**
Water-resistant chalk, bottle	1
Lumber crayons, each	4
18 in. diameter concrete saw blade	2

Italicized items are not included in a Standard USAF SuPR kit.

4. Demolition preparation - Longitudinal sawcutting (4 work days, 6.0 hr)
   a. See Tables C-7 and C-8 for projected equipment, supply, and personnel needs before conducting work.
   b. Mark sawcut locations on the pavement (Figure C-5).
      (1) Lay out sawcuts to make using a tape measure and a lumber crayon. Marks should be spaced approximately 6 in. apart.

Figure C-5. Longitudinal sawcutting locations.



(2) Snap a chalk line between the corresponding parallel marks made with water-resistant chalk.
   (a) Use two, three man teams: one operates the tool, one holds the free end, and one snaps the line.
   (b) Work transversely starting at the shoulders. This will allow the saws to start before all lines are made.
(3) Make additional marks 20 in. off the PCC pavement for cuts in the AC area just off the AC/PCC construction joint. Four marks are needed at 30 ft spacings centered for each joint.

c. Begin sawcutting with the small walk-behind saws using 18 in. saw blades (Figure C-6).
   (1) Allow ample time for the chalking crew to snap lines before starting sawing efforts. Chalk will not stick and stain the concrete surface if wet.
   (2) Cut to a depth of 3¾ in. minimum.

Figure C-6. Making longitudinal cuts.

(3) Have pressure washers lightly clean the surface to see chalk lines as needed. Use a less aggressive spray nozzle if available.

(4) If multiple saws are used at one time, spread saws across the work area to minimize the need to move the saws long distances and allow for continuous cutting.

(a) Scheduling shown uses one saw.

(b) If two or four saws are used, 2 or 1 work day is required, respectively. Make the appropriate number of marks required for the area per work day. Have as many marking teams as sawing teams used.

d. Water blast the cut area and surrounding pavement with a pressure washer to remove saw slurry and debris. Start at the pavement crown and work towards the shoulder.

e. Vacuum the project area with the airfield sweeper truck.

f. Finalize site cleanup and exit the runway. The surface of the pavement should look similar to that shown in Figure C-7 after completion.

Figure C-7. Pavement surface after all sawcuts are made.

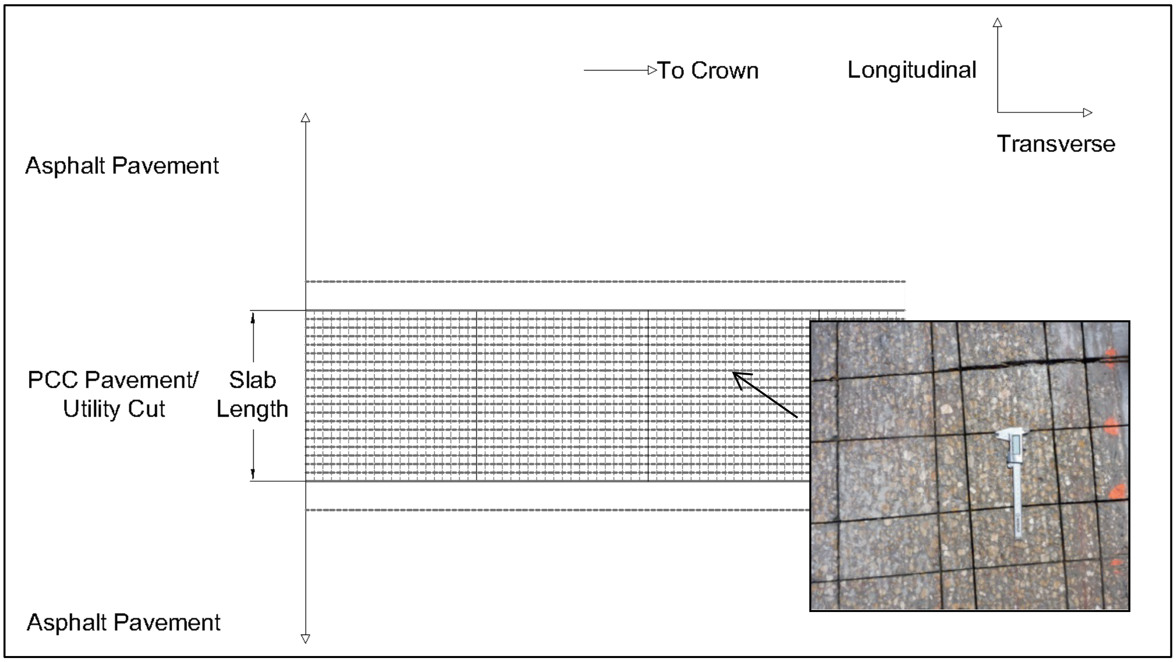


Table C-7. Personnel needs and tasks for longitudinal sawing activity.

Description	Task	Quantity
Marker	Mark locations for chalk lines	2
Chalk line team	Make chalk lines	4 (2 teams of 2)
Equipment operator	Operate floor saw	2
Hose tender	Move and maintain water truck and hoses	1
Cleaner	Pressure wash and clean pavement	2
Equipment operator	Operate airfield sweeper truck	1

Table C-8. Equipment and supply needs for longitudinal sawing activity.

Equipment	
Item	**Quantity**
Measuring tape	2
Chalk line tool	2
Small walk-behind saw	2
Push broom	2
Squeegee	2
Water truck	1
Water hoses, ¾ in. diameter x 50 ft long	8
Pressure washer	2
Airfield sweeper truck	1
Supplies	
Item	**Quantity**
Water-resistant chalk, bottle	1
Lumber crayons, each	4
18 in.-diameter concrete saw blade	2

Italicized items are not included in a Standard USAF SuPR kit.

5. AC overlaying (5 work days, 8.4 hr total each day)
   a. See Tables C-9 and C-10 for projected equipment, supply, and personnel needs before conducting work.
   b. Mill a 20 in. strip of AC pavement at the AC/PCC construction joint using the compact track loader and cold planer attachment (FigureC-8).
      (1) Keep the milling head within the sawcut boundary. Excessively crossing the sawcut may result in the need to recut the joint straight and fully parallel to the UHMW panels.
      (2) Mill the asphalt pavement between the sawcuts and foundation full depth to expose the underlying base material.
         (a) Make passes in 1 in. increments. One pass per cut depth will be required. Maintain approximately 1 in. away from the precut edges to prevent damaging materials outside the boundaries.
         (b) Continually lower the milling head with each pass made. This allows the cold planer to use existing pavement as a stable guide to control the cutting depth.

(3) Have the airfield sweeper truck vacuum the patch slot after each pass of the CTL to clean the millings. Excess millings under the CTL track paths will reduce its traction and cutting speed.

(4) Complete milling on one side of the panels before moving forward.

(5) After milling is complete on each side, use a demolition hammer or light jackhammer to remove the unmilled portions within the slot perimeter.

c. Wet the exposed base material with water to prepare for compaction. Apply approximately 1 gal/yd^2 evenly across the base material.

d. Compact the exposed base material with a plate compactor. Make a minimum of three passes over all areas.

Figure C-8. Milling AC at construction joint.

e. Chisel the existing concrete panel foundation to a minimum depth of 3¾ in (Figure C-9).
   (1) Use two jackhammers and teams of two: one person operates the jackhammer and the other removes the debris generated.
   (2) Operate the jackhammer such that it impacts at the depth of the relief cuts made at a 30 to 45° angle from horizontal. The idea is to pop off the individual square pieces as whole units from the surface of the existing foundation. Operating the jackhammer more vertically than recommended chips the units into multiple small pieces that take more time to remove, makes debris clearing efforts more extensive, and removes more material than needed.
   (3) Remove medium and large pieces of debris by hand and deposit them in a front end loader or backhoe bucket. Empty the bucket into a dump truck as needed.

Figure C-9. Concrete foundation surface removal.

f. Mill the surface of the remaining concrete foundation using the compact track loader (Figure C-10).
   (1) The goal of the task is to take out the high spots that remain in the existing surface. Some low spots may be present may still exist after this task. Mill the surface approximately ¼ in. such that the elevation difference between before and after demolition is greater 3¾ in. as a whole and the majority of the large, higher peaks are removed.
   (2) The AC/PCC construction joint can be used as an initial guide to help set the cut depth of the milling head. Adjust the milling head skis such that one rides on the higher AC joint surface and the other cuts into the PCC the desired depth. Remember to consider the difference in elevation of AC pavement that was not milled earlier. This is only an approximate measure since the compact track loader will ride on the uneven surface of the demolished concrete.
   (3) Use the jackhammers to knock down the areas where the milling machine cannot reach.
   (4) Larger and deeper surface voids will require filling with a skin coat of rapid-setting mortar or concrete repair material.
g. Remove all the smaller debris within the repair void.
   (1) Vacuum the demolition area with the airfield vacuum truck to remove the small debris that remains.
   (2) Water blast the concrete surface to remove any loose portions of the surface.
   (3) Heavily air blast the surface to remove all standing water and dry the surface as best as possible. Use the airfield vacuum truck hand wand to remove the material collected around the void perimeter.
h. Apply tack material to patching area surfaces.
   (1) Apply tack coat material at a rate of 0.10 ± 0.05 gal/yd^2.
   (2) Distribute the material evenly with a roofing brush. Minimize pooling in low areas with the uneven, rough surface.
i. Place the asphalt pavement overlay over the milled repair area (Figure C-11).
   (1) Current instructions are built around using ADR rapid asphalt patching technology. Follow guidance and job mix requirements given for material and equipment used. See ADR guidance on the use of the materials and equipment specified.

(2) Evenly dump hot mixed asphalt at one corner of the void. Spread material as needed by hand to allow for efficient screeding. Leave sufficient material head in front of the screed to produce smooth, full lifts, and paving lanes. Minimize hand placing material if possible.

(3) Use the compact track loader with asphalt screed attachment to screed the hot mixed asphalt placed. Use a tape measure to set the screed height.

(4) If the screed length does not reach and place material into the interior of the repair, place material by hand as needed.

(5) Compact placed material with a small dual smooth steel drum roller (Figure C-12).

(a) Roll loosely placed asphalt with the steel wheel roller. Follow guidance on ADR asphalt placement and materials. Use of density monitoring equipment and straightedge to ensure density and surface smoothness is met is highly recommended.

(b) If other local methods and materials are used to place the asphalt overlay, follow local practices. General procedures will be approximately as followed.

i. Start by making two static rolls around each perimeter edge of the repair.

ii. Break down the material with two vibrated passes.

iii. Finish roll the pavement with two static passes.

(c) Monitor compaction process with density measuring equipment and a straightedge. Tailor procedure as necessary to meet compaction requirements.

Figure C-10. Milling rough surface of patch area.

Figure C-11. Asphalt placement.

Figure C-12. Compacting asphalt patch.

j. Watershock the overlay surface to accelerate cooling the asphalt.
   (1) Distribute water over the surface of the asphalt overlay to help the material cool and gain strength. This can be done intermittently by hand (Figure C-13) or continuously with the help of a lawn sprinkler.
      (a) Use of a cart-mounted lawn sprinkler is recommended for continuous cooling.
      (b) When the lawn sprinkler is used, set up the sprinkler and water truck towards the runway crown end of the overlay and allow the water to flow to the shoulder. Set equipment such that it lies on cool pavement and the water sprayed lands at 1 ft from the start of the overlay.
      (c) Place sandbags over the cart wheels to prevent movement.
      (d) Two systems will be required for overlaid areas at the pavement crown.

(2) Monitor the surface temperature of the overlay with an infrared thermometer at 5-min intervals. Take at least six measurements at random locations across the patched area.

(3) Stop cooling once the surface reaches 125°F or is similar to surrounding pavement.

k. Finalize site cleanup and exit the runway. The surface of the pavement should look similar to that shown in Figure C-14 after completion.

Figure C-13. Watershocking freshly compacted asphalt pavement by hand.

Figure C-14. Finished patched area.

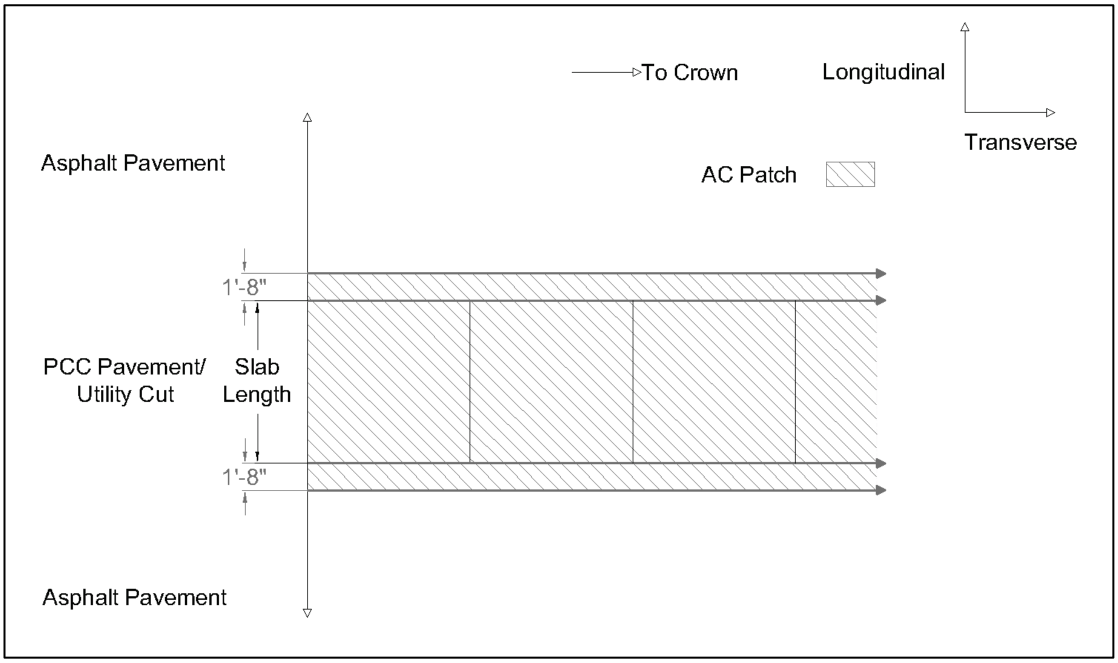


Table C-9. Personnel needs and tasks for AC overlaying activity.

Description	Task	Quantity
Equipment operator	Cold mill pavement with CTL, screed hot mixed asphalt	1
	Operate airfield vacuum sweeper, operate CTL with bucket/front end loader	1
	Operate dump truck, deliver hot mixed asphalt	1
	Operate soil compactors	1
Spotter	Assist CTL and airfield sweeper operators	1
Demolisher	Break concrete and remove large pieces	4 (2 teams of 2)
Hose tender	Operate water truck and manage water hoses	1
Cleaner	Air blast and pressure wash pavement surfaces	2
Asphalt placer	Apply tack coat, hand distribute hot mixed asphalt	4

Table C-10. Equipment and supply needs for AC overlaying activity.

Equipment	
Item	**Quantity**
Compact track loader	1
Cold milling head for CTL, 18 in.-wide	1
Airfield sweeper truck	1
Water truck, 1000-gal min	1
Plate compactor, plate less than 18 in.-wide	1
Jackhammer 40-lb max	2
¾ in.-diameter air house, 50 ft	2
Air compressor, 100-cfm min	1
Bits for jackhammer	-
Cold chisel	2
Scaling chisel	2
Moil point	2
Bushing bit	2
Front end loader or backhoe	1
Dump truck, 5-yd^3 min	1
Wrecking bar, 36 in.	2
Engineer's hammer/maul, 3-lb	2
Push broom	2
Square shovel	3
Backpack blower	1
Drill and paddle mixer	1
Measuring cup, 1-gal capacity	1
Bucket, 5-gal	4
Water hoses, ¾ in.-diameter x 50 ft long	6
Pressure washer	2
Roofing broom	2
Asphalt rake/lute	2
Asphalt screed CTL attachment	1
Tape measure, 25 ft	1
Roller compactor, dual steel wheel	1
10- to 12 ft straight edge, aluminum	1

Equipment	
Item	**Quantity**
Water sprinkler	1
Infrared temperature gun	1
Supplies	
Item	**Quantity**
Set of replacement teeth for cold milling head	3*
Rapid-setting concrete or mortar mix, approximately 50-lb units, per work day	8
*Asphalt binder, paving grade, gallons***	8
*Hot mixed asphalt, airfield grade, ton***	11.5

*Total for entire project work.

** Include 20% waste, assumes 4 in. total placement across patch.

Italicized items are not included in a Standard USAF SuPR kit.

6. Panel Installation Preparation (1 work day, 3.3 hrs)
7. See Tables C-11 and C-12 for projected equipment, supply, and personnel needs before conducting work.
   a. Mark the slot perimeter (Figures C-15 and C-16).
      (1) Determine the centerline where the panels will be placed. Lay out sawcuts using a tape measure and lumber crayon. Make marks to produce a 25 in.-wide slot centered over the determined centerline.
      (2) Snap a chalk line between the corresponding parallel marks made with water-resistant chalk.
   b. Sawcut the panel slot perimeter with the floor saw using 18 in. diameter saw blades. Cut to a minimum depth of 4 in.
   c. Water blast the sawed area.

Figure C-15. Location of new panel slot.

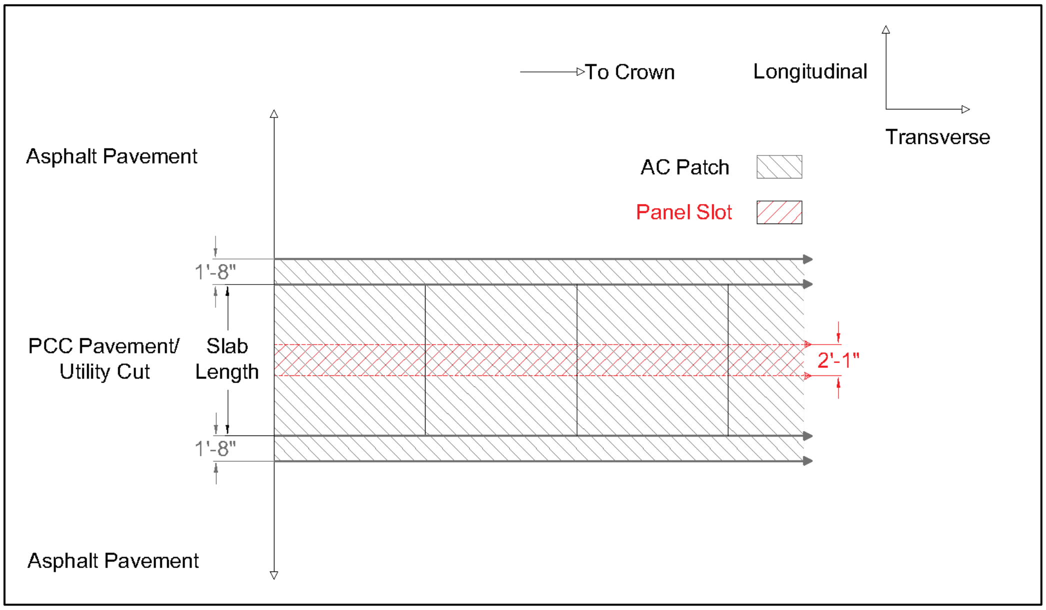


Figure C-16. Sawcutting new panel slot area.

Table C-11. Personnel needs and tasks for transverse sawing activity.

Description	Task	Quantity
Marker	Mark locations for chalk lines	2
Chalk line team	Make chalk lines	4 (2 teams of 2)
Equipment operator	Operate floor saw	1
Spotter	Assist with aligning saw	1
Hose tender	Move and maintain water truck and hose	1
Cleaner	Pressure wash and clean pavement	2
Equipment operator	Operate airfield sweeper truck	1

Table C-12. Equipment and supply needs for transverse sawing activity.

Equipment	
Item	**Quantity**
Measuring tape	2
Chalk line tool	2
Floor saw	1
Push broom	2
Squeegee	2
Water truck	1
Water hoses, ¾ in.-diameter by 50 ft long	4
Pressure washer	2
Airfield sweeper truck	1
Supplies	
Item	**Quantity**
Water-resistant chalk, bottle	1
Lumber crayons, each	4
18 in.-diameter concrete saw blade	2

Italicized items are not included in a Standard USAF SuPR kit.

8. Panel Installation (5 work days, 11.0 hr total each day)
   a. See Tables C-13 and C-14 for projected equipment, supply, and personnel needs before conducting work.
   b. Slot panel demolition (Figure C-17).

(1) Place eight panels per work day. Start on one edge of the runway and work across the crown transversely.
(2) Remove any immediately adjacent panels touching the work perimeter for the day to prevent damage.
(3) Remove the material within the sawcuts with the compact track loader with cold planer attachment.
  (a) Cut to a minimum depth of 3-¾ in. Mill in 1 in. depth increments maximum until the surface of the concrete foundation is visible. Mill approximately an additional ¼ in. into the exposed PCC surface to ensure all asphalt coated surfaces are removed.
  (b) Focus on the center 23 in. width to ensure the slot edges are not damaged. Make two passes for each lift cut.
  (c) Use an airfield vacuum truck to remove the millings made after each pass.
  (d) Remove the edges of the material not milled with a demolition hammer or light jackhammer. A wrecking bar and hammer may also be used on the asphalt portion. Powered equipment will be required for demolishing any concrete requiring modification.
  (e) Remove any large loose or delaminated pieces of asphalt by hand as needed.
(4) Verify the minimum depth of material was removed with the depth checking tool.
(5) Verify the smoothness of the slot depth. Remove any gross surface elevation deviations or patches of asphalt residue still present.
(6) Remove any remaining debris with the airfield vacuum truck hand wand.
(7) Water blast the slot surface.
(8) Vacuum the slot area with the airfield sweeper truck.
(9) Air blast the panel slot.

c. Place the bedding layer.
(1) Place the appropriate bonding agent for the pavement repair material used on the concrete surface. Materials that use water as the bonding agent are preferred for this work. If water is used, this work task is not required if the panel slot surface is still saturated surface dry after air blasting.

(2) A CTL with concrete mixing drum is the preferred method of mixing and transport due to the larger quantity of material made and large discharge point area (Figure C-18).
   (a) Use an approved cementitious pavement repair material for permanent runway or temporary crater repairs.

Figure C-17. Milling panel slot location.

Figure C-18. Batching concrete with CTL.

(b) Use manufacturer or typical guidance for hot or cold weather placements to mitigate changes in set time. Some recommended mitigation techniques include the following:
   i. Hot: Replace mixing water with chilled or ice water, use a retarding admixture.
   ii. Cold: Keep materials warm until used, use warmed water.

(c) The panel slot will require approximately 15.5 ft^3 of material with a conservative amount of waste (two slab installation, 15 ft wide slabs, 2.5 in. deep bedding layer repair, 25% waste). Assuming typical prepackaged products yield 0.4 ft^3, approximately 38 units will be required for each work day. Ensure enough material for an additional two full CTL deliveries is available in case deeper than expected repairs are encountered.

(d) Mix the concrete at the batch site for at least two min once all components are added. Mix materials at a speed and angle that allow for complete incorporation of the materials, but minimizes splatter and material loss from the drum. Rotating the drum back and forth, if allowed by the equipment, can help mix all components together efficiently.

(3) Continue agitating the material slowly while delivering the material.

(4) Washout the drum and equipment at an approved location close to the site. A portable washout station consisting of a small, watertight dumpster is recommended such that it can be accomplished in the vicinity of the site without any

environmental issues. The container can be emptied at an approved site at the conclusion of the work day.

(5) Have a three-person finishing team construct the bedding layer (Figure C-19).

(a) Two people will screed and trowel the concrete; and one person will direct material placement, move concrete as needed, and maintain site cleanliness.

(b) Place material from the shoulder to the runway interior. Use a square shovel to block and prevent concrete splatter.

(c) Screed the surface of the concrete to a depth of 1-5/8 in. below the pavement surface. Pass the screed multiple times to remove excess material. Start the screed over previously placed areas to provide smooth transitions between placements.

(d) Float and trowel the surface to make it flush and smooth. Work fast and efficiently to ensure the material does not set up before work is complete.

(e) Remove excess material at the end of the placement and deposit it into an empty bucket for removal.

Figure C-19. Placing and finishing the bedding material.

d. Allow the concrete to gain at least 2,500 psi of compressive strength before continuing with work activities within the panel slot. The estimated time to reach this strength is approximately 90 min at 70°F, but refer to the manufacturer's provided information. Use a nondestructive Schmitt hammer testing device to monitor strength gain.
e. Arrange the panels near their prospective installation locations in the correct order within the slab (Figure C-20). See AFI 32-1043 for the correct panel sequence for the width for the slabs. Ensure locations that require tie-down anchoring receive the correct panel type. Place panels approximate 5 ft away from the slot area to allow work to continue.
f. Reestablish joints at existing locations within the bedding layer. Use the handheld cutoff saw to cut joints 4-½ in. deep minimum (Figure C-21). Air blast each cut after completion.
g. Clean the vertical faces of the slot perimeter with an angle grinder and wire cup brush (Figure C-22).
h. Inspect the depth of the panel slot (Figure C-23). Ensure the surface is smooth and level so the panels lie correctly in the slot once completed.
    (1) Begin verifying the surface while the concrete is gaining strength. Mark locations that require leveling with a lumber crayon.

Figure C-20. Arranging panels.

Figure C-21. Joint cutting.

Figure C-22. Cleaning slot perimeter.

Figure C-23. Final leveling of the panel slot.

(2) Level locations with a small hand scabbler, handheld angle grinder with masonry disk, or demolition hammer/light jackhammer with a bushing bit after the surface reaches 2,500-psi compressive strength. Other appropriate equipment may be used if available to accomplish this task.

i. Air blast the panel slot to remove all small debris.

j. Cut water drain slots in the panel depth (Figure C-24).

(1) Use the walk-behind saw with two 18 in.-diameter saw blades butted together.

(2) Cut two slots transversely in the bedding layer ½ in. deep. Use the panel void vertical faces as guides. Ensure the cuts are not within 6 in. of the panel slot's vertical face to avoid panel anchoring locations.

(3) Connect previously cut drain slots from previously installed panels as best as possible. Do not damage any existing anchors.

Figure C-24. Cutting drain slots.

k. Water blast the panel slot.
l. Air blast the panel slot.
m. Place and install the panels.
    (1) Place panels in the slot. Ensure locations that require tie-down anchoring receive the correct panel type.
    (2) Shim panels into position using wooden wedges (Figure C-25).
        (a) Arrange panels such that approximately ½ in. joints are between the slot vertical faces and between each panel.
        (b) Draw a stringline across the top of the panels. Pick a convenient location/point to assist in aligning the panels. Tangent to the panel anchoring holes is a good location to use as reference. Use masonry nails to fix the string line to the selected location.
        (c) Use wrecking bars to help move panels and add shims as needed to prevent movement.
        (d) Do not break shims after installation. Shims will be removed after anchoring is installed.
        (e) Ensure the panels are solidly locked into position before moving forward with work tasks. Use wrecking bars to help move panels and add shims as needed.
    (3) Install panel anchoring (Figure C-26).
        (a) Drill holes into the concrete foundation using an appropriately sized masonry drill bit and hammer drill. Use the panel anchoring drill guide to ensure a vertical cut is made to the correct depth. Use two drills for increased speed, one on each side of the panel transversely.
        (b) Clean the anchoring holes following the adhesive manufacturer's directions. Typical cleaning procedures include air blasting, wire brushing, and another round of air blasting to remove all loose material in the drilled hole.
        (c) Set out and prepare each anchor for installation.
            i. Anchors should be prepared with setting hardware arranged before placement. Ensure the acorn nut is rotated a full twist loose from fully hand tightened on the thread rod before placement. Set out any tie-down anchoring encountered.
            ii. Embedded steel within the concrete may be encountered if the concrete is reinforced and/or ties or dowels are present. The masonry bit will not cut through the steel. Anchors must be trimmed to accommodate the shorter

embedment length. Use a portable band saw to trim the affected anchors to an appropriate length where the threaded rod does not extend above the panel surface.

Figure C-25. Aligning panels within the slot.

Figure C-26. Anchor hole production line.

(d) Install anchoring hardware into each hole (Figure C-27).

i. AFI 32-1043 describes the use of prepackaged adhesive packets for this task. Ensure the correct amount (or combination of packets if applicable) of adhesive is placed into the hole to ensure all necessary adhesive is provided. Follow all manufacturer directions to correctly use adhesive.

ii. Bulk adhesive cartridges that use a mixing tube to premix adhesive before entering the drilled holes are highly recommended to ensure all adhesive is properly mixed at the correct ratio. Large cartridges with pneumatic handheld dispensing equipment are recommended to minimize time lost to changing cartridges. An off-site trial of this work is highly recommended to determine the proper equipment settings the filling times.

(i) Ensure enough adhesive is used to embed the anchor. Adjust the air regulator such that adhesive is deposited without leaving air voids but is allowed to flow expeditiously enough to install all anchors in a timely fashion without clogging.

(ii) The proper amount of adhesive has been dispensed when the adhesive is level with the bottom surface of the panel slot when the anchor is installed. Use the first few holes to determine the amount of adhesive needed.

(iii) Clean any excess adhesive that enters the countersunk area with a paper towel before it hardens.

(iv) Rotate the anchor back and forth while in the hole to ensure adhesive completely surrounds the anchor thread.

(v) Cool or heat adhesive to modify setting times as needed in extreme weather conditions.

Figure C-27. Anchor installation.

(4) Install tie-down anchoring (if present in panel arrangement installed on work day, Figure C-28).

(a) Once the drilling is complete, preparations for tie-down anchoring can begin. One drill operator makes the small partial depth core for the anchoring eye, and the other makes the embedding hole deeper into the concrete foundation for the anchor shank.

(b) The first drill operator must change drill bits to the dry coring bit. Center the core bit in the tie-down anchor hole and cut to a depth of 3 in. Make one continuous cut if possible. Removing the core bit at any time in the process requires the hole to be cleaned before continuing to prevent clogging and allow for additional cutting.

(c) The dry core bit used in hammer mode should demolish the majority of the cored material while used. If material is still present, use a chisel or bushing bit to level the bottom of the core.

(d) Air blast the core hole.

(e) Drill the tie-down anchor embedment hole. Use the tie-down anchoring drill guide to ensure a vertical cut made to the correct depth.

(f) Clean the anchoring hole following the adhesive manufacturer's directions.

(g) Install the tie-down anchor into the hole. Ensure the eye is aligned in the longitudinal direction.

n. Allow the adhesive to cure to full strength. This is temperature dependent; colder temperatures and base material (concrete foundation) require more set time than warmer temperatures. Do not activate the anchor until the cure time has been met.

o. Begin any cleanup efforts that do not disturb the anchoring adhesive. Remove the wooden wedges from the panels near the end of the cure period.

p. Once the adhesive has cured, install the hardware on the panel anchoring (Figure C-29).

(1) Remove the setting hardware and install a hex nut on each anchor stud. Use a 1-1/8 in. socket and an impact hammer/ratchet to aid in removal.

(2) Gross torque the hex nut on the panel anchoring with an impact wrench. Two short bursts are needed to spin the nut hand tight and begin torqueing the nut. Do not over torque the hex nuts.

(3) Fine torque the hex nuts on the panel anchoring with a torque wrench set to 60 ft-lbs.

q. Verify the final anchor head elevations. Grind off any anchors that stick above the panel with an angle grinder (Figure C-30). Be careful not to damage the panel.

r. Finalize site cleanup and sweep project area. Exit the runway.

Figure C-28. Tie down anchorage installation.

Figure C-29. Permanent hardware installation.

Figure C-30. Grinding an anchor head flush with the panel surface.

Table C-13. Personnel needs and tasks for demolition and panel installation activities.

Description	Task	Quantity
Complete Demolition		
Equipment operator	Operate CTL	1
	Operate vacuum sweeper truck	1
Spotter	Assist with cold milling, verify cut depth	1
Cleaner	Pressure wash and air blast pavement surface	2
Bedding Layer Placement		
Equipment operator	Operate CTL	1
Concrete batchers	Prepare and measure materials for concrete, wash out concrete mixer	3-4
Concrete finishers	Apply bonding agent, place and finish concrete	4
Final Bedding Layer Leveling		
Demolisher	Verify and level concrete surface as needed, sawcut joints, sawcut drain slots	3
Cleaner	Maintain site cleanliness, pressure wash and air blast pavement surface	2
Anchorage Installation		
Panel installer	Place and shim panels	4
Driller	Drill anchor holes	2
Cleaner	Clean anchor holes	2-3
Adhesive hardware installer	Arrange and lay out anchors, trim anchors as needed, install anchors, assist adhesive dispenser	1
Adhesive dispenser	Install anchor adhesive	1
Everyone begins cleaning the site once complete		
Hardware Installation		
Installer	Remove temporary and place permanent hardware	2
	Tighten nuts with torque wrench	2
Validator	Verify all anchors are recessed below panel surface, grind anchors that require recessing	1

Table C-14. Equipment and supply needs for demolition and panel installation activities.

Equipment	
Item	**Quantity**
Impact hammer	2
1-1/8 in. socket	4
Extension cords, 50 ft	8
5000-W generator	2
Compact truck loader	1
Cold planer attachment for CTL	1
Airfield vacuum truck	1
Depth guide tool, 3-5/8 in. deep	2
Demolition or jack hammer, 40-lb max	2
Air hose, ¾ in. diameter x 50 ft*	2
Air compressor, 100-cfm minimum*	1
Bits for demolition or jackhammer	-
Cold chisel	2
Scaling chisel	2
Moil point	2
Slotting tool	2
Bushing bit	2
Square shovel	2
Wrecking/pry bar, 36 in.	2
Engineer's hammer/maul, 3-lb	2
Push broom	2
Water truck, 1,000-gal minimum	1
Pressure washer	2
Water hose, ¾ in.-diameter, 50 ft long	4
Small air compressor lance	2
Small air compressor hose, 3/8 in. diameter, 50 ft long	4
Small air compressor, 4-gal min, 2 outlets	2
Hopper/dumpster	2
Concrete mixer attachment for CTL	1
Concrete float, magnesium	2
Concrete trowel, steel	2

Equipment	
Item	**Quantity**
Cutoff saw with concrete blade	1
Walk-behind saw	1
Depth tool guide/screed, 1-5/8 in. deep	2
Handheld scabbler	2
Air hose, ¾ in.-diameter x 50 ft	2
Air compressor, 100-cfm minimum	1
Angle grinder	2
Rotary hammer drill	2
Portable band saw	1
Setting hardware	75
Epoxy adhesive dispensing gun, pneumatic	1
Panel anchor alignment tool	2
Dry core bit	1
Tie down anchor alignment tool	1
Torque wrench, ½ in. drive, 100 ft-lb capacity min	2
Supplies	
Item	**Quantity/ work day**
4-½ in. diameter masonry grinding stone	10
Lumber crayon	2
Rapid-setting concrete, approximately 50-lb *	40
Sponge	2
Bucket, 5-gal	10
Measuring cup, 1-gal capacity	2
Concrete saw blade, 18 in.-diameter	3
Wooden shims, 3/8 in. thick	200
Stringline	1
Masonry nail, 3 in., box	1
*Masonry drill bit, 7/8 in.-diameter**	3
*Wire brushes for anchoring adhesive**	3*
Threaded rod, steel, ¾ in.-10 x 10 in. long	50*
Temporary setting hardware	50*

Equipment	
Item	**Quantity**
¾ in. washer, SAE, steel	50*
Hex hut, ¾ in., steel	50*
4-½ in.-diameter steel grinding stone	5
*Epoxy adhesive, cartridge**	5
*Additional mixing tubes for epoxy adhesive**	3
Shop towels, box/roll	4
Eyebolt	4 or 8*

* Varies by existing slab and prospective panel arrangement.
Italicized items are not included in a Standard USAF SuPR kit.

9. Joint sealing (1 work day, 7.0 hr)
   a. See Tables C-15 and C-16 for projected equipment, supply, and personnel needs before conducting work.
   b. Schedule a day when the weather will accommodate sealant placement.
   c. Air blast the panel joints and anchor holes.
   d. Install backer rod in all panel joints (Figure C-31).
      (1) There is approximately 400 linear feet in total.
      (2) For ½ in.-wide joints and use of silicone-based joint sealants, the backer rod should be placed ¼ in. below the panel surface.
      (3) Start with placing the long transverse pieces, follow with the shorter longitudinal pieces.
      (4) Install longitudinal pieces from the runway interior to the shoulders.
   e. Install silicone sealant following manufacturer's directions (Figure C-32).
      (1) If a priming material is required, apply material before backer rod is placed.
      (2) Installation of sealant with pneumatic applicator guns using large cartridges is recommended. Adjust regulator to appropriate pressure for best installation. Provide a recess of approximately 1/8 in. below the panel surface.
      (3) Begin at the runway interior and work towards the shoulders. This will allow the sealant at the center portion of the runway to have the maximum amount of time to cure.
   f. Allow sealant to cure to tack free. Finalize site cleanup and exit the runway.

Figure C-31. Backer rod installation.

Figure C-32. Joint sealant installation.

Table C-15. Personnel needs and tasks for joint sealing activity.

Description	Task	Quantity
Installer	Place backer rod	4 (2 teams of 2)
Sealant dispenser	Place sealant	2
Dispenser assistant	Assist sealant dispensers, maintain site cleanliness	1

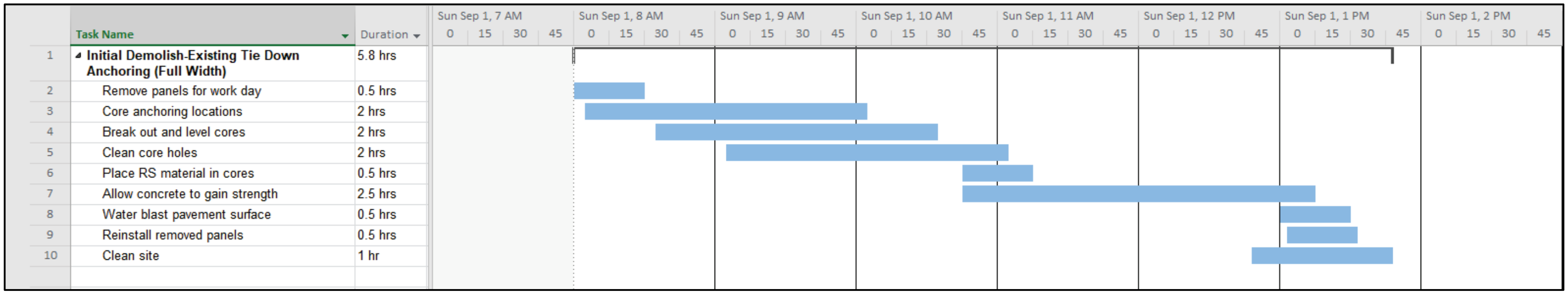
Table C-16. Equipment and supply needs for joint sealing activity.

Equipment	
Item	**Quantity**
Backer rod installation tool	2
Air compressor, 4-gal	1
Air hose, 3/8 in.-diameter x 50 ft long	4
5,000-W generator	1
Sealant dispenser, for 29-oz$_f$ cartridges, pneumatic	2
Supplies	
Item	**Task**
Backer rod, HDPE closed cell, ¾ in.-diameter	1 box (500 ft minimum)
Silicone sealant, airfield grade, 29-oz$_f$ cartridge	42

Italicized items are not included in a Standard USAF SuPR Kit.

Figure C-33. Project Phasing Expedient UHMW-PE Panel Installation – Retrofit of an existing PCC foundation in an AC runway, PCC is surfacing material underneath pendant – Plan A

1. Initial demolition – Remove tie-down anchoring



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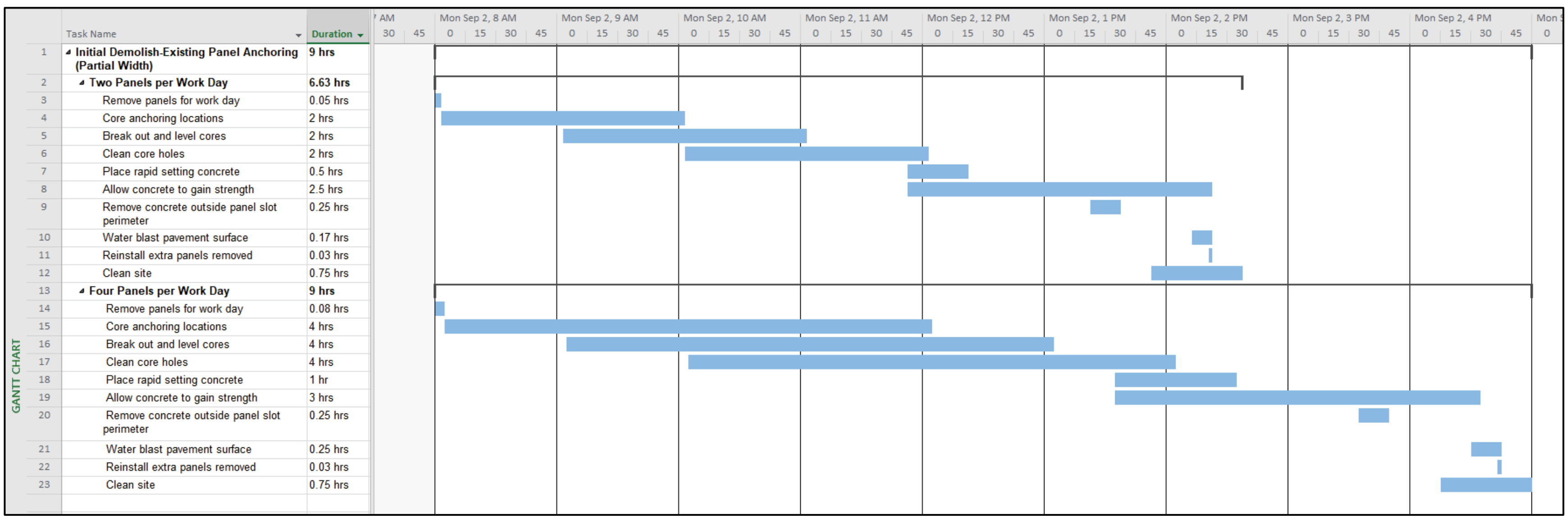
2. Initial demolition – Remove panel anchoring



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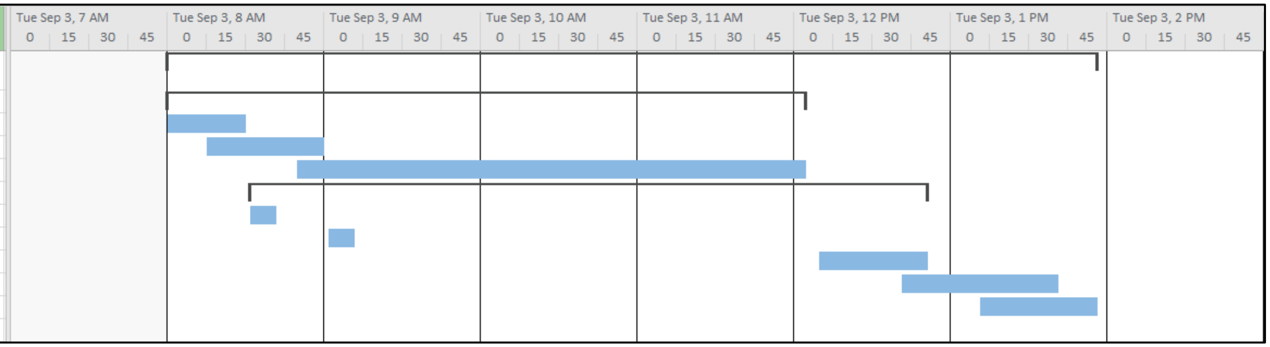
3. Demolition preparation – Transverse sawcutting

	Task Name	Duration
1	**Demolition Preparation (Half Width, Transverse)**	**5.94 hrs**
2	**PCC Relief Sawcuts**	4.08 hrs
3	Mark cut locations	0.5 hrs
4	Snap chalk line	0.75 hrs
5	Saw cut transverse relief cuts	3.25 hrs
6	**AC Patch Sawcuts**	4.33 hrs
7	Mark cut locations	0.17 hrs
8	Snap chalk line	0.17 hrs
9	Saw cut AC patch cuts	0.7 hrs
10	Wash saw slurry	1 hr
11	Clean work zone	0.75 hrs



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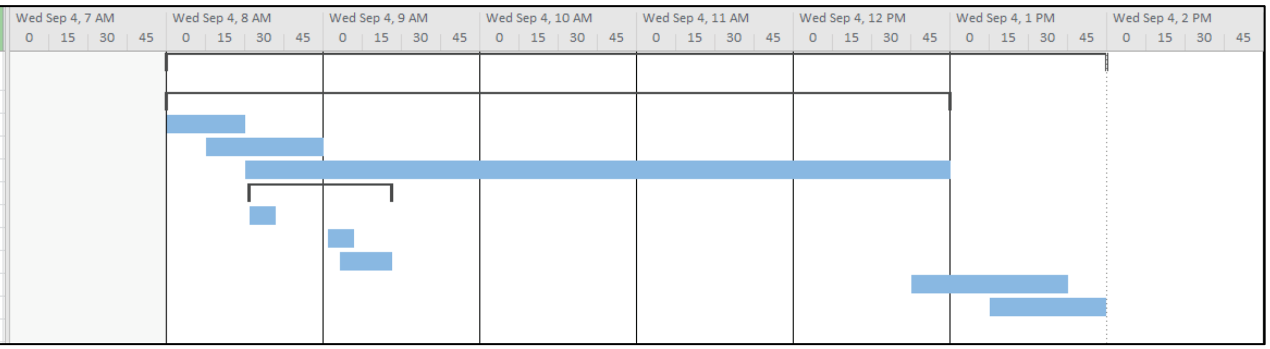
4. Demolition preparation – Longitudinal sawcutting

	Task Name	Duration
1	**Demolition Preparation (Quarter Width, Longitudinal)**	**6 hrs**
2	PCC relief cuts	5 hrs
3	Mark cut locations	0.5 hrs
4	Snap chalk line	0.75 hrs
5	Saw cut relief cuts	4.5 hrs
6	AC cuts	0.91 hrs
7	Mark cut locations	0.17 hrs
8	Snap chalk line	0.17 hrs
9	Make cuts	0.33 hrs
10	Wash saw slurry	1 hr
11	Clean work zone	0.75 hrs



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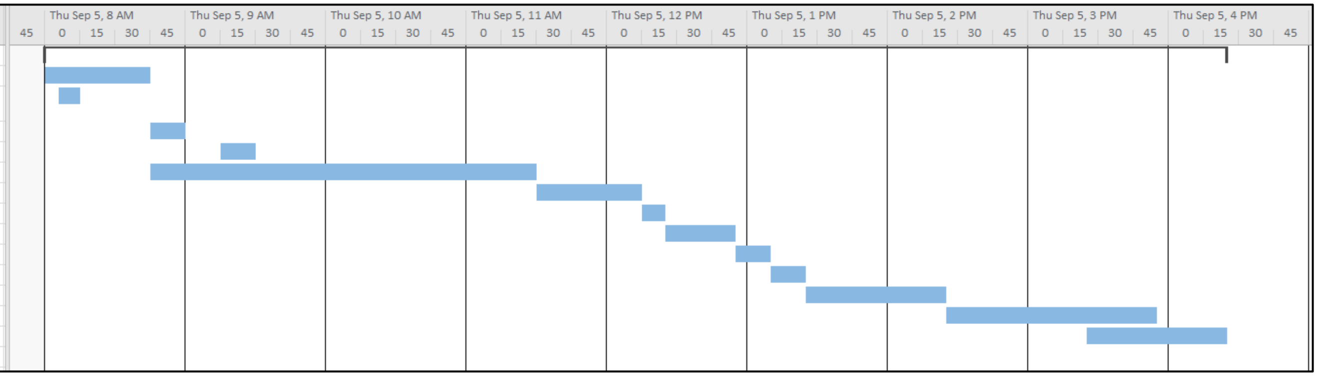
5. AC overlay

	Task Name	Duration
1	AC Overlaying (Partial Width)	8.42 hrs
2	Mill AC at foundation ends	0.75 hrs
3	Make sawcut in previously placed AC for clean construction joint	0.15 hrs
4	Wet base material	0.25 hrs
5	Compact base layer	0.25 hrs
6	Break PCC surface	2.75 hrs
7	Mill PCC within patch area	0.75 hrs
8	Vacuum patch area	0.17 hrs
9	Water blast patch area	0.5 hrs
10	Heavily air blast patch area	0.25 hrs
11	Place tack coat	0.25 hrs
12	Place AC patch	1 hr
13	Watershock AC patch	1.5 hrs
14	Clean work site	1 hr



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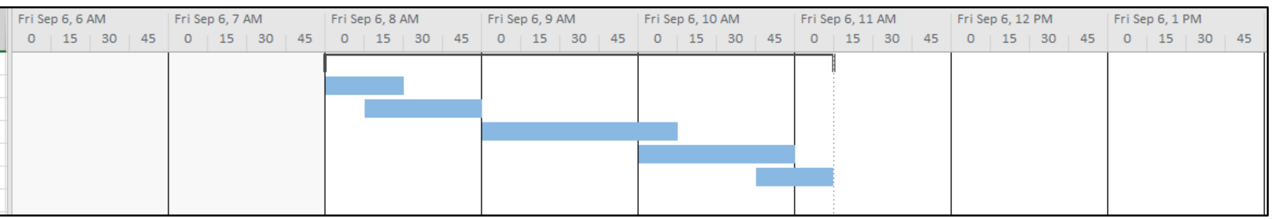
6. Panel installation preparation

	Task Name	Duration
1	Panel Installation Preparation (Full Width)	3.25 hrs
2	Mark slot perimeter	0.5 hrs
3	Snap chalk lines	0.75 hrs
4	Saw cut slot perimeter	1.25 hrs
5	Water blast slot	1 hr
6	Clean site	0.5 hrs



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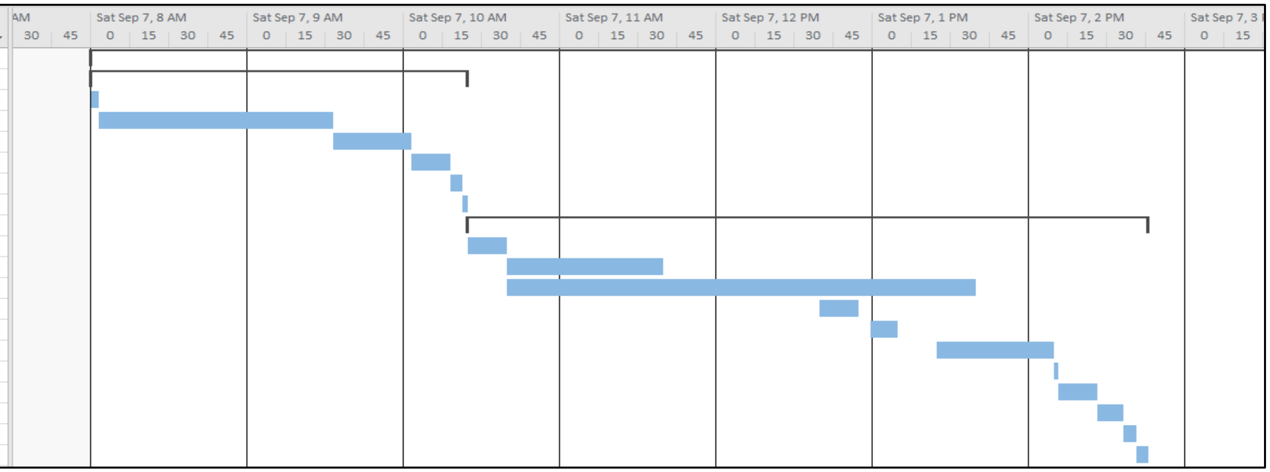
7. Panel installation

	Task Name	Duration
1	Panel Installation (Partial Width)	10.95 hrs
2	Panel Slot Demolition	2.41 hrs
3	Remove any previously placed panels	0.05 hrs
4	Remove slot material	1.5 hrs
5	Perform final slot inspection	0.5 hrs
6	Water blast slot	0.25 hrs
7	Vacuum the slot area	0.08 hrs
8	Air blast slot	0.03 hrs
9	Bedding Layer Placement	4.36 hrs
10	Apply bonding agent	0.25 hrs
11	Place bedding layer	1 hr
12	Allow concrete to gain strength	3 hrs
13	Reestablish joints	0.25 hrs
14	Clean slot perimeter	0.17 hrs
15	Perform final slot inspection	0.75 hrs
16	Air blast slot	0.03 hrs
17	Cut water drain holes	0.25 hrs
18	Water blast slot	0.17 hrs
19	Vacuum the slot area	0.08 hrs
20	Air blast slot	0.08 hrs



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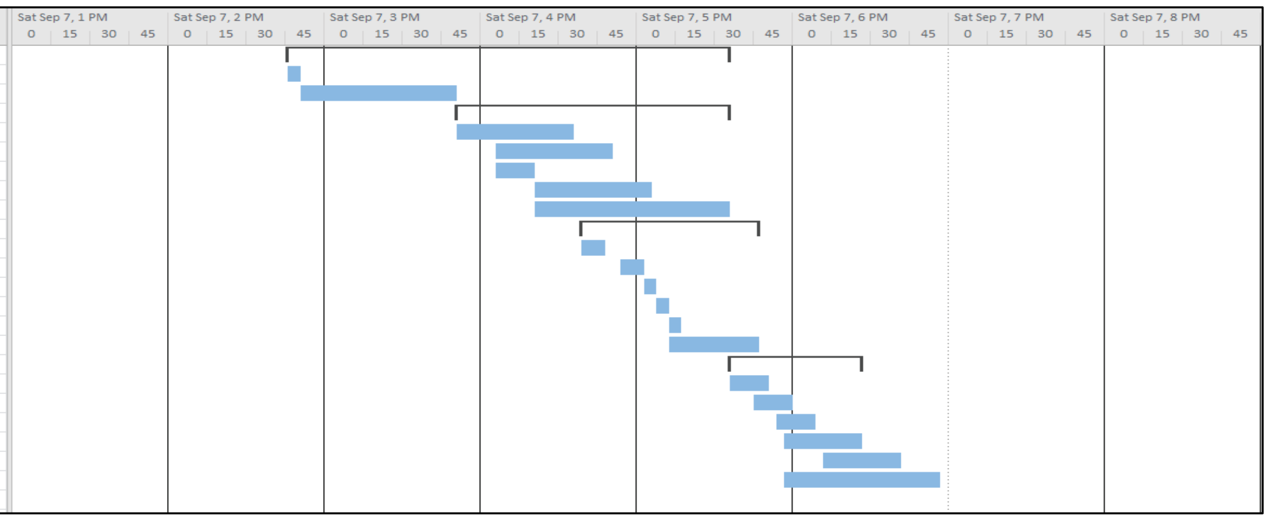
	Task Name	Duration
21	Place and Install Panels	2.83 hrs
22	Place and arrange panels	0.08 hrs
23	Shim panels	1 hr
24	Panel Anchor Installation	1.75 hrs
25	Drill anchoring holes	0.75 hrs
26	Clean anchoring holes	0.75 hrs
27	Set out anchors	0.25 hrs
28	Install hardware	0.75 hrs
29	Allow adhesive to cure	1.25 hrs
30	Install Tie Down Anchoring (As Required)	1.14 hrs
31	Dry core and remove interior	0.15 hrs
32	Clean hole made	0.15 hrs
33	Drill anchor embedding hole	0.08 hrs
34	Clean hole made	0.08 hrs
35	Install tie down anchors	0.08 hrs
36	Allow adhesive to cure	0.58 hrs
37	Install Hardware on Panel Anchors	0.85 hrs
38	Remove setting hardware	0.25 hrs
39	Install hex nuts	0.25 hrs
40	Gross torque hex nuts	0.25 hrs
41	Fine torque hex nuts	0.5 hrs
42	Verify panel anchors elevation	0.5 hrs
43	Remove shims and clean up	1 hr



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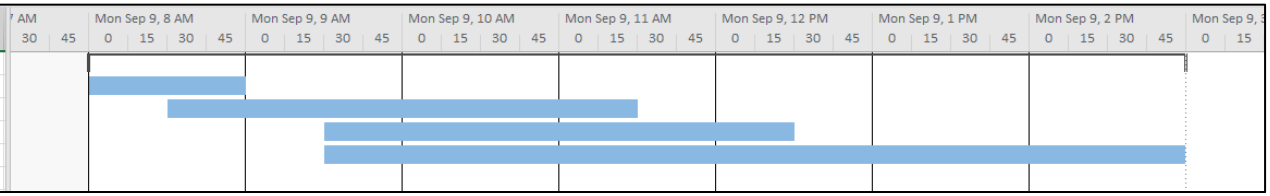
8. Joint sealing

	Task Name	Duration
1	**Joint Sealing (Full Width)**	**7 hrs**
2	Air blast joints and anchor holes	1 hr
3	Install backer rod	3 hrs
4	Install sealant	3 hrs
5	Allow sealant to cure, begin clean up	5.5 hrs



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Appendix D: Expedient AAS-UHMW Panel Installation Methods - Partial Retrofit of an Existing PCC Foundation in an AC Runway

This plan assumes a portion of the panel and tie-down anchors are in acceptable working order and recycles more of the existing concrete foundation than discussed in Appendix C. The goal with recycling is to significantly reduce the amount of work required (and corresponding amount of total project time) to bring the AAS back into operation by neither constructing a new panel slot nor installing new anchorage points after the AC overlay is placed. Personnel requirements for each task and supplies and equipment needs for the work are provided. Estimated durations of the required work tasks and their scheduling are also provided in Figure D-24 at the end of this appendix.

Guidance for planning for the number of defective anchors in need of replacement is given and can be varied to the situation encountered. If the existing anchorages are in working order and only the AC pavement resurfacing is required to bring the panel system into compliance with AFI 32-1043, work planning efforts can be started at Step 5.

If any anchor points are not in acceptable working order, it is recommended to spot remove and replace defective anchorages before the asphalt overlay to complete future work tasks that use the anchor points. Current methods to determine panel anchorage adequacy include the following:

1. torque (spin) testing to ensure the anchor is adequately bonded to the foundation
2. ultrasonic testing for anchor length to determine the risk of concrete surface damage
3. nondestructive proof testing of the anchorages to determine their load capacity for comparison against design values.

The three test options are recommended to be completed in the order shown. Failure of the torque or proof loading test warrants removal and replacement of the individual anchor tested. Ultrasonic testing is used to determine the length of the anchor before proof loading to verify the loading applied will not damage the concrete. Anchors with short embedments may lead to concrete cone-shaped failure (spall) at higher than designed loads rather than debonding of the adhesive from either the concrete or the anchor rod. Damaging the concrete surface will require spall repairs to correct the damage before reinstalling the paneling. Ultrasonic testing of tie-down anchorage may not be possible due to its geometry. Adequacy testing is not required for Appendix C work, since all anchorage points are demolished and replaced, but recycling should be considered if the total project timeline is longer than required or desired.

The Gantt charts detailing the scheduling for this retrofit work assume all anchoring must be removed within a given work day as a worst-case scenario; however, this is not expected on all days, and most work tasks will take less time than shown. Timing for the removal and replacement of identified anchorages will be similar to the timing given in Appendix C except that the pavement repair materials and adhesive cure time does not scale up or down with the number of anchors replaced. These work activities are fixed values, and any repair or anchor replaced cannot be returned to service or activated until this minimum time requirement is met. More anchors can be removed and replaced per work event since the cure time is expensed off over all the anchors placed at one time. Estimated timing is provided to assist with planning efforts after each anchor's adequacy is determined, but the maximum number of anchors replaced should not exceed that listed for each event to ensure the preferred or maximum allowable runway closure times are met.

1. Determine adequacy of existing anchorage points.
    a. Discuss TTPs with the Air Force Civil Engineer Center regarding UHMW anchor extraction protocol. Procedures used follow those used at Bagram Air Base in 2014.
    b. Additional equipment may be required for this work past what is described in this manual.
2. Remove and replace tie-down anchorages (as needed pending results of Step 1, 1 day projected, 6.8 hr maximum for eight anchors).
    a. See Tables D-2 and D-3 for projected equipment, supply, and personnel needs before conducting work.

b. Work planning and scheduling
   (1) See Table D-1 for estimated required timing to use for scheduling and planning efforts.Demolition and installation are successive events on each day.

Table D-1. Estimated time required to demolish and install tie-down anchorage points.

Tie-Down Anchorage Points Repaired	Time Required for Event (hr)		
	Demolish	Install	Total
1	2.9	1.4	4.1
2	3.3	1.7	4.6
4	3.9	2.1	5.7
6	4.4	2.3	6.3
8	4.9	2.3	6.8

   (2) Timing shown assumes the full 2 hr is needed for the concrete to cure, but installation tasks can begin once individual pavement repair material sites have reached a compressive strength of at least 2,500 psi. This ensures the repair material used has enough strength to withstand drilling efforts. The estimated time to reach this strength is approximately 90 min at 70°F, but refer to the manufacturer's provided information. Use a nondestructive Schmitt hammer testing device to monitor strength gain.
   (3) Separate days are highly recommended when planning events for each anchorage type (tie-down vs. panel) to ensure the preferred or maximum allowable runway closure times are met.

c. Anchor demolition
   (1) Remove panels with tie-down anchoring.
      (a) Use an impact hammer to remove the panel anchoring nut from each panel. Collect nuts and washers removed and save for later use.
      (b) Remove the UHMW panel from its position.
         i. Use a wrecking bar to help pry and lift one end of the panel up so it can be lifted by hand. Be careful not to damage the panel.
         ii. Place the panel to the side of the location from which it was removed from.

iii. Use a putty knife to remove any joint sealant and backer rod from the panel (perimeter and anchoring holes) and from the portion of the panel void perimeter where the panel was removed. Clean the washers and nuts removed from the panel anchoring.

(2) Partial depth core around each tie-down anchor.
   (a) Center the core bit over the center of the tie-down anchor.
   (b) Cut to a depth of at least 10 in. measured from the depth of the panel slot.

(3) Remove the material within the cored perimeter.
   (a) Use a wrecking bar to pry the material and break it free from its base.
   (b) If prying does not work, demolish the material with power equipment. Use a demolition hammer or light jackhammer to break out the material. Be careful not to damage the surrounding pavement.
   (c) Level the depth of the core using a bushing bit on the demolition hammer or jackhammer to create a smooth surface.
   (d) Remove large debris by hand. Use a vacuum to help remove small debris material from the depth of the core.

(4) Thoroughly clean the perimeter of each cored void.
   (a) Scrub the void surfaces with a stiff-bristled brush to remove saw slurry and fine particles.
   (b) Generously rinse the void surfaces with water.
   (c) Use the vacuum to remove the dirty water from the cored void. Remove water to the full depth of the core and clean the bottom.
   (d) Repeat this cleaning process two more times.
   (e) Air blast the cleaned void when complete.

(5) Place rapid-setting concrete.
   (a) Start batching material once multiple voids are cleaned, and the entire unit batched can be utilized at one time. The drill and paddle method is the preferred method of mixing due to the small volume of material made.
   (b) Batch material following manufacturer directions. Products without aggregate extensions will require aggregates to be added. Most prepackaged products will yield enough material to fill cored voids with some waste. Use an approved

cementitious pavement repair material for permanent runway repairs.

(c) For 4 in. diameter cores, typical prepackaged materials will fill four repairs with some waste (assumes product yields 0.4 ft^3).

(d) Place material in each void. Strike off each repair at the surface of the concrete to remove excess material. Float and trowel the surface to make it flush and smooth with the panel slot depth surface. No texturing is needed.

(6) Allow the concrete placed to gain strength. Ensure at least 2,500 psi of compressive strength is achieved before carrying on with work activities within the panel slot. The estimated time to reach this strength is approximately 90 min at 70°F, but refer to the manufacturer's provided information. Use a nondestructive Schmitt hammer testing device to monitor strength gain.

(7) Water blast the panel slot and surrounding pavement with a pressure washer to remove saw slurry and debris. Start at the pavement crown and work towards the shoulder.

(8) Install removed panel once their areas are completely water blasted.

(a) Position the panel to align the anchoring studs through the holes.

(b) Replace the washers and nuts on the anchoring studs.

(c) Gross tighten the nuts using an impact hammer.

(d) Fine tighten the nuts using a torque wrench set to 60 ft-lb.

(9) Do not replace joint sealant at this time. All joint sealant will be reinstalled at the conclusion of the project.

d. Anchor installation (Figure D-1).

(1) With the panels reinstalled and the repair material meeting the minimum required strength, install the tie-down anchoring.

(2) Create the void for installing the tie-down anchoring in a two-step process: make a void for the anchor eye followed by a hole to embed the shank of the anchor.

(a) Use the dry coring bit to partial-depth core a void for the eye of the anchor.

i. Center the core bit in the tie-down anchor hole and cut to a depth of 3 in.

ii. Make one continuous cut if possible. Removing the core bit at any time in the process requires the hole to be cleaned before continuing to prevent clogging and to allow for additional cutting.

Figure D-1. Tie-down anchorage installation.

iii. The dry core bit used in hammer mode should demolish the majority of the cored material. If material is still present, use a chisel or bushing bit to level the core depth.

(b) Air blast the core hole.

(c) Drill the tie-down anchor embedment hole. Use the tie-down anchoring drill guide to ensure a vertical cut is made to the correct depth.

(d) Clean the hole following the adhesive manufacturer's directions.

(e) Install the tie-down anchor into the void constructed.

(i) Apply enough adhesive to fill the shank when in the hole.

(ii) Clean any excess adhesive.

(iii) Ensure the eye is aligned in the longitudinal direction.

(3) Allow the adhesive to cure to activation strength. This is temperature dependent: colder temperatures and base material (concrete foundation) require additional time than warmer environments. Do not activate the anchor until the cure time has been met.

(4) Finalize site cleanup and exit the runway.

Table D-2. Personnel needs and tasks for tie-down anchoring removal activity.

Description	Task	Quantity
Anchor Demolition		
Installer	Remove and installs panels	2
Equipment operator	Operate core rig	1
	Move and maintain water truck and hoses	1
Spotter	Assist with aligning core rig, move and maintain electrical cords as needed	1
Demolisher	Remove anchoring equipment and concrete	1
Cleaner	Clean core voids, pressure wash and clean pavement	2
Concrete batcher	Make and distribute concrete	2
Concrete finisher	Place and finish concrete	1
Anchor Replacement		
Driller	Drill anchor holes	2
Cleaner	Clean anchor holes	2
Adhesive hardware installer	Install anchors, assist adhesive dispenser	1

Description	Task	Quantity
Adhesive dispenser	Install anchor adhesive	1
Installer	Replace panels	2
	Place hardware	1
	Gross tighten nut with impact hammer	1
	Tighten nuts with torque wrench	2
Equipment operator	Operate airfield sweeper truck	1

Table D-3. Equipment and supply needs for tie-down anchoring activity.

Equipment	
Item	**Quantity**
Impact hammer	1
1 1/8 in. socket	3
Electric generator, 5000 W minimum	2
Electric extension cord, 25 ft minimum, 15 A rated	4
Putty knife, 1 in. blade	2
Wrecking bar, 36 in.	1
Core rig	1
Water truck, 1,000 gal min	1
Water hose, ¾ in. diameter by 50 ft long	6
Engineer hammer/maul, 3 lb	1
Demolition or jack hammer, 40 lb max	1
Variety of bits for demolition hammer	-
Scaling chisel, 3 in.	1
Cold chisel, 1 in.	1
Moil point	1
Slotting tool	1
Bushing bit	1
Air compressor, 100 cfm minimum*	1
Air hose, ¾ in. diameter, 50 ft*	1
Wet/dry vacuum, 5 hp min, with accessory tools	1
Steel wire brush	2
Plastic bucket, 5 gal	10
Small air compressor lance	1

Equipment	
Small air compressor hose, $^3/_8$ in. diameter, 50 ft	1
Small air compressor, 4 gal minimum, electric	1
Electric drill, 6 A min**	1
Magnesium concrete float	1
Steel concrete trowel	1
Torque wrench, 100 ft-lb capacity	2
Push broom	1
Squeegee	1
Pressure washer	2
Airfield sweeper truck	1
Rotary hammer drill	2
Dry core bit	1
Tie down anchor alignment tool	1
Epoxy adhesive dispensing gun, pneumatic	1
Supplies	
Item	**Quantity**
Diamond core barrel, 1 -in. long minimum, 4 in. inner diameter	2
Measuring cup, 1 gal capacity	2
Paddle mixer bit**	2
Rapid-setting concrete mix, approximately 50 lb per unit	3
Masonry drill bit, $1^1/_8$ in. diameter	1
Wire brushes for anchoring adhesive	1
Epoxy adhesive, cartridge	1
Additional mixing tubes for epoxy adhesive	1
Shop towels, box/roll	4
Eyebolt	8***

* Required only if pneumatic jackhammer is used.
** Other acceptable handheld concrete mixer may be used.
*** Varies by prospective panel arrangement.
Italicized items are not included in a Standard USAF SuPR kit.

3. Remove and replace panel anchorages (as needed pending results of Step 1, multiple days may be required, up to 10.1 hr for 24 anchors)
   a. See Tables D-5 and D-6 for projected equipment, supply, and personnel needs before conducting work.
   b. Work planning and scheduling.
      (1) See Table D-4 for estimated required timing to use for scheduling and planning efforts. Demolition and installation are successive events on each day.

Table D-4. Estimated time required to demolish and install panel anchorage points.

Panel Anchorage Points Repaired per Work Day	Time Required for Event (hr)		
	Demolish	Install	Total
1	2.4	1.4	3.7
2	2.7	1.5	4.1
6	5.2	2.2	7.0
12	6.3	2.5	8.0
18	7.3	2.7	9.1
24	8.3	2.8	10.1

      (2) Timing shown assumes the full 2 hr is needed for the concrete to cure, but installation tasks can begin once individual pavement repair material sites have reached a compressive strength of at least 2,500 psi. This ensures the repair material used has enough strength to withstand drilling efforts. Estimated time is approximately 90 min at 70°F, but refer to the manufacturer's provided information. Use a nondestructive Schmitt hammer testing device to monitor strength gain.
      (3) Estimated times have the potential to be highly variable depending on the distance between anchorage sites. Groupings of fewer than eight continuous panels in a series are considered close to one another, and little deviation is expected from the timing. Defective anchors scheduled for removal that are farther spaced apart require more mobilization time to move equipment between locations. Spreading equipment teams across the intended work day repair area will assist in minimizing the difference in mobilization time used in estimated times.
   c. Anchor demolition

(1) Remove panels.
  (a) Approximately four to six panels will be demolished per work day to accomplish this task within the time requirements given. Assuming 40 panels across a 150 ft runway, this work event will take 10 work days at most.
  (b) Use an impact hammer to remove the panel anchoring nut from each panel. Collect nuts and washers removed and save for later.
  (c) Remove the UHMW panel from its position.
    i. Use a wrecking bar to help pry and lift one end of the panel up so it can be lifted by hand. Be careful not to damage the panel.
    ii. Place the panel to the side of the location from which it was removed.
    iii. Use a putty knife to remove any joint sealant and backer rod from the panel (perimeter and anchoring holes) and from the portion of the panel void perimeter where the panel was removed. Clean the washers and nuts removed from the panel anchoring.

(2) Partial depth core around each panel anchor.
  (a) Center the core bit over the center of the tie-down anchor
  (b) Cut to a depth of at least 10 in. measured from the depth of the panel slot.

(3) Remove the material within the cored perimeter.
  (a) Use a wrecking bar to pry the material and break it free from its base.
  (b) If prying does not work, demolish the material with power equipment. Use a demolition hammer or light jackhammer to chisel out the material. Be careful not to damage the surrounding pavement.
  (c) Level the depth of the core using a bushing bit on the demolition hammer or jackhammer to create a smooth surface.
  (d) Use a vacuum to help remove debris material from the depth of the core.

(4) Thoroughly clean the perimeter of each cored void.
  (a) Scrub the void surfaces with a stiff-bristled brush to remove saw slurry and fine particle.
  (b) Generously rinse the void surfaces with water.

(c) Use the vacuum to remove the dirty water from the cored void. Remove water to the full depth of the core and clean the bottom.
(d) Repeat this cleaning process two more times.
(e) Air blast the cleaned void when complete.

(5) Place rapid-setting concrete in the demolished cored areas.
(a) Start batching material once air blasting removes standing water. The drill and paddle method is the preferred method of mixing due to the small volume of material made.
(b) Batch material following manufacturer directions. Products without aggregate extensions will require aggregates to be added. Most prepackaged products will yield enough material to fill four cored voids with some waste. Bring enough material to repair the number of holes demolished. Have additional set of units available during work to ensure enough material is provided for work.

(6) Allow the concrete placed to gain strength. Ensure at least 2,500 psi of compressive strength is achieved before carrying on with work activities around the panel. The estimated time to reach this strength is approximately 90 min at 70°F, but refer to the manufacturer's provided information. Use a nondestructive Schmitt hammer testing device to monitor strength gain.

(7) Water blast the panel slot and surrounding pavement with a pressure washer to remove saw slurry and debris. Start at the pavement crown and work towards the shoulder.

d. Panels can be installed once their areas are completely water blasted.

(1) If three or more panel anchors are still present within each panel installed, the panel does not need to be shimmed to center the panel and lock it into position for drilling.
(a) Position the panel to align the anchoring studs through the holes. Provide approximately ½ in. joints between the panels and the surrounding pavement.
(b) Replace the washers and nuts on the anchoring studs.
(c) Gross tighten the nuts using an impact hammer. Do not make any attempt to tighten the nut all the way to its required torque.
(d) Fine tighten the nuts using a torque wrench set to 60 ft-lb.

(2) If fewer than three panel anchors are present, the panel must be shimmed around the perimeter of the panel slot to prevent it from shifting during drilling operations (Figure D-2).
(a) Arrange panels such that approximately ½ in. joints are between the slot vertical faces and between each panel.
(b) Draw a stringline across the top of the panels. Pick a convenient location/point to assist in aligning the panels. Tangent to the panel anchoring holes is a good location to use as reference. Use masonry nails to fix the stringline to the selected location.
(c) Use wrecking bars to help move panels and add shims as needed to prevent movement. Ensure the panels are solidly locked into position before moving forward.
(d) Do not break shims after installation. Shims will be removed after anchoring is installed.

Figure D-2. Shimming panels.

e. Anchor installation (Figure D-3)
(1) Drill holes into the concrete foundation using appropriately sized masonry drill bit and hammer drill. Use the panel anchoring drill guide to ensure a vertical cut is made to the correct depth. Use two drills for increased speed if more than six anchors must be installed.
(2) Clean the anchoring holes following the adhesive manufacturer's directions. Typical cleaning procedures include air blasting, wire brushing, and another round of air blasting to remove all loose material in the drilled hole.
(3) Set out and prepare each anchor for installation.

(a) Anchors should be prepared with setting hardware arranged before placement. Ensure the setting hardware is fully hand tightened on the thread rod before placement. Set out any tie-down anchoring encountered.

(b) Embedded steel within the concrete may be encountered if the concrete is reinforced and/or ties or dowels are present. The masonry bit will not cut through the steel. Anchors must be trimmed to accommodate the shorter embedment length. Use a portable band saw to trim the affected anchors to an appropriate length where the threaded rod does not extend above the panel surface.

(4) Install anchoring hardware in each hole (Figure D-4).

(a) AFI 32-1043 describes the use of prepackaged adhesive packets for this task. Ensure the correct amount (or combination of packets if applicable) of adhesive is placed in the hole. Follow all manufacturer directions to correctly measure and use adhesive.

i. Bulk adhesive cartridges that use a mixing tube to premix adhesive before entering the drilled holes are highly recommended to ensure all adhesive is properly mixed at the correct ratio. Large cartridges with pneumatic handheld dispensing equipment are recommended to minimize time lost to changing cartridges. An off-site trial of this work is highly recommended to determine the proper equipment settings and the filling times.

ii. Ensure enough adhesive is used to embed the anchor. Adjust the air regulator such that adhesive is deposited without leaving air voids but is allowed to flow expeditiously enough to install all anchors in a timely fashion without clogging.

iii. The proper amount of adhesive has been dispensed when the adhesive is level with the bottom surface of the panel slot when the anchor is installed. Use the first couple of holes to determine the amount of adhesive needed.

iv. Clean any excess adhesive that enters the countersunk area with a paper towel before it hardens.

v. Rotate the anchor back and forth while in the hole to ensure adhesive completely surrounds the anchor thread.

vi. Cool or heat adhesive to modify setting times as needed in extreme weather conditions.

(5) Allow the adhesive to cure to full strength. This is temperature dependent: colder temperatures and base material (concrete foundation) require additional time than warmer environments. Do not activate the anchor until the cure time has been met.
(6) Begin any cleanup efforts that do not disturb the anchoring adhesive. Remove the wooden wedges from the panels towards the end of the cure period.
(7) Once adhesive has cured, install the permanent hardware on the panel anchoring (Figure D-5).
    (a) Remove the setting hardware and install the hex nut on each anchor stud. Use a $1^1/_8$ in. socket and an impact hammer/ratchet to aid in removal.
    (b) Gross torque the hex nut on the panel anchoring with an impact wrench.
    (c) Fine torque the next nut on the panel anchoring with a torque wrench set to 60 ft-lb.
(8) Verify the final anchor head elevations. Grind off any anchors that stick above the panel with an angle grinder. Be careful not to damage the panel (Figure D-6).
(9) Finalize site cleanup and exit the runway.

Figure D-3. Anchor hole installation.

Figure D-4. Anchor installation.

Figure D-5. Permanent hardware installation.

Figure D-6. Grinding an anchor head flush with the panel surface.

Table D-5. Personnel needs and tasks for panel anchoring removal activity.

Description	Task	Quantity
Anchor demolition		
Installer	Remove and install panels	3
Demolisher	Remove anchoring equipment and concrete	1-2
Equipment operator	Operate core rig	1-2
Spotter	Assist with aligning core rig, move and tend electrical cords as needed	1-2
Cleaner	Clean core voids, pressure wash and clean pavement	2-3
Concrete batcher	Produce, transport, and place concrete	1
Concrete finisher	Place and finish concrete	1
Equipment operator	Operate airfield sweeper truck	1
	Move and maintain water truck, manage water hoses	1
Anchor Replacement		
Driller	Drill anchor holes	1-2
Cleaner	Clean anchor holes	2-3
Adhesive hardware installer	Arrange and lay out anchors, trim anchors as needed, install anchors, assist adhesive dispenser	1
Adhesive dispenser	Install anchor adhesive	1
Installer	Remove and replace hardware	1
	Gross tighten nut with impact hammer	1
	Tighten nuts with torque wrench	2
Equipment operator	Operate airfield sweeper truck	1

Table D-6. Equipment and supply needs for panel anchoring activity.

Equipment	
Item	**Quantity**
Impact hammer	1
$1^1/_8$ in. socket	3
Electric generator, 5000 W minimum	2
Electric extension cord, 25 ft minimum, 15 A rated	4
Putty knife, 1 in. blade	2
Wrecking bar, 36 in.	1
Core rig	1
Water truck, 1,000 gal min	1
Water hoses, ¾ in. diameter by 50 ft long	6
Engineer hammer/maul, 3 lb	1
Demolition or jack hammer, 40 lb max	1
Variety of bits for demolition hammer	-
Scaling chisel, 3 in.	1
Cold chisel, 1 in.	1
Moil point	1
Slotting tool	1
Bushing bit	1
Air compressor, 100 cfm minimum*	1
Air hose, ¾ in. diameter, 50 ft*	1
Wet/dry vacuum, 5 hp min, with accessory tools	1
Steel wire brush	2
Plastic bucket, 5 gal	10
Small air compressor lance	1
Small air compressor hose, $^3/_8$ in. diameter, 50 ft	1
Small air compressor, 4 gal minimum, electric	1
Magnesium concrete float	2
Steel concrete trowel	2
Push broom	1
Squeegee	1

Equipment	
Item	**Quantity**
Pressure washer	2
Torque wrench, ½ in. drive, 100 ft-lb capacity min	2
Rotary hammer drill	2
Portable band saw	1
Setting hardware	25
Epoxy adhesive dispensing gun, pneumatic	1
Panel anchor alignment tool	2
Airfield sweeper truck	1
Supplies	
Item	**Quantity**
Diamond core barrel, 12 in. long min., 4 in. inner diameter	2
Measuring cup, 1 gal capacity	2
18 in. diamond saw blade	1
Rapid-setting concrete mix, approximately 50 lb, per work day	8
Wooden shims, ⅜ in. thick	200
Stringline	1
Masonry nails, 3 in.	4
Masonry drill bit, ⅞ in. diameter	3
Wire brushes for anchoring adhesive	2
Threaded rod, steel, ¾ in. 10 x 10 in. long	25
Epoxy adhesive, cartridge	2
Additional mixing tubes for epoxy adhesive	2
Shop towels, box/roll	2

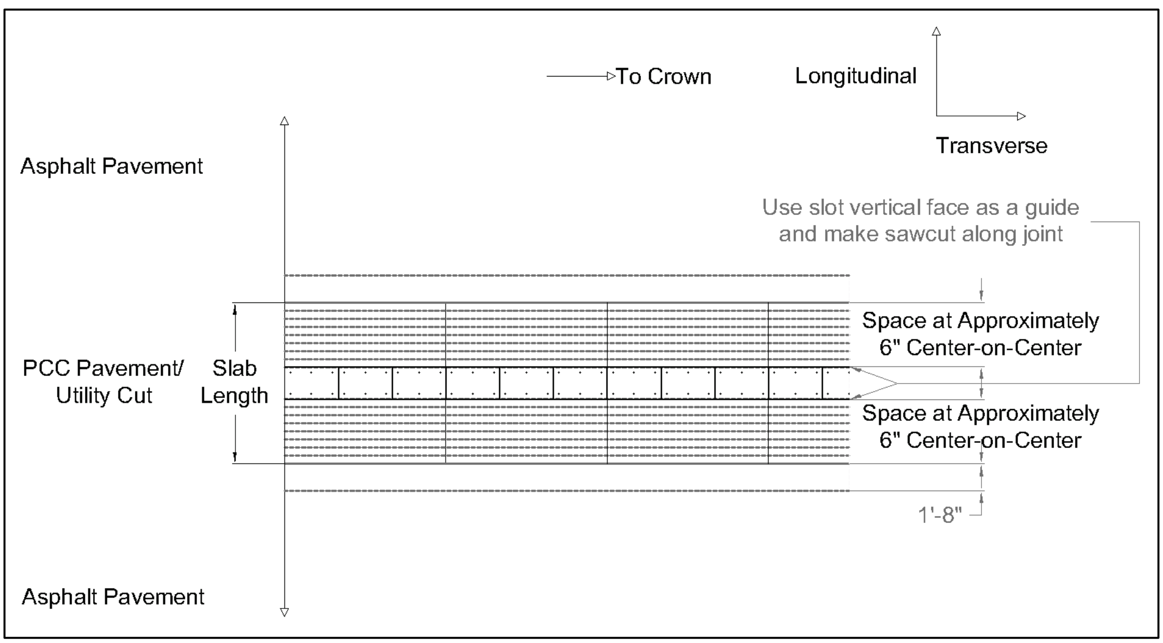
* Required only if pneumatic jackhammer is used.

** Other acceptable handheld concrete mixer may be used.

Italicized items are not included in a Standard USAF SuPR kit.

5. Resurfacing preparations - Transverse sawcutting (2 work days, cuts on one side of paneling 5.8 hr)
   a. See Tables D-7 and D-8 for projected equipment, supply, and personnel needs before conducting work.
   b. Mark sawcut locations on the pavement (Figure D-7).
      (1) The panels do not need to be removed for this work.
      (2) Lay out sawcut locations using a tape measure and lumber crayon. Marks should be spaced approximately 6 in. apart. Make sets of marks every 30 ft transversely across the runway (four total sets).
      (3) Make additional marks for cuts 20 in. off each AC/PCC construction joint.
      (4) Snap a chalk line between the corresponding parallel marks made with water-resistant chalk.
         (a) Use two three-person teams: one operates the tool, one holds the free end, and one snaps the line.
         (b) Complete all lines longitudinally within a set of crayon marks before moving transversely across the runway. This will allow the saws to start before all lines are made.

Figure D-7. Required transverse sawcuts.



c. Begin sawcutting at the marked locations. Use 18 in. saw blades for all machines used (Figure D-8).
   (1) For the large floor saws
      (a) Allow ample time for the chalking crew to snap lines before starting sawing efforts. Chalk will not stick and stain the concrete surface if wet.
      (b) Cut to a depth of 3 ¾ in. minimum with the floor saws. Seven saw cuts are needed per side of panel.
   (2) For the walk-behind saw
      (a) Make the sawcut just to the interior of the panel slot along the vertical face. Use the vertical face as a guide to help control the wander of the saw.
      (b) Begin sawing once ample space is available to simultaneously operate with the floor saws.
   (3) Have pressure washers lightly clean the surface to see chalk lines as needed. Use a less aggressive spray nozzle if available or water hose nozzle.
   (4) If multiple saws are used at one time, stagger saw start times and cuts made to allow for continuous cutting.
      (a) Scheduling shown uses two floor saws and one walk-behind saw.
      (b) If one floor saw is used, 2 work days are required. Only half of the marks are required for this per work day, slightly reducing the time spent out of the runway.

Figure D-8. Making transverse cuts with the floor and walk behind saws.

d. Water blast the cut area and surrounding pavement with a pressure washer to remove saw slurry and debris (Figure D-9). Start at the pavement crown and work towards the shoulder.
e. Finalize site cleanup and exit the runway.

Figure D-9. Waterblasting saw slurry.

Table D-7. Personnel needs and tasks for transverse sawing activity.

Description	Task	Quantity
Marker	Mark locations for chalk lines	2
Chalk line team	Make chalklines	6 (2 teams of 3)
Equipment operator	Operate floor saw	1
Spotter	Assist with aligning saw	1
Hose tender	Move and maintain water truck and hose	1
Cleaner	Pressure wash and clean pavement	2
Equipment operator	Operate airfield sweeper truck	1

Table D-8. Equipment and supply needs for transverse sawing activity.

Equipment	
Item	**Quantity**
Measuring tape	2
Chalk line tool	2
Floor saw	1
Push broom	2
Squeegee	2
Water truck, 1,000.gal minimum	1
Water hoses, ¾.in..diameter by 50.ft long	6
Pressure washer	2
Airfield sweeper truck	1
Supplies	
Item	**Quantity**
Water-resistant chalk, bottle	1
Lumber crayons, each	4
18.in..diameter concrete saw blade	2

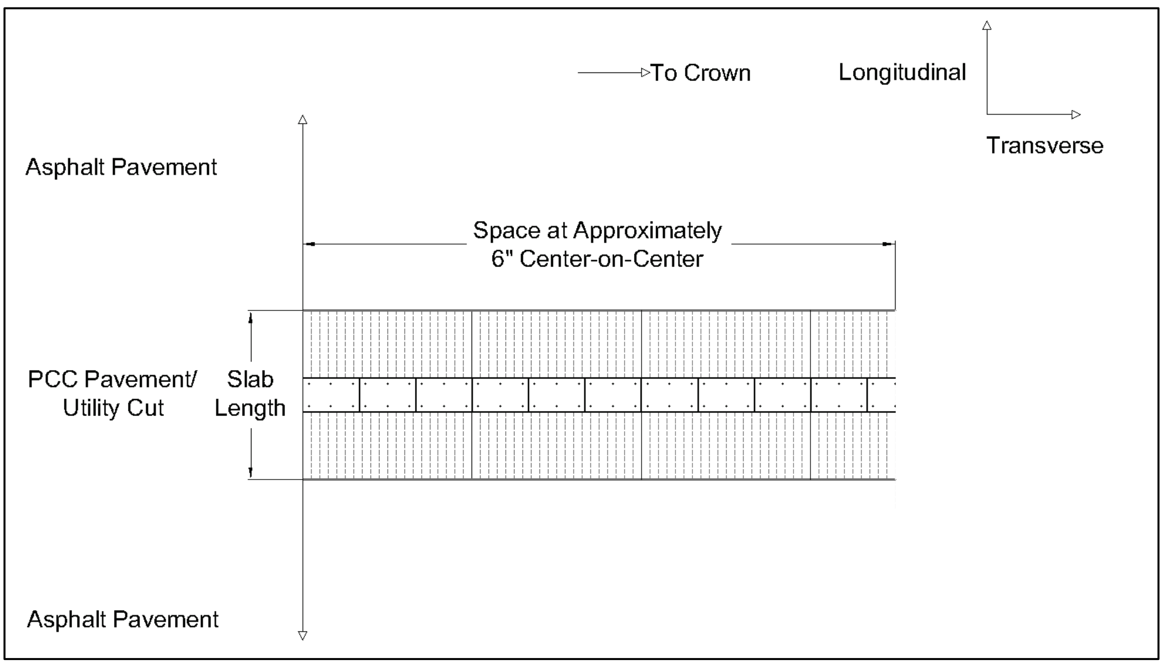
Italicized items are not included in a Standard USAF SuPR kit.

6. Resurfacing preparations - Longitudinal sawcutting (4 work days, half width on one side of paneling, 4.9 hr)
   a. See Tables D-9 and D-10 for projected equipment, supply, and personnel needs before conducting work.
   b. Remove panels across the runway within the project area.
      (1) Use an impact hammer to remove the panel anchoring nuts from each panel. Collect nuts and washers removed and save for later.
      (2) Remove the UHMW panel from its position.
         (a) Use a wrecking bar to help pry and lift one end of the panel up so it can be lifted by hand. Be careful not to damage the panel.
         (b) Place the panel 10 ft off the PCC surface from where it was removed to have it out of the way.
         (c) Use a putty knife to remove any remaining joint sealant and backer rod from the panel (perimeter and anchoring holes) and from the portion of the panel void perimeter where the

panel was removed. Clean the washers and nuts removed from the panel anchoring.

c. Mark sawcut locations on the pavement.
   (1) Lay out sawcuts using a tape measure and lumber crayon on the PCC foundation. Marks should be spaced approximately 6 in. apart. Make additional marks every 30 ft in the AC portion as well (Figure D-10).
   (2) Snap a chalk line between the corresponding parallel marks made with water-resistant chalk.
      (a) Use four two-person teams: one operates the tool, one holds the free end. Either can snap the line.
      (b) Work transversely starting at the shoulders. This will allow the saws to start before all lines are made. This will also prevent draining slurry water from affecting chalk lines.

Figure D-10. Longitudinal sawcut locations.



d. Begin sawcutting with the small walk-behind saws using 18 in. saw blades (Figure D-11).
   (1) Allow ample time for the chalking crew to snap lines before starting sawing efforts. Chalk will not stick and stain the concrete surface if wet.
   (2) Cut to a depth of 3 ¾ in. minimum.

(3) Have pressure washers lightly clean the surface to see chalk lines as needed. Use a less aggressive spray nozzle or water hose nozzle if available.
(4) If multiple saws are used at one time, have saws on opposite sides of the panel area. Stagger saw crews slightly such that each saw's operation does not interfere with the others'.
(a) Scheduling shown uses two saws. Use two saws on each side of the panel starting from the shoulder and working to the interior.
(b) If one saw is used, 4 work days are required respectively working in quadrants of the concrete foundation. Make the appropriate number of marks required for half the area per work day. This slightly reduces the time spent out of the runway to around 6½ hr per work day but increases the number of work days required.
(c) If four saws are available, all longitudinal cuts can be completed in one 7 hr day or two 5 hr days.

Figure D-11. Making longitudinal cuts.

e. Water blast the cut area and surrounding pavement with a pressure washer to remove saw slurry and debris. Start at the pavement crown and work towards the shoulder.

f. Air blast the panel slot area. Start at the pavement crown and work towards the shoulder.
g. Removed panels can be installed once their areas are completely air blasted. Start at the pavement crown and work towards the shoulder.
   (1) Position the panel to align the anchoring studs through the holes.
   (2) Replace the washers and nuts on the anchoring studs.
   (3) Gross tighten the nuts using an impact hammer. Do not make any attempt to tighten the nuts all the way to their required torque.
   (4) Fine tighten the nuts using a torque wrench set to 60 ft-lb.
h. Finalize site cleanup and exit the runway. The surface of the pavement should look as shown in Figure D-12 at this point.

Table D-9. Personnel needs and tasks for longitudinal sawing activity.

Description	Task	Quantity
Marker	Mark locations for chalk lines	2
Chalk line team	Make chalk lines	4 (2 teams of 2)
Equipment operator	Operate floor saw	2
Hose tender	Move and maintain water truck and hoses	1
Cleaner	Pressure wash and clean pavement	2
Equipment operator	Operate airfield sweeper truck	1

Figure D-12. Pavement surface after all sawcuts are made.

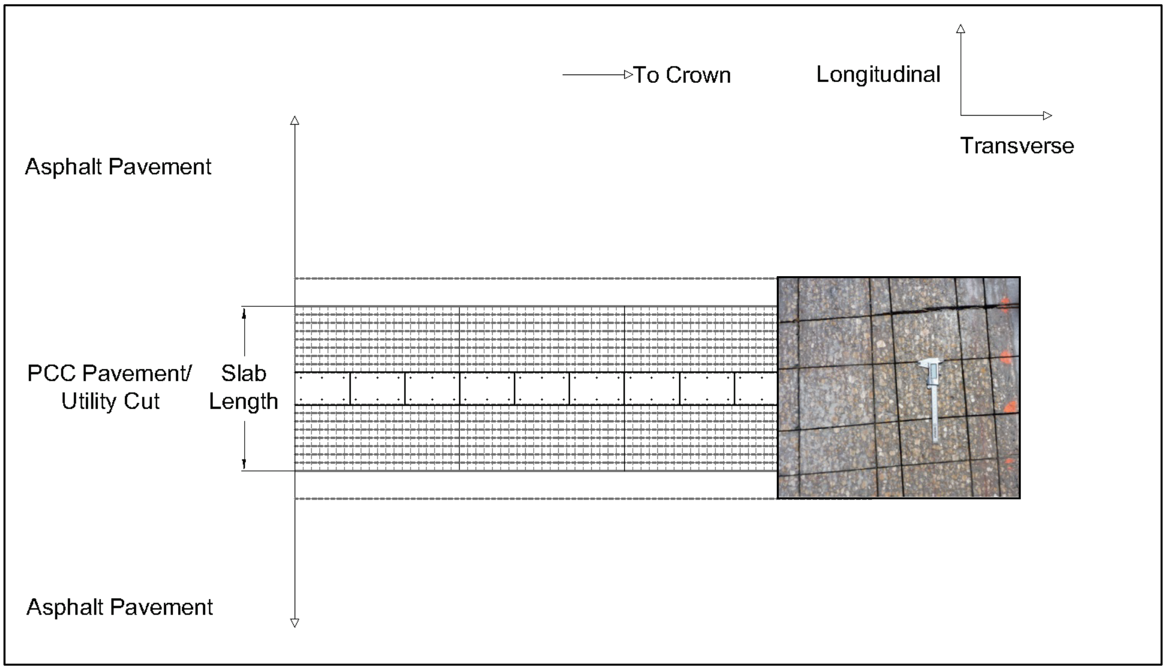


Table D-10. Equipment and supply needs for longitudinal sawing activity.

Equipment	
Item	**Quantity**
Measuring tape	2
Chalk line tool	2
Walk behind saw	2
Push broom	2
Squeegee	2
Water truck	1
Water hoses, ¾ in. diameter x 50 ft long	8
Pressure washer	2
Airfield sweeper truck	1
Supplies	
Item	**Quantity**
Water-resistant chalk, bottle	1
Lumber crayons, each	4
18 in. diameter concrete saw blade	2

Italicized items are not included in a Standard USAF SuPR kit.

7. AC Overlay (2 work days, 10.4 hr total each day)
    a. See Tables D-11 and D-12 for projected equipment, supply, and personnel needs before conducting work.
    b. Mill a 20 in. strip of AC pavement at the AC/PCC construction joint using the compact track loader and cold planer attachment (Figure D-13).
        (1) Maintain approximately 1 in. away from the precut edges to prevent damaging materials outside the boundaries. Excessively crossing the sawcut may result in the need to recut the joint straight and fully parallel to the UHMW panels.
        (2) Mill the asphalt pavement between the sawcuts and foundation full depth to expose the underlying base material.
            (a) Make passes in 1 in. increments. One pass per cut depth is required.
            (b) Continually lower the milling head with each pass made. This allows the cold planer to use existing pavement as a stable guide to control the cutting depth.
        (3) Have the airfield sweeper truck vacuum the patch slot after each pass of the CTL to clean the millings made. Excess millings under the CTL track paths will reduce the CTL's traction and cutting speed.
        (4) Complete milling on one side of the panels before moving forward.
        (5) After milling is complete on each side, use a demolition hammer or light jackhammer to remove the unmilled portions within the slot perimeter.

Figure D-13. Milling AC at construction joint.

c. Wet the exposed base material with water to prepare for compaction. Apply approximately 1 gal/yd^2 evenly across the base material.
d. Compact the exposed base material with a plate compactor. Make a minimum of three passes over all areas.
e. Chisel the existing concrete panel foundation to a minimum depth of 3¾ in. (Figure D-14).
   (1) Start on one side of the panel and work as a team. This will allow other additional work tasks to begin on the completed side as chiseling begins on the other side.
   (2) Use two jackhammers and teams of two: one person operates the jackhammer and the other removes the debris generated.
   (3) Operate the jackhammer such that it impacts at the depth of the relief cuts made at a 30° to 45° angle from horizontal. The idea is to pop off the individual square pieces as whole units from the surface of the existing foundation. Operating the jackhammer more vertically than recommended chips the units into multiple

small pieces that take more time to remove, make debris clearing efforts more extensive, and remove more material than needed.

(4) Remove medium and large pieces of debris by hand and deposit them in a front end loader or backhoe bucket. Empty the bucket into a dump truck as needed.

Figure D-14. Concrete foundation surface removal.

f. Mill the surface of the remaining concrete foundation using the compact track loader (Figure D-15).

(1) The goal is to take out the high spots. Some low spots may be present. Mill the surface approximately ¼ in. such that the elevation difference between before and after demolition is greater than 3¾ in. as a whole and the majority of the large high peaks are removed.

(2) The AC/PCC construction joint can be used as an initial guide to help set the cut depth of the milling head. Adjust the milling head skis such that one rides on the higher AC joint surface and the other cuts into the PCC the desired depth. Remember to

consider the difference in elevation of AC pavement was not milled earlier. This is only an approximate measure, since the compact track loader will ride on the uneven surface of the demolished concrete.
   (3) Use the jackhammers to knock down the areas where the milling machine cannot reach.
   (4) Larger and deeper surface voids will require filling with a skin coat of rapid-setting concrete repair material.

g. Remove the panels.
   (1) Use an impact hammer to remove the panel anchoring nut from each panel.
   (2) Collect nuts and washers removed and save for later.
   (3) Remove the UHMW panel from its position. Use a wrecking bar to help pry and lift one end of the panel up so it can be lifted by hand. Be careful not to damage the panel.

h. Remove all the smaller debris within the repair void.
   (1) Use the airfield vacuum truck to vacuum the demolished surface.
   (2) Water blast the concrete surface to remove any loose portions of the surface.
   (3) Heavily air blast the surface to remove all standing water and dry the surface as best as possible.

i. Install steel asphalt formwork to the panel anchoring.
   (1) Install formwork while the roller operates, but start only in areas where the roller has completed work.
   (2) Apply form release oil to the steel to assist in form removal.
   (3) Use an impact wrench to quickly tighten the forms to the concrete. Use a quick burst to prevent overtightening and damaging the anchorage points.

j. Apply tack material to patching area surfaces.
   (1) Start placing tack material after cleaning efforts have ended.
   (2) Apply tack coat material at a rate of 0.10 ± 0.05 gal/yd^2 with the roofing brush.
   (3) Distribute the material evenly with a roofing brush. Minimize pooling in low areas with the uneven, rough surface.

Figure D-15. Milling rough surface of patch area.

k. Place the asphalt pavement overlay over the milled and chiseled area (Figure D-16).
   (1) Current instructions are built around using ADR rapid asphalt patching technology. Follow guidance and job mix requirements given for material and equipment if used. ADR information for more guidance on the use of the materials and equipment is specified.
   (2) Evenly place hot mixed asphalt at one corner of the void. Spread material as needed by hand to allow for efficient screeding. Leave sufficient material head in front of the screed to produce smooth, full lifts and paving lanes. Minimize hand placing material if possible.

(3) Use the compact track loader with asphalt screed attachment to screed the hot mixed asphalt placed. Use a tape measure to help set screed height.
(4) If the screed length does not place material into the interior of the repair, place material by hand as needed.
(5) Immediately remove and clean material that flows over the formwork. Ensure the steel anchors remain clean and do not get coated in asphalt.
(6) Compact placed material with a small dual smooth steel drum roller (Figure D-17).
   (a) Roll loosely placed asphalt with the steel wheel roller. Follow guidance on ADR asphalt placement and materials. Use of density monitoring equipment and a straightedge to ensure density and surface smoothness is met is highly recommended.
   (b) If other local methods and materials are used to place the asphalt overlay, follow local practices. General procedures will be approximately as follows:
      i. Start by making two static rolls around each perimeter edge of the repair.
      ii. Break down the material with two vibrated passes.
      iii. Finish roll the pavement with two static passes.
      iv. Monitor the compaction process with density measuring equipment and a straightedge. Tailor the procedure as necessary to meet compaction requirements.

l. Watershock the overlay surface to accelerate cooling the asphalt placed.
(1) Distribute water over the surface of the asphalt overlay to help the material cool and gain strength. This can be done intermittently by hand (Figure D-18) or continuously with the help of a lawn sprinkler.
   (a) Use of a cart-mounted lawn sprinkler is recommended for continuous cooling.
   (b) When the lawn sprinkler is used, set up the sprinkler and the water truck towards the runway crown end of the overlay and allow the water to flow to the shoulder. Set up equipment such that it lies on cool pavement and the water sprayed lands at 1 ft from the start of the overlay.

(c) Place sandbags over the cart wheels to prevent movement. Two systems will be required for overlaid areas at the pavement crown.

Figure D-16. Asphalt placement.

Figure D-17. Compacting asphalt patch.

(2) Monitor the surface temperature of the overlay with an infrared thermometer at 5 min intervals. Take at least six random measurements across the patch area.

(3) Stop cooling once the surface reaches 125 °F or is similar to surrounding pavement.

m. Remove the formwork with an impact hammer. Collect the nuts and washers.

n. Reinstall the panels.

(1) Position the panel to align the anchoring studs through the holes.

(2) Replace the washers and nuts on the anchoring studs. Gross tighten the nuts using an impact hammer.

(3) Fine tighten the nuts using a torque wrench set to 60 ft-lb.

o. Finalize site cleanup and exit the runway. The surface of the pavement should look as shown in Figure D-19 at this point.

Figure D-18. Watershocking freshly compacted asphalt pavement by hand.

Figure D-19. Patched area.

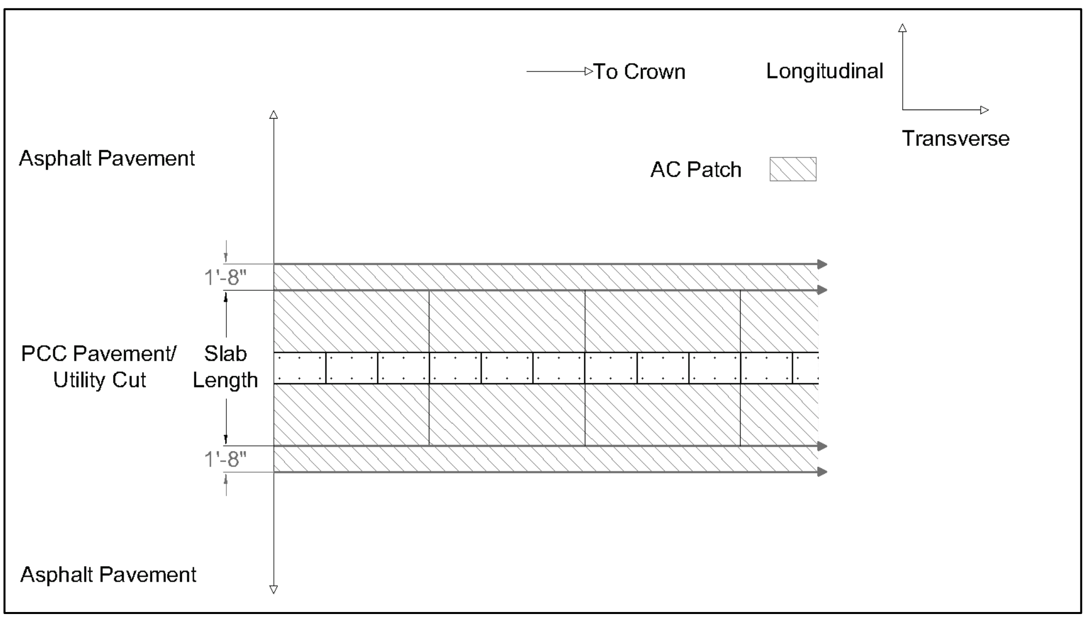


Table D-11. Personnel needs and tasks for AC overlaying activity.

Description	Task	Quantity
Equipment operator	Cold mill pavement with CTL, screed hot mixed asphalt	1
	Operate airfield vacuum sweeper, operate CTL with bucket/front end loader	1
	Operate dump truck, deliver hot mixed asphalt	1
	Operate soil compactors	1
Spotter	Assist CTL and airfield sweeper operators	1
Demolisher	Break concrete and remove large pieces	4 (2 teams of 2)
Hose tender	Operate water truck and manage water hoses	1
Cleaner	Air blast and pressure wash pavement surfaces	2
Asphalt placer	Apply tack coat, hand distribute hot mixed asphalt	6

Table D-12. Equipment and supply needs for AC overlaying activity.

Equipment	
Item	**Quantity**
Compact track loader	1
Cold milling head for CTL, 18 in. wide	1
Airfield sweeper truck	1
Water truck, 1,000 gal min	1
Plate compactor, plate less than 18 in. wide	1
Jackhammer 40 lb max.	2
Air house, ¾ in. diameter 50 ft	2
Air compressor, 100 cfm min.	1
Bits for jackhammer	-
cold chisel	2
scaling chisel	2
moil point	2
bushing bit	2
Front end loader or backhoe	1
Dump truck, 5 yd³ min.	1
Wrecking bar, 36 in.	2
Engineer’s hammer/maul, 3 lb	2

Equipment	
Item	**Quantity**
Push broom	2
Square shovel	3
Backpack blower	1
Water hoses, ¾ in. diameter x 50 ft long	6
Pressure washer	2
Roofing broom	4
Asphalt rake/lute	2
Asphalt screed CTL attachment	1
Tape measure, 25 ft	1
Roller compactor, dual steel wheel	1
10 to 12 ft straight edge, aluminum	1
Water sprinkler	1
Sandbags, 25 lb	2
Infrared temperature gun	1
Supplies	
Item	**Quantity**
Set of replacement teeth for cold milling head	3*
Rapid-setting concrete mix, approximately 50 lb per unit	6
*Asphalt binder, paving grade, gallons***	8
*Hot mixed asphalt, airfield grade, ton***	11.5

*Total for entire project work.

** Include 20% waste, assumes 4 in. total placement across patch.

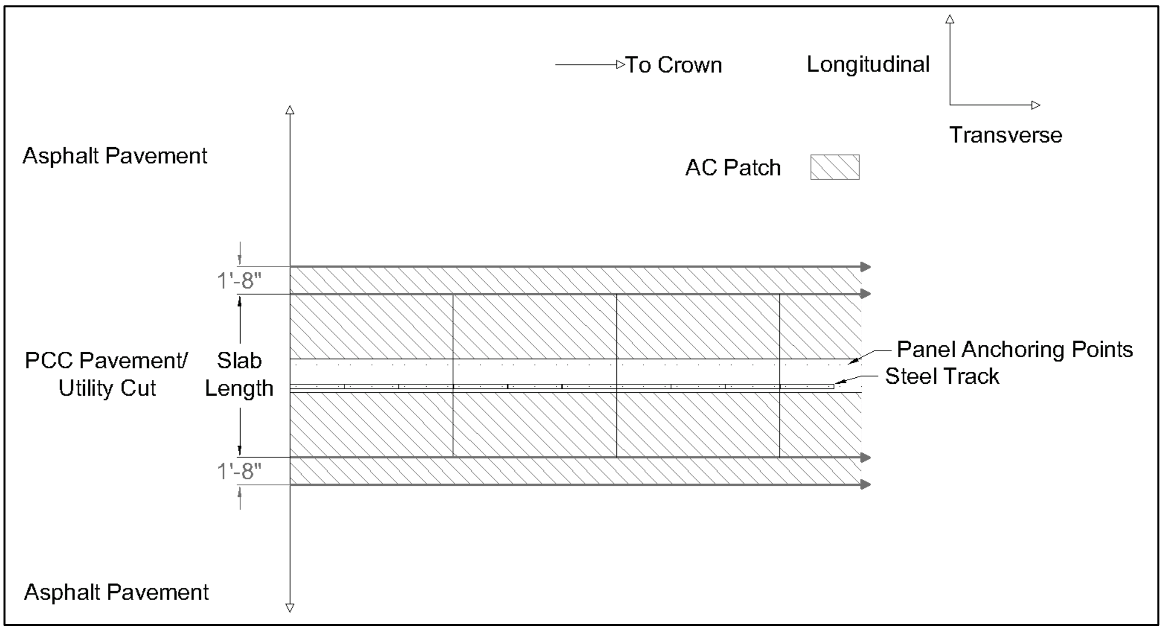
Italicized items are not included in a Standard USAF SuPR kit.

8. Construct drain slots (2 days, half-width each day, 4.6 hr total)
   a. See Tables D-13 and D-14 for projected equipment, supply, and personnel needs before conducting work.
   b. Remove panels across the runway.
      (1) Use an impact hammer to remove the panel anchoring nuts from each panel. Collect nuts and washers removed and save for later.
      (2) Remove the UHMW panel from its position.

(a) Use a wrecking bar to help pry and lift one end of the panel up so it can be lifted by hand. Be careful not to damage the panel.
(b) Place the panel 10 ft off the PCC surface from where it was removed to have it out of the crew's way.

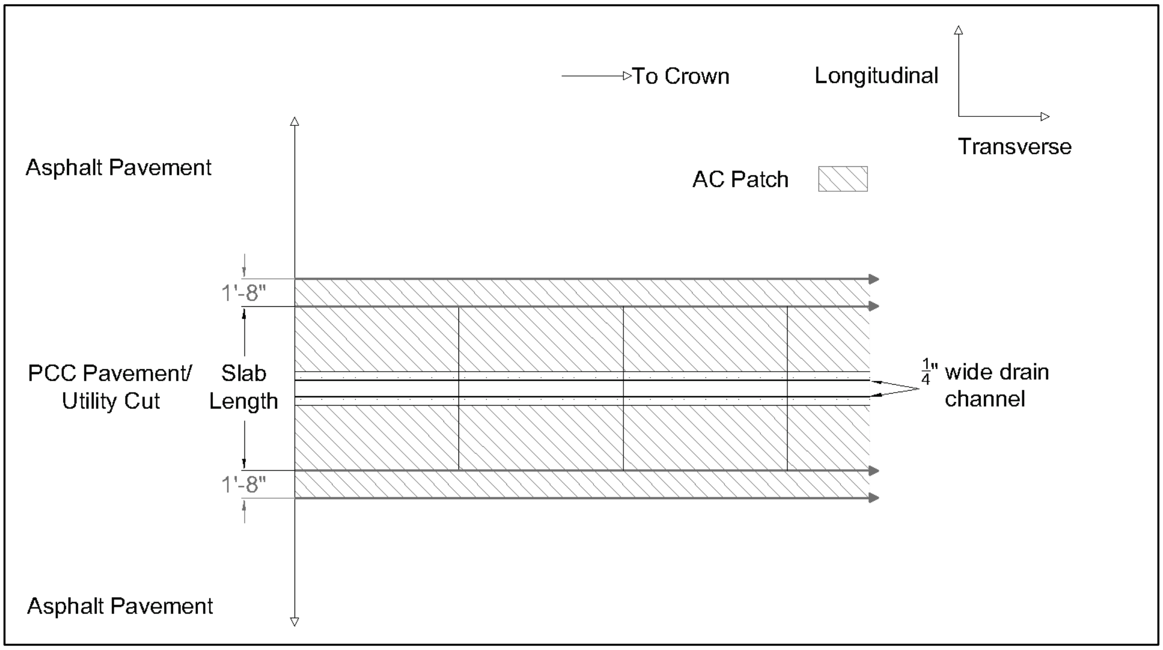
c. Place the steel track in the panel slot (Figure D-20). The panel anchor holes should align with the holes on the underside of the track.

Figure D-20. Steel track placement.



d. Cut the drain channels in the interior of the concrete (Figure D-21).
(1) Use the walk-behind saw with two 18 in. diameter saw blades butted together. Cut two slots transversely in the bedding layer ½ in. deep.
(2) Use the vertical face of the steel track as a guide for a straight cut.
(3) Remove and place segments of steel track ahead of the sawing team as sawing is completed.

Figure D-21. Constructed drain channel.



e. Water blast the panel slot.
f. Remove the steel track.
g. Air blast the panel slot.
h. Reinstall the panels.
   (1) Position the panel to align the anchoring studs through the holes.
   (2) Replace the washers and nuts on the anchoring studs.
   (3) Gross tighten the nuts using an impact hammer.
   (4) Fine tighten the nuts using a torque wrench set to 60 ft-lb.
i. Finalize site cleanup and exit the runway.

Table D-13. Personnel needs and tasks for drain slot construction.

Description	Task	Quantity
Installer	Remove and reinstall panels	6
	Install and remove steel track	2
Equipment operator	Operate walk behind saw	1
	Operate airfield vacuum sweeper	1
	Operate water truck and tend water hoses	1
Spotter	Assist saw operators and tend water hoses	1
Cleaner	Air blast and pressure wash pavement surfaces	3

Table D-14. Equipment and supply needs for drain slot construction.

Equipment	
Item	**Quantity**
impact hammer	1
$1^1/_8$ in. socket	3
electric generator, 5000 W minimum	1
electric extension cord, 25 ft minimum, 15 amp rated	2
wrecking bar, 36 in.	1
small walk behind saw	
water hoses, ¾. diameter x 50 ft long	6
pressure washer	2
water truck, 1000 gal min	1
backpack blower	1
airfield sweeper truck	1
Supplies	
Item	**Quantity**
18 in. concrete saw blade	3

Italic items are not included in a Standard USAF SuPR kit.

9. Joint sealing (1 work day, 7.0 hr)
   a. See Tables D-15 and D-16 for projected equipment, supply, and personnel needs before conducting work.
   b. Schedule a day when the weather will accommodate sealant placement.

c. Air blast the panel joints and anchor holes.
d. Install backer rod in all panel joints (Figure D-22).
   (1) There is approximately 400 linear ft in total.
   (2) For ½ in. wide joints and use of silicone-based joint sealants, the backer rod should be placed ¼ in. below the panel surface.
   (3) Start with placing the long transverse pieces, follow with the shorter longitudinal pieces.
   (4) Install longitudinal pieces from the runway interior to the shoulders.
   (5) Install silicone sealant following manufacturer's directions (Figure D-23).
   (6) If a priming material is required, apply material before backer rod is placed.
   (7) Installation of sealant with pneumatic applicator guns using large cartridges is recommended. Adjust regulator to appropriate pressure for best installation. Provide a recess of approximately 1/8 in. below the panel surface.
   (8) Begin at the runway interior and work towards the shoulders. This will allow the sealant at the center portion of the runway to have the maximum amount of time to cure.
e. Allow sealant to cure to tack free. Finalize site cleanup and exit the runway.

Figure D-22. Backer rod installation.

Figure D-23. Joint sealant installation.

Table D-15. Personnel needs and tasks for longitudinal sawing activity.

Description	Task	Quantity
Installer	Place backer rod	4 (2 teams of 2)
Sealant dispenser	Place sealant	2
Dispenser assistant	Assist sealant dispensers, maintain site cleanliness	1

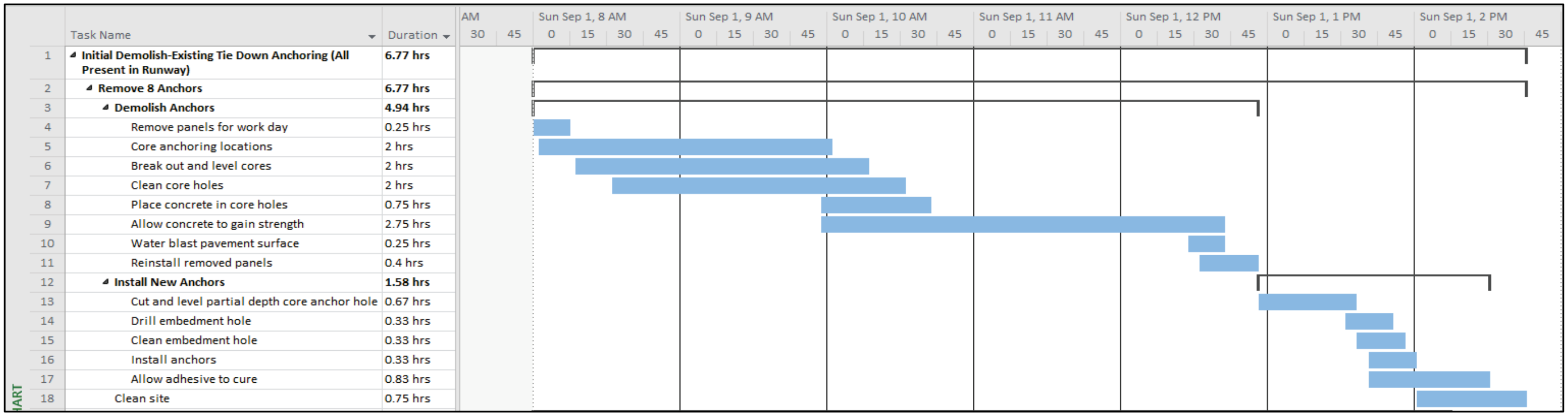
Table D-16. Equipment and supply needs for joint sealing activity.

Equipment	
Item	**Quantity**
Backer rod installation tool	2
Air compressor, 4 gal	1
Air hose, 3/8 in. diameter x 50 ft long	4
5,000 W generator	1
Sealant dispenser, for 29 oz$_f$ cartridges, pneumatic	2
Supplies	
Item	**Task**
Backer rod, HDPE closed cell, ¾ in.-diameter	1 box (500-ft minimum)
Silicone sealant, airfield grade, 29 oz$_f$ cartridge	42

Italicized items are not included in a Standard USAF SuPR Kit.

Figure D-24. Project Phasing Expedient UHMW-PE Panel Installation – Partial retrofit of an existing PCCfoundationin an AC runway.

1. Initial demolition – Existing tie-down anchoring



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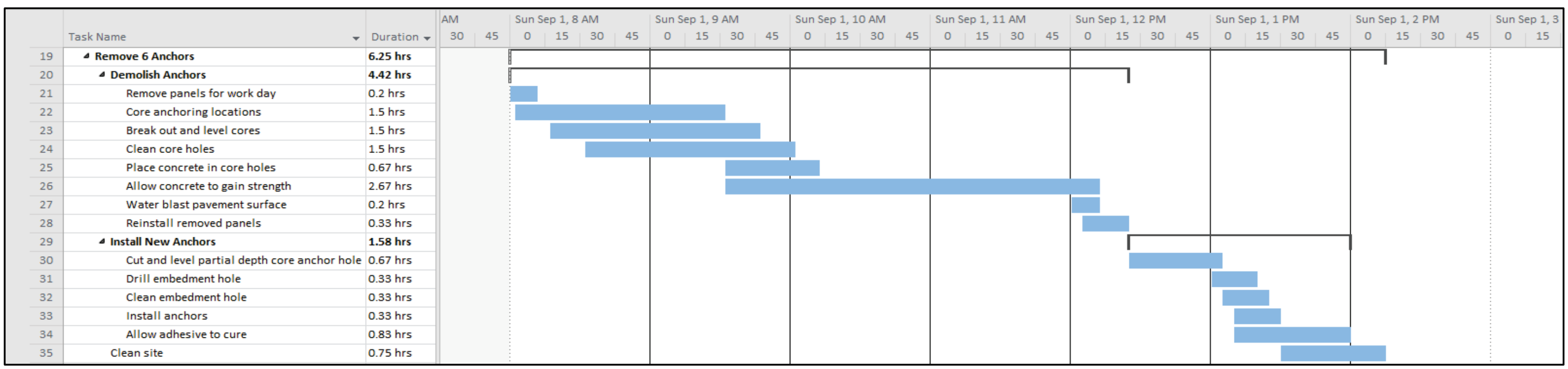

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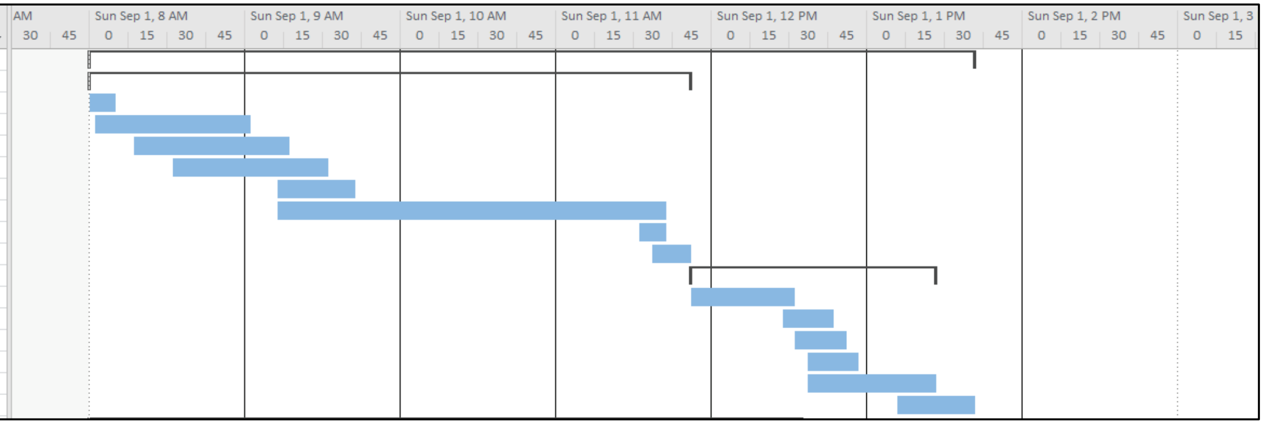
	Task Name	Duration
36	Remove 4 Anchors	5.7 hrs
37	Demolish Anchors	3.87 hrs
38	Remove panels for work day	0.17 hrs
39	Core anchoring locations	1 hr
40	Break out and level cores	1 hr
41	Clean core holes	1 hr
42	Place concrete in core holes	0.5 hrs
43	Allow concrete to gain strength	2.5 hrs
44	Water blast pavement surface	0.17 hrs
45	Reinstall removed panels	0.25 hrs
46	Install New Anchors	1.58 hrs
47	Cut and level partial depth core anchor hole	0.67 hrs
48	Drill embedment hole	0.33 hrs
49	Clean embedment hole	0.33 hrs
50	Install anchors	0.33 hrs
51	Allow adhesive to cure	0.83 hrs
52	Clean site	0.5 hrs



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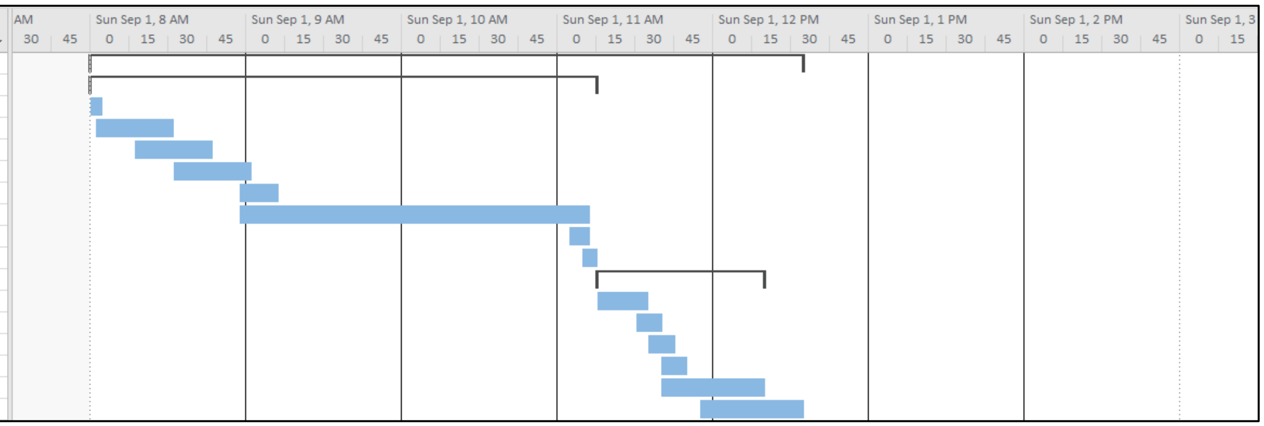
	Task Name	Duration
53	Remove 2 Anchors	4.59 hrs
54	Demolish Anchors	3.26 hrs
55	Remove panels for work day	0.08 hrs
56	Core anchoring locations	0.5 hrs
57	Break out and level cores	0.5 hrs
58	Clean core holes	0.5 hrs
59	Place concrete in core holes	0.25 hrs
60	Allow concrete to gain strength	2.25 hrs
61	Water blast pavement surface	0.13 hrs
62	Reinstall removed panels	0.1 hrs
63	Install New Anchors	1.08 hrs
64	Cut and level partial depth core anchor hole	0.33 hrs
65	Drill embedment hole	0.17 hrs
66	Clean embedment hole	0.17 hrs
67	Install anchors	0.17 hrs
68	Allow adhesive to cure	0.67 hrs
69	Clean site	0.67 hrs



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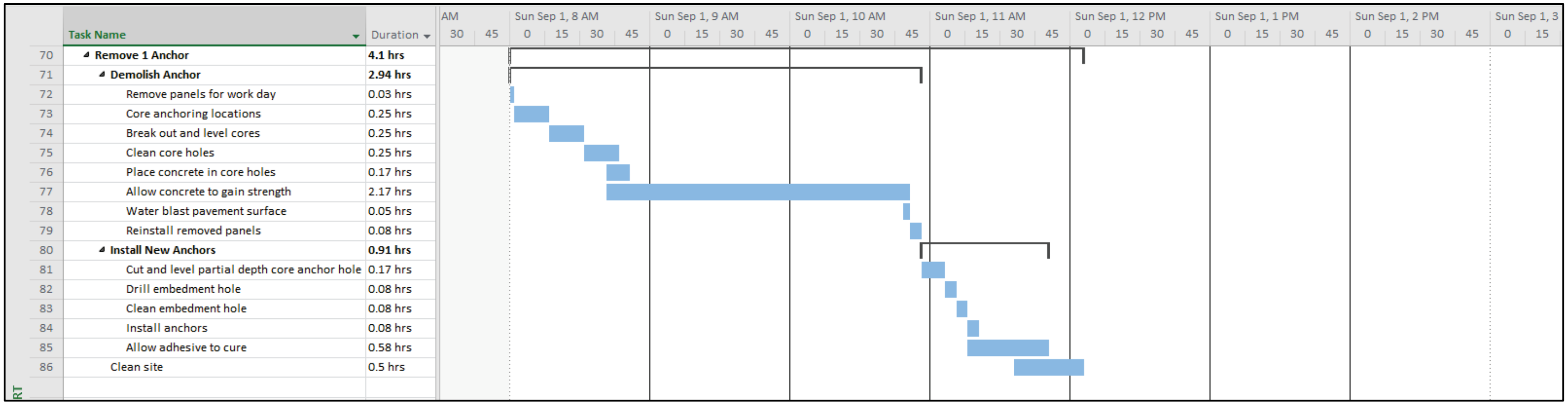

	Task Name	Duration
70	Remove 1 Anchor	4.1 hrs
71	Demolish Anchor	2.94 hrs
72	Remove panels for work day	0.03 hrs
73	Core anchoring locations	0.25 hrs
74	Break out and level cores	0.25 hrs
75	Clean core holes	0.25 hrs
76	Place concrete in core holes	0.17 hrs
77	Allow concrete to gain strength	2.17 hrs
78	Water blast pavement surface	0.05 hrs
79	Reinstall removed panels	0.08 hrs
80	Install New Anchors	0.91 hrs
81	Cut and level partial depth core anchor hole	0.17 hrs
82	Drill embedment hole	0.08 hrs
83	Clean embedment hole	0.08 hrs
84	Install anchors	0.08 hrs
85	Allow adhesive to cure	0.58 hrs
86	Clean site	0.5 hrs

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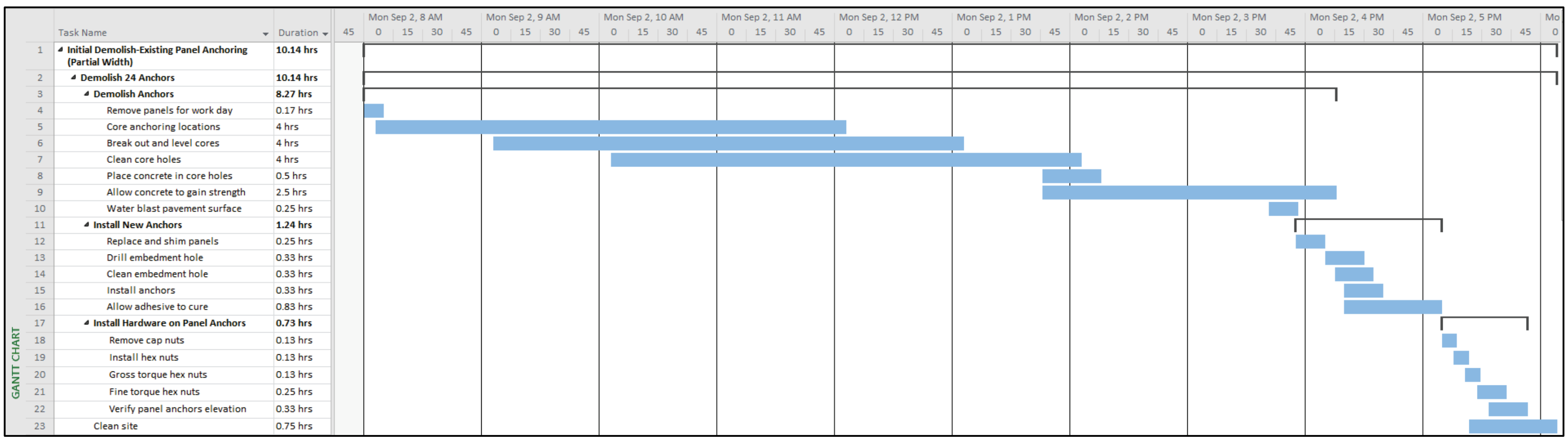
2. Initial demolition – Existing panel anchoring



	Task Name	Duration
1	Initial Demolish-Existing Panel Anchoring (Partial Width)	10.14 hrs
2	Demolish 24 Anchors	10.14 hrs
3	Demolish Anchors	8.27 hrs
4	Remove panels for work day	0.17 hrs
5	Core anchoring locations	4 hrs
6	Break out and level cores	4 hrs
7	Clean core holes	4 hrs
8	Place concrete in core holes	0.5 hrs
9	Allow concrete to gain strength	2.5 hrs
10	Water blast pavement surface	0.25 hrs
11	Install New Anchors	1.24 hrs
12	Replace and shim panels	0.25 hrs
13	Drill embedment hole	0.33 hrs
14	Clean embedment hole	0.33 hrs
15	Install anchors	0.33 hrs
16	Allow adhesive to cure	0.83 hrs
17	Install Hardware on Panel Anchors	0.73 hrs
18	Remove cap nuts	0.13 hrs
19	Install hex nuts	0.13 hrs
20	Gross torque hex nuts	0.13 hrs
21	Fine torque hex nuts	0.25 hrs
22	Verify panel anchors elevation	0.33 hrs
23	Clean site	0.75 hrs

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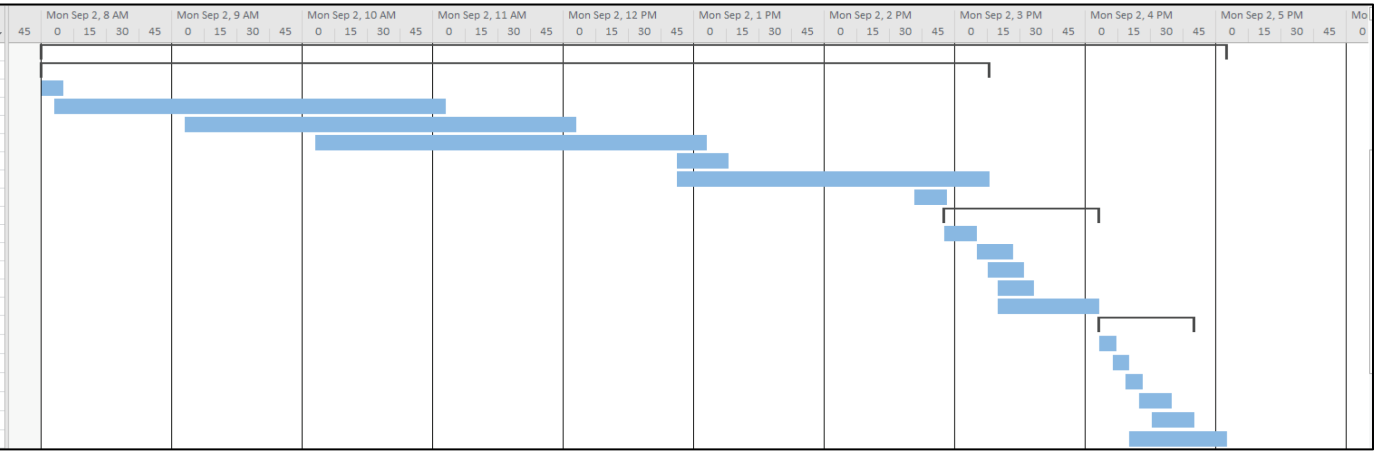
	Task Name	Duration
24	Demolish 18 Anchors	9.09 hrs
25	Demolish Anchors	7.27 hrs
26	Remove panels for work day	0.17 hrs
27	Core anchoring locations	3 hrs
28	Break out and level cores	3 hrs
29	Clean core holes	3 hrs
30	Place concrete in core holes	0.4 hrs
31	Allow concrete to gain strength	2.4 hrs
32	Water blast pavement surface	0.25 hrs
33	Install New Anchors	1.19 hrs
34	Replace and shim panels	0.25 hrs
35	Drill embedment hole	0.28 hrs
36	Clean embedment hole	0.28 hrs
37	Install anchors	0.28 hrs
38	Allow adhesive to cure	0.78 hrs
39	Install Hardware on Panel Anchors	0.73 hrs
40	Remove cap nuts	0.13 hrs
41	Install hex nuts	0.13 hrs
42	Gross torque hex nuts	0.13 hrs
43	Fine torque hex nuts	0.25 hrs
44	Verify panel anchors elevation	0.33 hrs
45	Clean site	0.75 hrs



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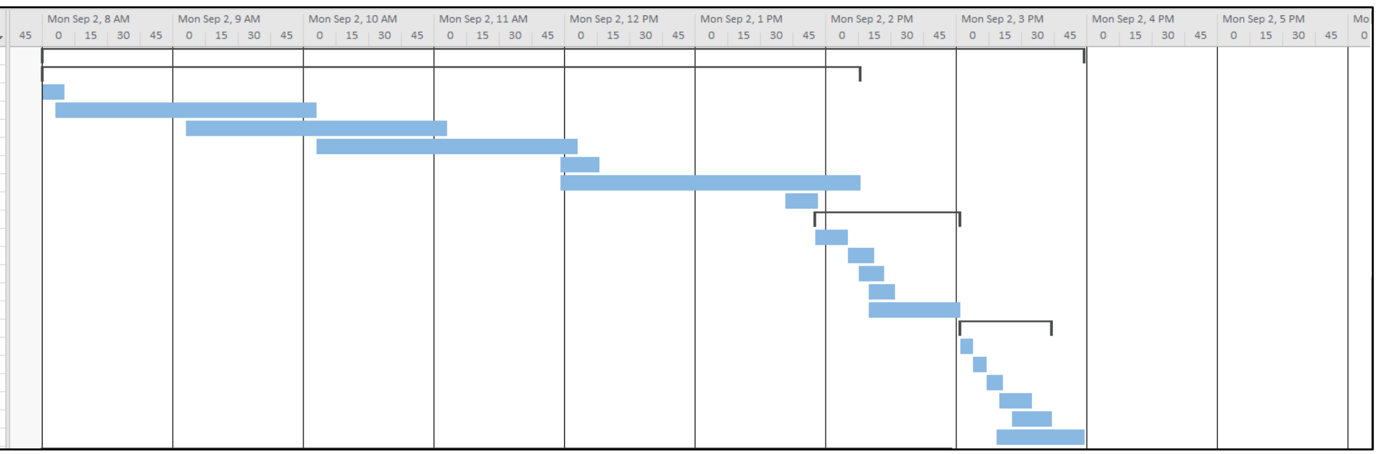
GANTT CHART

	Task Name	Duration
46	Demolish 12 Anchors	7.98 hrs
47	Demolish Anchors	6.27 hrs
48	Remove panels for work day	0.17 hrs
49	Core anchoring locations	2 hrs
50	Break out and level cores	2 hrs
51	Clean core holes	2 hrs
52	Place concrete in core holes	0.3 hrs
53	Allow concrete to gain strength	2.3 hrs
54	Water blast pavement surface	0.25 hrs
55	Install New Anchors	1.11 hrs
56	Replace and shim panels	0.25 hrs
57	Drill embedment hole	0.2 hrs
58	Clean embedment hole	0.2 hrs
59	Install anchors	0.2 hrs
60	Allow adhesive to cure	0.7 hrs
61	Install Hardware on Panel Anchors	0.7 hrs
62	Remove cap nuts	0.1 hrs
63	Install hex nuts	0.1 hrs
64	Gross torque hex nuts	0.13 hrs
65	Fine torque hex nuts	0.25 hrs
66	Verify panel anchors elevation	0.3 hrs
67	Clean site	0.67 hrs



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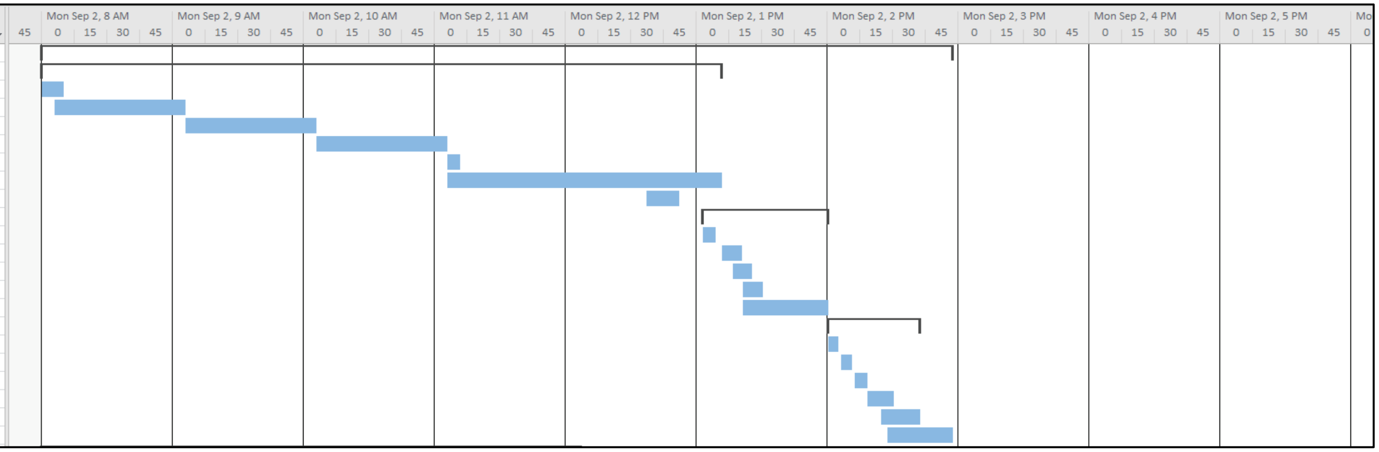
GANTT CHART

	Task Name	Duration
68	**Demolish 6 Anchors**	**6.96 hrs**
69	**Demolish Anchors**	**5.2 hrs**
70	Remove panels for work day	0.17 hrs
71	Core anchoring locations	1 hr
72	Break out and level cores	1 hr
73	Clean core holes	1 hr
74	Place concrete in core holes	0.1 hrs
75	Allow concrete to gain strength	2.1 hrs
76	Water blast pavement surface	0.25 hrs
77	**Install New Anchors**	**0.96 hrs**
78	Replace and shim panels	0.1 hrs
79	Drill embedment hole	0.15 hrs
80	Clean embedment hole	0.15 hrs
81	Install anchors	0.15 hrs
82	Allow adhesive to cure	0.65 hrs
83	**Install Hardware on Panel Anchors**	**0.7 hrs**
84	Remove cap nuts	0.08 hrs
85	Install hex nuts	0.08 hrs
86	Gross torque hex nuts	0.1 hrs
87	Fine torque hex nuts	0.2 hrs
88	Verify panel anchors elevation	0.3 hrs
89	Clean site	0.5 hrs



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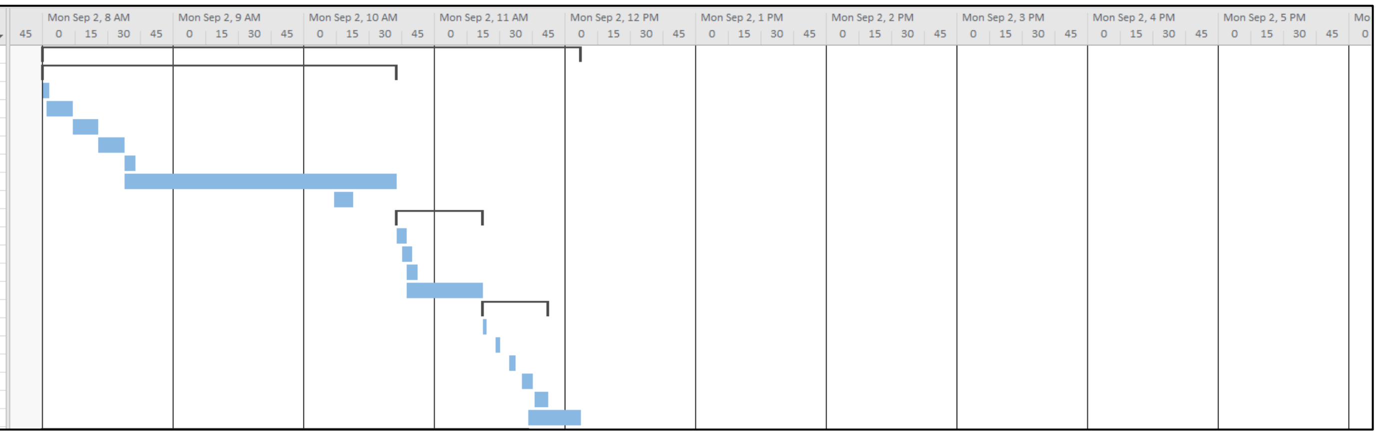
	Task Name	Duration
90	**Demolish 2 Anchors**	**4.12 hrs**
91	**Demolish Anchors**	**2.71 hrs**
92	Remove panels for work day	0.05 hrs
93	Core anchoring locations	0.2 hrs
94	Break out and level cores	0.2 hrs
95	Clean core holes	0.2 hrs
96	Place concrete in core holes	0.08 hrs
97	Allow concrete to gain strength	2.08 hrs
98	Water blast pavement surface	0.15 hrs
99	**Install New Anchors**	**0.66 hrs**
100	Drill embedment hole	0.08 hrs
101	Clean embedment hole	0.08 hrs
102	Install anchors	0.08 hrs
103	Allow adhesive to cure	0.58 hrs
104	**Install Hardware on Panel Anchors**	**0.5 hrs**
105	Remove cap nuts	0.03 hrs
106	Install hex nuts	0.03 hrs
107	Gross torque hex nuts	0.05 hrs
108	Fine torque hex nuts	0.08 hrs
109	Verify panel anchors elevation	0.1 hrs
110	Clean site	0.4 hrs



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	Task Name	Duration
111	**Demolish 1 Anchors**	**3.72 hrs**
112	**Demolish Anchors**	**2.4 hrs**
113	Remove panels for work day	0.02 hrs
114	Core anchoring locations	0.1 hrs
115	Break out and level cores	0.1 hrs
116	Clean core holes	0.1 hrs
117	Place concrete in core holes	0.08 hrs
118	Allow concrete to gain strength	2.08 hrs
119	Water blast pavement surface	0.1 hrs
120	**Install New Anchors**	**0.62 hrs**
121	Drill embedment hole	0.04 hrs
122	Clean embedment hole	0.04 hrs
123	Install anchors	0.04 hrs
124	Allow adhesive to cure	0.54 hrs
125	**Install Hardware on Panel Anchors**	**0.45 hrs**
126	Remove cap nuts	0.01 hrs
127	Install hex nuts	0.01 hrs
128	Gross torque hex nuts	0.02 hrs
129	Fine torque hex nuts	0.05 hrs
130	Verify panel anchors elevation	0.05 hrs
131	Clean site	0.33 hrs

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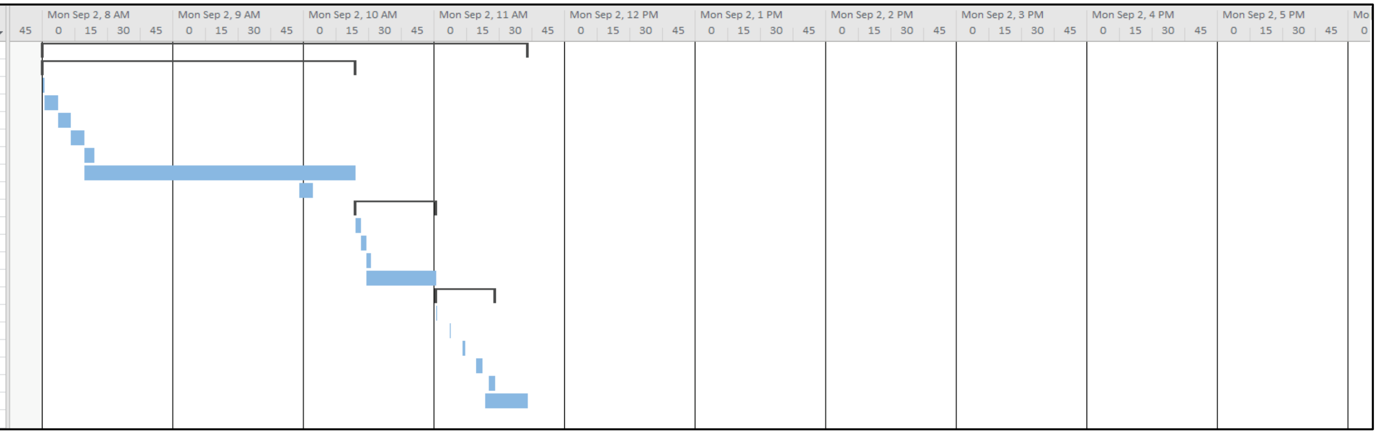

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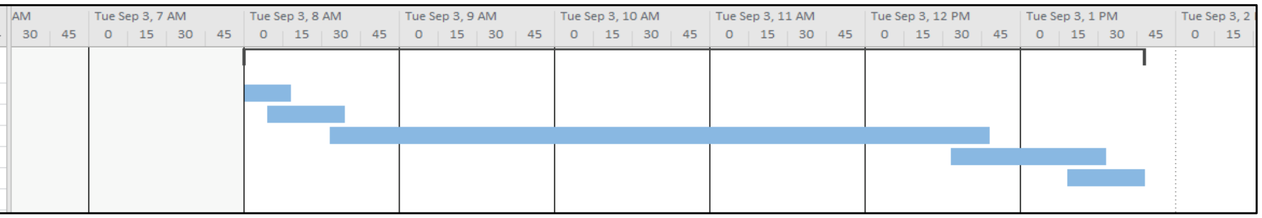
3. Resurfacing preparations – Transverse sawcutting

	Task Name	Duration
1	**Resurfacing Preparation (Full Width Transverse Cuts, Half of Total Cuts Made)**	**5.8 hrs**
2	Mark chalk line locations	0.3 hrs
3	Snap chalk line	0.5 hrs
4	Saw cut transverse relief cuts	4.25 hrs
5	Wash saw slurry	1 hr
6	Clean work zone	0.5 hrs



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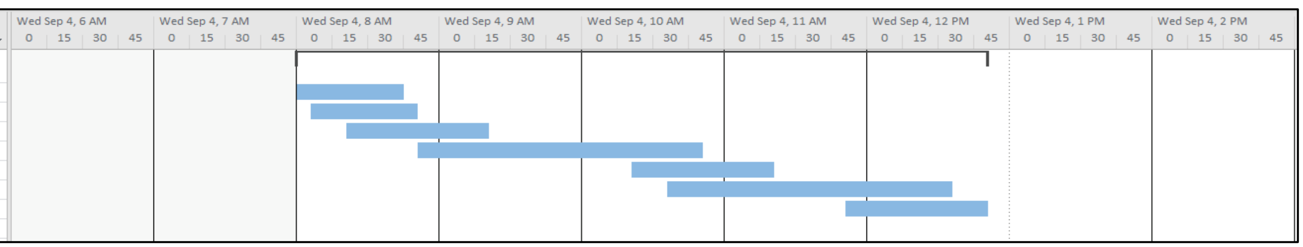
4. Resurfacing preparations – Longitudinal sawcutting

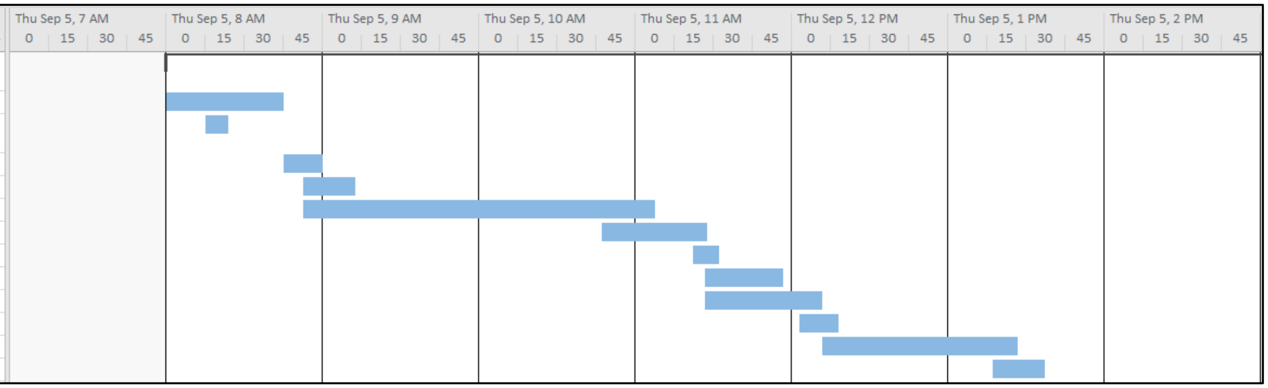
	Task Name	Duration
1	**Demolition Preparation (Partial Width Longitudinal Cuts, Quarter of Cuts Made)**	**4.85 hrs**
2	Remove panels	0.75 hrs
3	Mark chalk line locations	0.75 hrs
4	Snap chalk line	1 hr
5	Saw cut relief cuts	2 hrs
6	Wash saw slurry	1 hr
7	Replace panels	2 hrs
8	Clean work zone	1 hr



Sheet 1 of 1

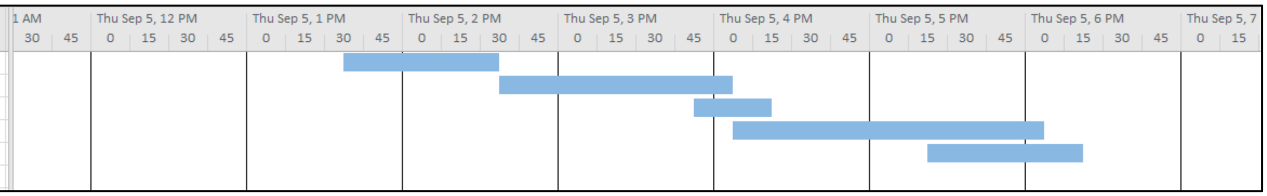
5. AC Overlay

	Task Name	Duration
1	AC Overlaying (Half Width, Both Sides of Paneling)	10.37 hrs
2	Mill AC at foundation ends	0.75 hrs
3	Make sawcut in previously placed AC for clean construction joint (day 2 only)	0.15 hrs
4	Wet base material	0.25 hrs
5	Compact base layer	0.33 hrs
6	Chisel PCC	2.25 hrs
7	Level PCC surface	0.67 hrs
8	Vacuum patch area	0.17 hrs
9	Water blast patch area	0.5 hrs
10	Remove panels	0.75 hrs
11	Heavily air blast patch areas	0.25 hrs
12	Install steel formwork	1.25 hrs
13	Place tack coat	0.33 hrs



Sheet 1 of 2

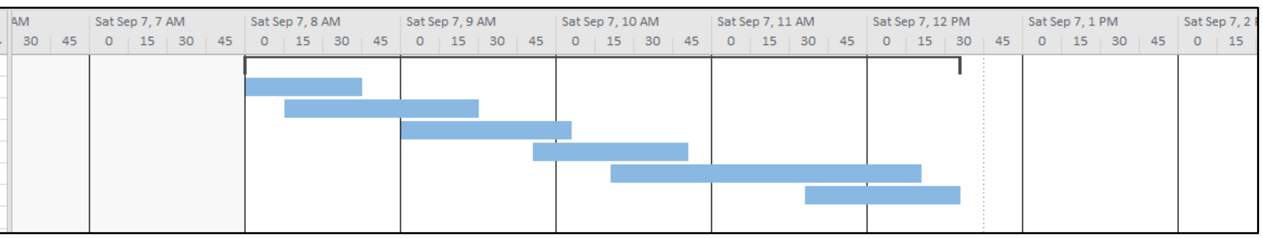
	Task Name	Duration
14	Place AC patch	1 hr
15	Watershock AC patch	1.5 hrs
16	Remove formwork	0.5 hrs
17	Reinstall panels	2 hrs
18	Clean work site	1 hr



Sheet 2 of 2

6. Drain channel construction

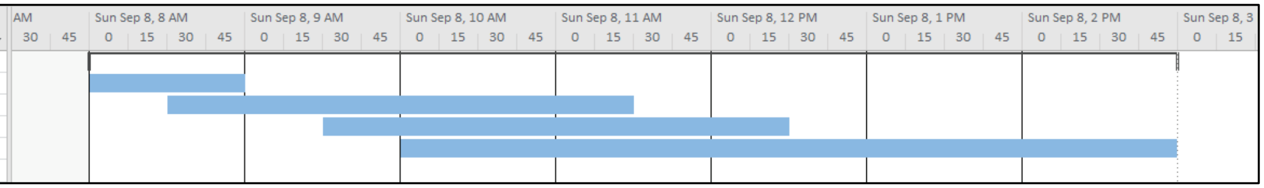
	Task Name	Duration
1	Drain Channel Construction (Half Width)	4.6 hrs
2	Remove panels	0.75 hrs
3	Install saw guides	1.25 hrs
4	Cut drain channel	1.1 hrs
5	Water blast slot	1 hr
6	Reinstall panels	2 hrs
7	Clean site	1 hr



Sheet 1 of 1

7. Joint sealing

	Task Name	Duration
1	**Joint Sealing (Full Width)**	**7 hrs**
2	Air blast joints and anchor holes	1 hr
3	Install backer rod	3 hrs
4	Install sealant	3 hrs
5	Allow sealant to cure, begin clean up	5 hrs



Sheet 1 of 1

Appendix E: Expedient AAS-UHMW Panel Installation Methods - Combination Installation for New AC and PCC Pavement Construction

This installation manual follows the traditional method for installing UHMW panels in existing PCC and AC pavements given in AFI 32-1043. Materials, equipment, installation techniques, and work phasing were modified to allow for efficient and optimal installation following the runway closure criteria given. The construction efforts start by installing panels in the center 75 ft PCC interior (keel) section followed by the exterior 37½ ft AC sections. Materials and processes are similar to those described in Appendices A and B; however, project phasing and time has been modified to accommodate the different widths of materials encountered. Timing was scaled as best as possible to fit the pavement dimensions for each individual work day; however, some work days may require more than 12 hr to complete all necessary tasks.

For the PCC interior keel section, the existing pavement is the foundation for the anchoring points required. A grid of relief cuts is made to assist in the removal and to control the depth of the pavement surface material removed for the panel slot. Concrete within the panel slot is demolished, and a long, partial depth patch is made to provide a smooth surface on which to place panels. Threaded anchorage points are installed, and the panels are installed.

For the AC exterior wing sections, materials, equipment, installation techniques, and work phasing are modified to allow for efficient and optimal installation. A 3 ft deep trench is excavated across the runway for the anchoring foundation. A 12 in. layer of rapid-setting flowable fill is placed on the subgrade followed by a 22 in. lift of concrete. The surface of the concrete is smoothed to accept the UHMW panels, which do not require a separate bedding layer. Threaded anchorage points are installed and the panels are installed.

After all sections of AC pavement receive paneling, a 3 ft wide full-depth asphalt patch is placed along the finished foundation to recompact the disturbed area along the vertical face of the foundation and to ensure that a quality joint is created.

Once all the panels are installed, anchorage points for the tie-down ropes are cut and hardware installed. Joint sealing is completed as a separate activity once all panels across the runway are installed. Personnel requirements for each task as well as a list of supplies and equipment needed for the work are provided for each set of work tasks. Estimated durations of the required work tasks and their scheduling are also provided in Figure E-46 at the end of this appendix.

1. Initial demolition - Transverse sawcutting for AC and PCC sections (1 work day, 4.4 hr)
   a. Identify the panel installation location. Panel installation is expected to be at a transverse slab edge to minimize damage to the pavement (Figure E-1).
   b. See Tables E-1 and E-2 for projected equipment, supply, and personnel needs before conducting work.
   c. Mark AC sawcut locations on the pavement (Figure E-2).
      (1) Lay out sawcut locations using a tape measure and lumber crayon. Make sets of marks every 20 ft transversely across the runway. Make marks for both the slot and the adjoining patches (four cuts required per exterior portion of pavement).
      (2) Snap a chalk line between the corresponding parallel marks made with water-resistant chalk (Figure E-3).
         (a) Use two, three-person teams: one operates the tool, one holds the free end of the string line, and one snaps the line.
         (b) Multiple snaps of the line may be needed to produce a solid, observable line.
      (3) Complete all lines longitudinally within a set of crayon marks before moving transversely across the runway. This will allow the saws to start before all lines are made.
   d. Begin full depth sawcutting of the AC areas with the floor saw using 18 in. saw blades (Figure E-4).
      (1) Allow ample time for the chalking crew to snap lines before starting sawing efforts. Chalk will not stick and stain the AC surface if wet.

(2) A larger diameter saw blade may be needed, depending on the asphalt pavement thickness encountered. Use multiple saw blades of increasing diameter to cut deeper surface pavement to assist with making straight cuts. For a cut depth of 6, 9, or 15 in., use an 18, 24, or 36 in. diameter blade, respectively.

(3) The spotter should use a floor broom to clear saw slurry. Cleaners should lightly spray water over the work area as sawing is completed to rinse the surface and allow the saw team to see chalk lines as needed (Figure E-5). Use a less aggressive spray nozzle if available to prevent chalk line removal.

(4) If multiple saws are used at one time, stagger saw start times and cuts made to allow for continuous cutting. Scheduling shown is based on the use of one saw.

e. Mark PCC sawcut locations on the pavement.

(1) Lay out sawcut locations using a tape measure and a lumber crayon. Marks should be spaced approximately 6 in. apart. Exterior marking should overlap those made in the PCC section. Make sets of marks every 25 ft transversely across the runway (four total sets for 75 ft of runway) (Figure E-2).

(2) Make additional marks to indicate cutting at the slab joint. Caulk lines may not be needed.

(3) Snap a water-resistant chalk line between the corresponding parallel marks.

(a) Use two, three-person teams to produce the chalk lines: one operates the tool, one holds the free end of the string line, and one snaps the line. Multiple snaps of the line may be needed to produce a solid, observable line. Two teams may be necessary to assist in making up time lost to repeated rewinding of the chalk line to produce solid, bold lines.

(b) Complete all lines longitudinally within a set of crayon marks before moving transversely across the runway. This will allow the saws to start before all lines are made.

Figure E-1. Panel slot location.

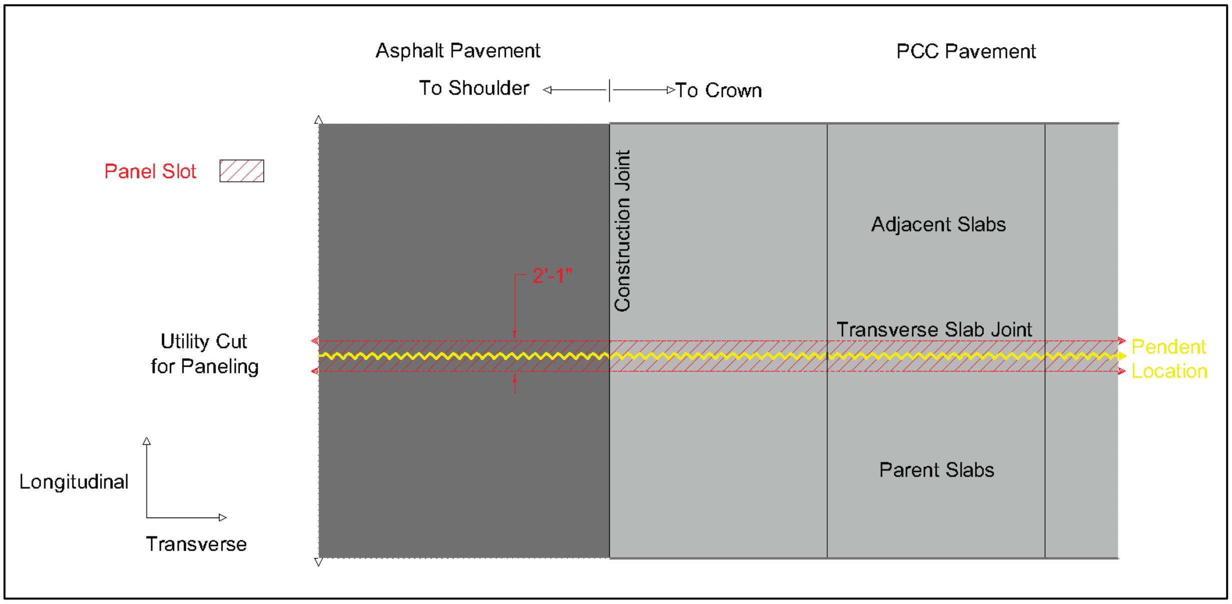


Figure E-2. Transverse saw cut locations for AC and PCC locations.

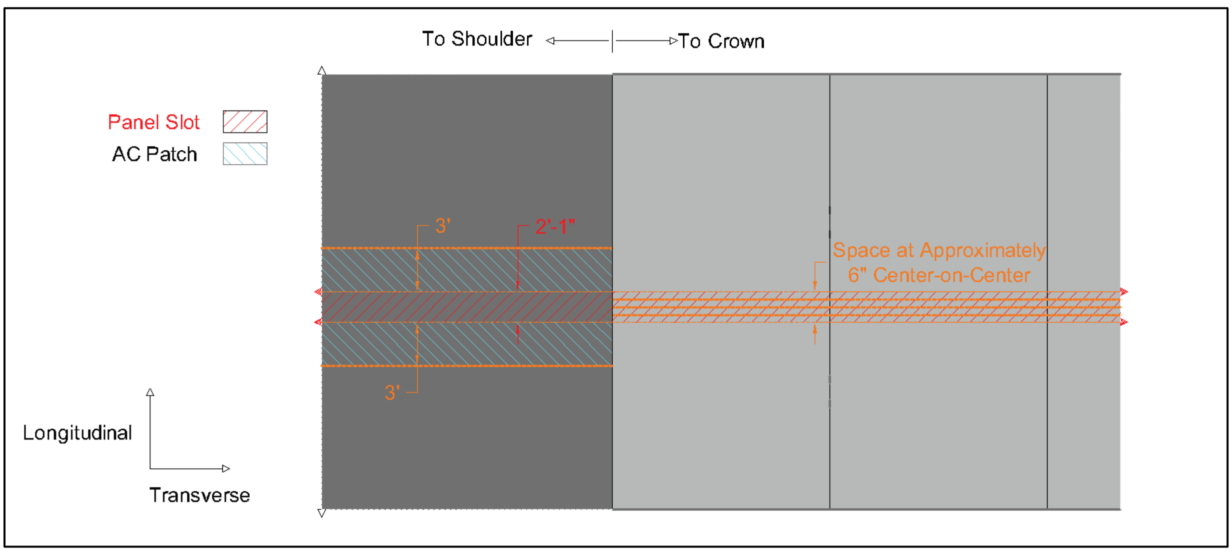


Figure E-3. Snapping chalk lines.

Figure E-4. Transverse cutting on AC areas.

Figure E-5. Lightly rinsing the surface while sawing.

f. Begin partial-depth sawcutting of the PCC areas with the floor saws using 18 in. saw blades (Figure E-6).
   (1) Allow ample time for the chalking crews to snap lines before starting sawing efforts. Chalk will not stick and stain the concrete if the surface is wet.
   (2) Cut to a depth of 3½ in. minimum. Avoid cutting deeper than 4 in.
   (3) The spotter should use a floor broom to clear saw slurry. Cleaners should lightly spray water over the work area as sawing is completed to rinse the surface and allow the saw team to see chalk lines as needed. Use a less aggressive spray nozzle if available to prevent chalk line removal.
   (4) If multiple saws are used at one time, stagger saw start times and cuts made to allow for continuous cutting. Scheduling shown is based on use of one saw as provided in a standard SuPR kit.
g. After all cuts are completed, water blast the cut areas and surrounding pavement with a pressure washer to remove saw slurry and debris (Figure E-7). Start at the pavement crown and work towards the shoulder.
h. Finalize site cleanup and exit the runway.

Figure E-6. Making transverse cuts on PCC areas.

Figure E-7. Waterblasting saw slurry.

Table E-1. Personnel needs and tasks for transverse sawing activity.

Description	Task	Quantity
Marker	Mark locations for chalk lines	2
Chalk line team	Make chalklines	6 (2 teams of 3)
Equipment operator	Operate floor saw	1
Spotter	Assist with aligning saw	1
Hose tender	Move and maintain water truck and hose	1
Cleaner	Pressure wash and clean pavement	2
Equipment operator	Operate airfield sweeper truck	1

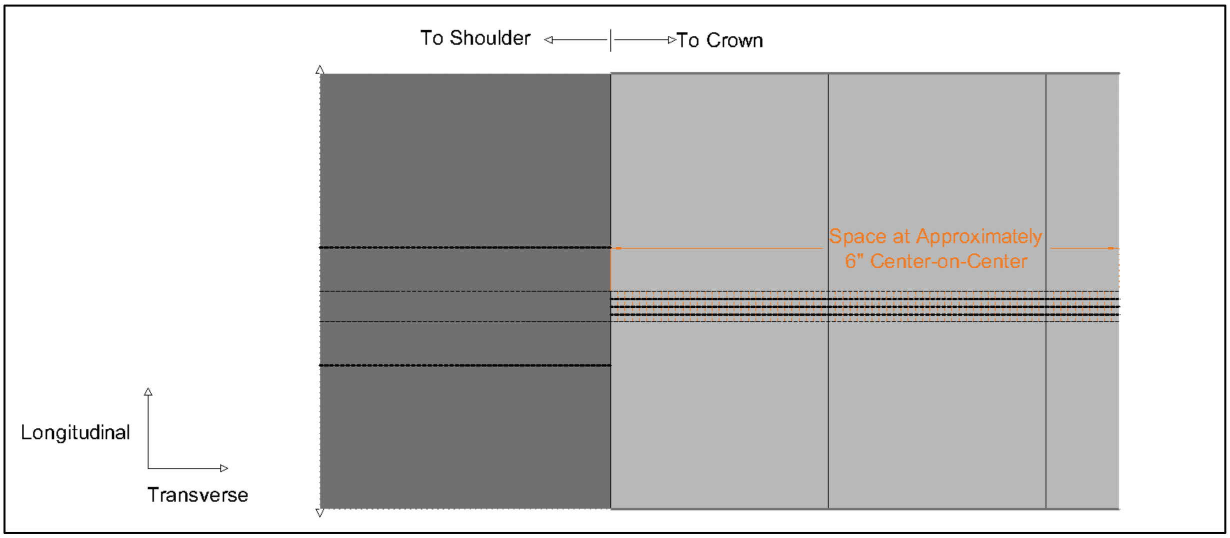
Table E-2. Equipment and supply needs for transverse sawing activity.

Equipment	
Item	**Quantity**
Measuring tape	2
Chalk line tool	2
Floor saw	1
Push broom	2
Squeegee	2
Water truck, 1,000 gal minimum	1
Water hoses, ¾ in. diameter by 50 ft long	6
pressure washer	2
airfield sweeper truck	1
Supplies	
Item	**Quantity**
Water-resistant chalk, bottle	1
Lumber crayons, each	4
18 in. diameter concrete saw blade	2

Italicized items are not included in a Standard USAF SuPR kit.

2. Longitudinal sawcutting for PCC sections (2 work day, half width, 4.8 hr per day)
   a. See Tables E-3 and E-4 for projected equipment, supply, and personnel needs before conducting work.
   b. Mark sawcut locations on the pavement (Figure E-8).
      (1) Lay out sawcuts using a tape measure and a lumber crayon. Marks should be spaced approximately 6 in. apart.

Figure E-8. Longitudinal cut locations.



      (2) Make additional marks to indicate cutting at the slab joint. Caulk lines may not be needed.
      (3) Snap a chalk line between the corresponding parallel marks with water-resistant chalk.
         (a) Use two, two-person teams: one operates the tool, and one holds the free end and snaps the line.
         (b) Work transversely starting at the shoulder side. This will allow the saws to start before all lines are made.
   c. Begin sawcutting with small walk-behind saws using 18 in. saw blades (Figure E-9).
      (1) Allow ample time for the chalking crew to snap enough lines to get beyond the area that will be affected by the sawcutting operations before starting sawing efforts. Chalk will not stick and stain the concrete if the surface is wet.
      (2) Cut to a depth of 3.5 in. minimum. Avoid cutting deeper than 4 in.
      (3) Minimize overcutting (saw kerfs) of concrete outside the marked area for the panel void. Cut short if necessary.

(4) Lightly spray water over the work area to rinse the surface and allow the saw team to see chalk lines as needed. Use a less aggressive spray nozzle if available to prevent chalk line removal.
(5) If multiple saws are used at one time, spread saws across the work area to minimize the need to move the saws long distances and to allow for continuous cutting.
   (a) Scheduling shown is based on the use of two saws.
   (b) If one saw is used, 2 work days will be required. Make the appropriate number of marks required for the area to be completed per work day. This slightly reduces the time spent out of the runway, but increases the number of work days required.

Figure E-9. Performing longitudinal cuts.

d. When sawcutting is completed, water blast the cut area and surrounding pavement with a pressure washer to remove saw slurry and debris. Start at the pavement crown and work towards the shoulders.
e. Finalize site cleanup and exit the runway. The PCC areas should look similar to that shown in Figure E-10 after completion.

Figure E-10. Completed transverse and longitudinal cuts.

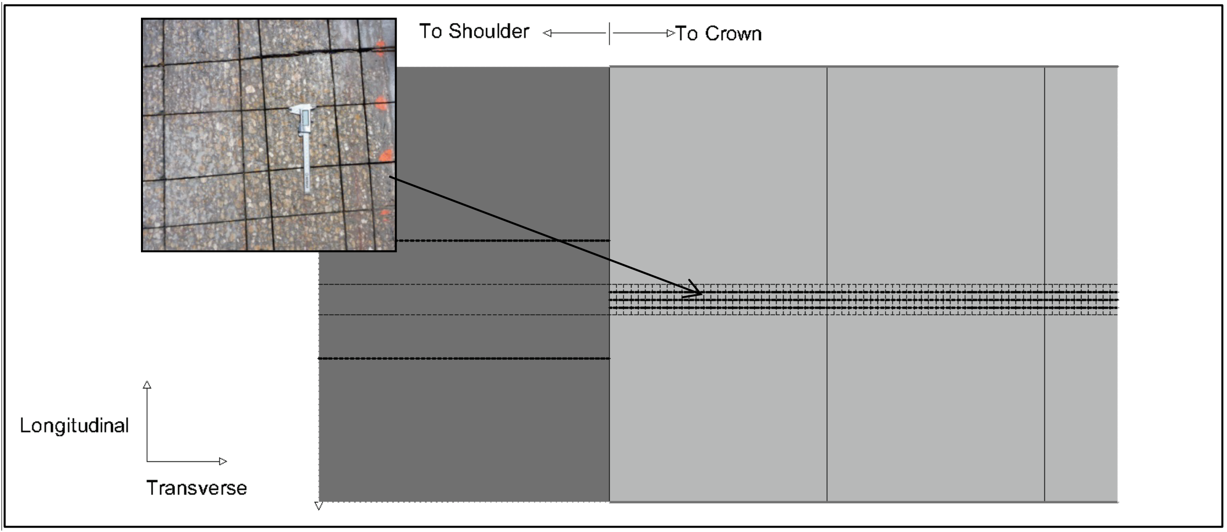


Table E-3. Personnel needs and tasks for longitudinal sawing activity.

Description	Task	Quantity
Markers	Mark locations for chalk lines	2
Chalk line teams	Make chalk lines	4 (2 teams of 2)
Equipment operators	Operate small walk-behind saw	2
Hose tender	Move and maintain water truck and hoses	1
Cleaners	Pressure wash and clean pavement	2
Equipment operator	Operate airfield sweeper truck	1

Table E-4. Equipment and supply needs for longitudinal sawing activity.

Equipment	
Item	**Quantity**
Measuring tape	2
Chalk line tool	2
Walk-behind saw	2
Push broom	2
Squeegee	2
Water truck	1
Water hoses, ¾ in. diameter x 50 ft long	8
Pressure washer	2
Airfield sweeper truck	1
Supplies	
Item	**Task**
Water-resistant chalk, bottle	1
Lumber crayons, each	4
18 in. diameter concrete saw blade	2

Italicized items are not included in a Standard USAF SuPR kit.

3. Demolition and Panel Installation in PCC Sections (2 work days, 12.5 hr total each day)

Install panels across approximately two to three full slabs per work day. Installation days may result in a partial installation of panels within the center slab. Install the correct sequence of panels following the drawings in AFI 32-1043 for the existing slab dimensions (combination of full and half panels as well as full panels with tie-down anchoring points).

a. See Tables E-5 and E-6 for projected equipment, supply, and personnel needs before conducting work.
b. Demolish concrete within panel slot area.
    (1) Remove the first panel adjacent to the panel slot to prevent damaging any installed panels.
    (2) Chisel the panel slot area to a minimum depth of 3.5 in. (Figure E-11).

(a) Use light jackhammers (less than 30 lb) to prevent damage to underlying pavement.

(b) Use two jackhammer teams of two personnel each.

i. One person operates the jackhammer, and the other removes the debris generated. Team members switch jobs as needed.

ii. Start each team on opposing ends of the slot area to be prepared for the work day and work to the interior of the void.

iii. Operate the jackhammer such that it impacts at the depth of the relief cuts made at a 30° to 45° angle from horizontal. This will allow the precut concrete to pop off as individual square piece units. Operating the jackhammer more vertically than recommended chips the units into multiple small pieces that take more time to remove, making debris clearing efforts more extensive and potentially removing more material than required.

(c) Remove medium and large pieces of debris by hand and deposit them into a front end loader or backhoe bucket. Empty the bucket into a dump truck as needed. The equipment operator should help the jackhammer teams remove debris and sweep the smaller debris with a push broom when free.

c. Mill the bottom surface of the panel slot area using the compact track loader and cold planer attachment (Figure E-12).

(1) The goal is to take out the high spots to achieve minimum depth while some low spots may still be present. Mill the surface approximately ¼ in. so that the average elevation difference between before and after demolition is greater than 3⁵⁄₈ in. and the majority of the large high peaks are removed. This should require two passes on each side of the slot.

(2) Set one of the skis on the cold planer to 3 ¾ and zero in. individually. This will allow the cold planer to use existing pavement as a stable guide to control the cutting depth.

(3) Position the cold planer such that the ski set to 3 ¾ in. rides along the pavement surface. Begin milling and ensure the ski remains parallel to the pavement surface.

(a) Make two passes with the CTL, one on each side of the repair void.

(b) Focus on the center 23 in. width to prevent damaging the slot edges. Significantly damaged edges (medium- and high-severity joint and corner spalls) will require partial depth repairs at the conclusion of the work day.
(c) The spotter should sweep debris out of the CTL track areas to provide maximum traction to the vehicle. A backpack blower may also be used to clean larger amounts of debris; however, more extensive project area cleaning with the airfield sweeper truck will be needed at the end of the work day.
(d) Do not overwork the milling head. Travel at a speed that efficiently removes material.

Figure E-11. Chiseling concrete within the repair void.

Figure E-12. Milling the panel slot.

d. Remove all the smaller debris within the slot void. Straddle the slot with the airfield vacuum truck and vacuum the surface. Complete at least twice.

e. Fine tune the slot depth to remove the high spots along the perimeter.

   (1) Use the depth guide tool to verify the minimum slot depth of $3^5/_8$ in. was achieved. Mark any high locations with a lumber crayon (Figure E-13).

   (2) Use the jackhammers or other hand tools to demolish the areas where the milling machine cannot reach along the slot perimeter and any high points as marked.

Figure E-13. Checking the slot depth.

f. Clean the slot area.
   (1) Water blast the concrete surface to remove any loose material at the surface.
   (2) Straddle the slot with the airfield vacuum truck and vacuum the surface again at least twice.
   (3) Heavily air blast the surface until saturated surface dry to remove all standing water. Do not try to dry the surface completely.
g. Place a thin bead of caulk along the slab joints to seal the cracks.
   (1) Start at the shoulder side of the void and work to the interior.
   (2) Use a putty knife to smear the compound over and into the joint if it is difficult to place a continuous bead over the rough surface to ensure the joint becomes sealed. Remove excess material at the surface and outside the vicinity of the crack.
h. Place the bedding layer.
   (1) Prepare a batching station approximately 30 ft away from the repair area to allow ample space to work and operate equipment. Station a water truck and towable dumpster near the batching station to assist with concrete mixer cleaning.
   (2) Place the appropriate bonding agent for the pavement repair material used on the concrete surface. If water is used, this work task is not required if the panel slot surface is still saturated surface dry after water blasting. Lightly apply additional water if the surface becomes dry and air blast before continuing with placing the bedding layer.
   (3) A compact track loader with concrete mixing drum is the preferred method of mixing and transporting due to the quantity of material made. Batch material such that no more than 50% of the total drum volume is used (Figure 14).
   (4) Have a four-person batching team prepare concrete for the bedding layer.
      (a) One person will operate the CTL, two people will handle adding materials to the drum, and one will handle measuring batch water and washing out the drum. A fifth person may be needed to batch aggregates if completed on site.
      (b) Have batch team prepare materials for each load while mixer is delivering material to the panel area.

Figure E-14. Batching concrete with CTL.

(5) Batch material following manufacturer directions.
   (a) Use an approved cementitious pavement repair material for permanent runway or temporary crater repairs.
   (b) Use manufacturer or typical guidance for hot or cold weather placements to mitigate changes in set time. Some recommended mitigation techniques include the following.
      i. Hot: Replace mixing water with chilled or ice water or use a retarding admixture.
      ii. Cold: Keep materials warm until used, use warmed water.
   (c) The panel slot will require approximately 30.5 ft^3 of material with a conservative amount of waste (2½ slab installation, 15 ft wide slabs and 25% waste). Assuming typical prepackaged products yield 0.4 ft^3, approximately 76 units will be required for each work day. Ensure enough material for an additional two full CTL deliveries is available in case deeper than expected repairs are encountered.
   (d) Mix the concrete at the batch site for at least 2 min once all components are added. Mix materials at a speed and drum angle that allow for complete incorporation of the materials, but minimize splatter and material loss from the drum. Rotating the drum back and forth, if allowed by the equipment, can help mix all components together efficiently.

(e) Continue agitating the material slowly while delivering the material.

(6) Have a three-person finishing team construct the bedding layer (Figure E-15).

(a) Two people will screed and trowel the concrete; one person will direct material placement, move concrete as needed, and maintain site cleanliness.

(b) Place material from the shoulder to the runway interior. Use a square shovel to block and prevent concrete splatter.

(c) Screed the surface of the concrete to a depth of 1$^5/_8$ in. below the pavement surface. Pass the screed multiple times to remove excess material. Start the screed over previously placed areas to provide smooth transitions between placements.

(d) Float and trowel the surface to make it flush and smooth. Work fast and efficiently to ensure the material does not set up before work is complete.

(e) Remove excess material at the end of the placement and deposit it into an empty bucket for removal.

(7) Wash out the drum and equipment at an approved location close to the site. A portable washout station consisting of a small, watertight dumpster is recommended so that washing out can be accomplished in the vicinity of the site without any environmental issues. The container can be emptied at an approved site at the end of the work day.

i. Allow the concrete to gain a compressive strength of at least 2,500 psi before continuing with work activities within the panel slot. The estimated time to reach this strength is approximately 90 min at 70°F, but refer to the manufacturer's provided information. Use a nondestructive Schmitt hammer testing device to monitor strength gain.

j. Arrange the panels near their prospective installation locations in the correct order within the slab (Figure E-16). See AFI 32-1043 for the correct panel sequence for the width for the slabs. Ensure locations that require tie-down anchoring receive the correct panel type. Place panels approximate 5 ft away from the slot area to allow work to continue.

Figure E-15. Placing and finishing the bedding material.

Figure E-16. Arranging panels.

k. Re-establish joints at existing locations within the bedding layer (Figure E-17).
   (1) Use the handheld cutoff saw for longitudinal cuts.
   (2) Use the walk-behind saw for the edge joint cut.

(3) Cut joints to $4^{1}/_{2}$ in. in depth minimum. Do not cut deeper than 40% of the slab thickness to prevent cutting any ties or dowels.
(4) Air blast each cut after completion.

Figure E-17. Joint cutting.

l. Clean the vertical faces of the slot perimeter with an angle grinder and a wire cup brush (Figure E-18).

m. Inspect the depth of the panel slot. Ensure the surface is smooth and level so the panels lie correctly in the slot once completed (Figure E-19).
(1) Begin verifying the surface while the concrete is gaining strength. Mark locations that require leveling with a lumber crayon.
(2) Level locations with a small hand scabbler, handheld angle grinder with masonry disk, or demolition hammer/light jackhammer with a bushing bit after the surface reaches 2,500 psi compressive strength. Other appropriate equipment may be used if available.
(3) Verify the final surface elevation in any areas modified. Repeat as necessary.

Figure E-18. Cleaning slot perimeter.

Figure E-19. Final leveling of the panel slot.

n. Air blast the panel slot to remove all small debris.
o. Cut the drain channels in the interior of the concrete.
   (1) Use the walk-behind saw with two 18 in. diameter saw blades butted together.
   (2) Cut two slots transversely in the bedding layer ½ in. deep.
p. Water blast the panel slot.

q. Vacuum the repair area. Straddle the slot with the airfield vacuum truck and vacuum the surface at least twice.
r. Heavily air blast the panel slot.
s. Place and install panels.
  (1) Place and arrange panels in the slot.
  (2) Shim panels into position using wooden wedges (Figure E-20).
    (a) Arrange panels such that approximately ½ in. joints are between the slot /vertical faces and between each panel.
    (b) Place ¼ in. thick boards at ends of the panel installation that touch AC pavement (days 1 and 2) and the central joint (day 1 only). This will construct ½ in. joints at all locations once all panels are installed.
    (c) Draw a string line across the top of the panels. Pick a convenient location/point to assist in aligning the panels. Tangent to the panel anchoring holes is a good location to use as reference. Use masonry nails to fix the string line to the selected location.
    (d) Use wrecking bars to help move panels and add shims as needed to prevent movement.
    (e) Do not break shims or boards after installation. Shims will be removed after anchoring is installed.
    (f) Ensure the panels are solidly locked into position before moving forward with work tasks. Use wrecking bars to help move panels and add shims as needed.
  (3) Install panel anchoring (Figure E-21).
    (a) Drill holes into the concrete foundation using an appropriately sized masonry drill bit and hammer drill. Use the panel anchoring drill guide to ensure a vertical cut is made to the correct depth. Use two drills for increased speed, one on each side of the panel.
    (b) Clean the anchoring holes following the adhesive manufacturer’s directions. Typical cleaning procedures include air blasting, wire brushing, and another round of air blasting to remove all loose material. Personnel requirements could include one airman — one brush cleaner or one airman; one brush cleaner; one airman. A three-person team requires an additional air compressor, hose, and blow gun that are not listed in the equipment requirements.

Figure E-20. Aligning panels within the slot.

Figure E-21. Anchor hole production line.

(c) Any holes that cannot be drilled to full depth because of encountering embedded steel located within the concrete should be marked. Steel within the concrete may be encountered if the concrete is reinforced and/or ties or dowels are present. The masonry drill bits will not cut through the steel. These locations will require a shortened anchor.

(d) Set out and prepare each anchor for installation (Figure E-22).

i. Anchors should be prepared with setting hardware and washers assembled before placement.

ii. Set out any tie-down anchoring needed. Locate the center of the anchoring hole and mark its location with a lumber crayon.

iii. Anchors requiring shortening should be trimmed with a portable band saw to an appropriate length so that the threaded rod is recessed below the panel surface (Figure E-23). Length determination includes the following steps:

(i) Place anchor in the indicated hole requiring modification. Install the washer and hex nut on the rod.

(ii) Twist the nut down within the countersunk hole to mark the maximum anchor length. Rotate the anchor an additional two turns to provide a void for adhesive at the hole depth.

(iii) Remove the anchor without moving the hex nut. Cut the portion of the rod that extended above the panel surface flush with the top of the nut with the band saw.

(iv) Remove the nut and replace on the uncut end of the anchor.

Figure E-22. Layout anchors.

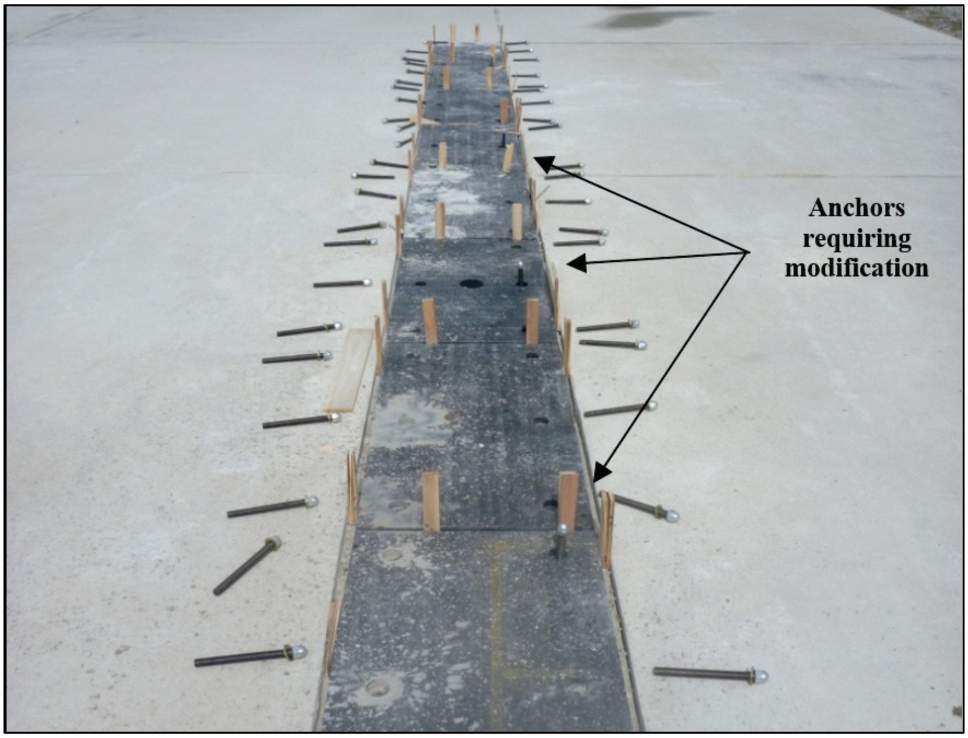


Figure E-23. Trimming a panel anchor.

(e) Install anchoring hardware in each hole (Figure E-24).

   i. AFI 32-1043 describes the use of prepackaged adhesive packets for this task. Ensure the correct amount (or combination of packets if applicable) of adhesive is placed into the hole. Follow all manufacturer directions to correctly measure and use adhesive.

   ii. Bulk adhesive cartridges that use a mixing tube to premix adhesive before entering the drilled holes are highly recommended to ensure all adhesive is properly mixed at the correct ratio. Large cartridges with pneumatic handheld dispensing equipment are recommended to minimize time lost to changing cartridges. An off-site trial of this work is highly recommended to determine the proper equipment settings the filling times.

(i) Ensure enough adhesive is used to embed the anchor. Adjust the air regulator such that adhesive is deposited without leaving air voids but is allowed to flow expeditiously enough to install all anchors in a timely fashion without clogging.

(ii) The proper amount of adhesive has been dispensed when the adhesive is level with the bottom surface of the panel slot when the anchor is installed. Use the first few holes to determine the amount of adhesive needed.

(iii) Clean any excess adhesive that enters the countersunk area with a paper towel before it hardens.

(iv) Rotate the anchor back and forth while in the hole to ensure adhesive completely surrounds the anchor thread.

(v) Cool or heat adhesive to modify setting times as needed in extreme weather conditions.

t. Allow the adhesive to cure to full strength. This is temperature dependent: colder temperatures and base material (concrete foundation) require additional time than warmer environments. Do not activate the anchor until the cure time has been met.

Figure E-24. Anchor installation.

u. Begin any cleanup efforts that do not disturb the anchoring adhesive. Remove the wooden wedges from the panels towards the end of the cure period.
v. Once adhesive has cured, install the hardware on the panel anchoring (Figure E-25).
   (1) Remove the setting hardware and install the hex nut on each anchor stud. Use a $1^{1}/_{8}$ in. socket and an impact wrench/ratchet to aid in removal.
   (2) Gross torque the hex nut on the panel anchoring with an impact wrench. A couple of short bursts are needed to spin the nut hand tight and begin torqueing the nut. Do not over torque the hex nuts.
   (3) Fine torque the hex nuts on the panel anchoring with a torque wrench set to 60 ft-lb.
w. Verify the final anchor head elevations. Grind off any anchors that extend above the panel with an angle grinder (Figure E-26). Be careful not to damage the panel.
x. Finalize site cleanup and sweep project area. Exit the runway. The panels should look similar to those shown in Figure E-27 after completion.

Figure E-25. Permanent hardware installation.

Figure E-26. Grinding an anchor head flush with the panel surface.

Figure E-27. Panel installation complete.

Table E-5. Personnel needs and tasks for demolition and panel installation for PCC sections activities.

Description	Task	Quantity
Complete Demolition		
Demolisher	Jackhammer concrete, remove large debris pieces, level panel surface	4 (2 teams of 2)
Equipment operator	Transport construction debris, clean small debris, operate CTL	1
	Operate vacuum sweeper truck	
Equipment operator / spotter	Transport construction debris, clean small debris, assist with cold milling	1
Bedding Layer Placement		
Equipment operator	Deliver concrete	1
Concrete batcher	Prepare and measures materials for concrete, wash out concrete mixer	3
Concrete finisher	Install caulk, place and finish concrete, saw cut joints and drain channel	3
Cleaner	Maintain site cleanliness, brush slot faces	1
Final Bedding Layer Leveling		
Demolisher	Jackhammer concrete, remove large debris pieces, level panel surface	4 (2 teams of 2)
Cleaner	Maintain site cleanliness, brush slot faces	1
Equipment operator	Operate walk behind saw	1
Spotter	Assist alignment of equipment operator, manage water hoses	1
Anchorage Installation		
Installer	Place and shim panels	4
Driller	Drill anchor holes	2
Cleaner	Clean anchor holes	2-3
Adhesive installer	Arrange and lay out anchors, trim anchors as needed, install anchors, assist adhesive dispenser	2
Adhesive dispenser	Install anchors	1
Everyone begins cleaning the site once complete.		
Hardware Installation		
Installer	Remove temporary and place permanent hardware	2
	Tighten nuts	3
	Verify all anchors are recessed below panel surface, grind anchors that require recessing	1
Cleaner	Collect removed temporary hardware	1

Table E-6. Equipment and supply needs for demolition and panel installation for PCC sections activities.

Equipment	
Item	**Quantity**
Impact wrench	2
$1^1/_8$ in. socket	4
Jackhammer, 40 lb max, with bits	2
Air hose, ¾ in. diameter x 50 ft	2
Air compressor, 100 cfm minimum	1
Backhoe or front end loaded	1
Dump truck	1
Shovel, square	2
Wrecking/pry bar, 36 in. long	2
Push broom	2
CTL	1
18 in. cold planer attachment for CTL	1
Backpack blower	1
Airfield vacuum truck	1
Depth guide tool, $3^5/_8$ in. deep	2
Handheld scabbler	2
Angle grinder	2
Demolition hammer/hammer drill, with bits	1
Pressure washer	1
Water truck	1
Water hose	2
Putty knife, ½ in., flexible	2
Hopper/dumpster	2
Concrete mixer attachment for CTL	1
Knife	2
Concrete float, magnesium	3
Concrete trowel, steel	3
Depth tool guide/screed, $1^5/_8$ in. deep	4
Cutoff saw	1

Equipment	
Item	**Quantity**
Walk-behind saw	1
18 in. concrete saw blade	3
Hammer/maul	3
Rotary hammer drill	2
Small air compressor lance	2
Small air compressor hose, $^3/_8$ in. diameter	6
Small air compressor, 4 gal minimum, 2 outlets	2
5000 W generator	2
Electric drill, 6 A	2
Portable band saw	1
Extension cords, 50 ft	8
Setting hardware	75
*Epoxy adhesive dispensing gun, pneumatic**	1
Panel anchor alignment tool	2
Tie down anchor alignment tool	1
Torque wrench, ½ in. drive, 100 ft-lb capacity	2
Supplies	
Item	**Quantity/ work day**
Lumber crayon	4
4½ in.-diameter masonry stone	10
Caulk compound, 14 oz_f container	6
Rapid-setting concrete, 0.4 ft^3 yield*	76
Sponge	2
Bucket, 5 gal	10
Measuring cup, 1 gal capacity	2
Steel cup brush	2
Wooden shims, $^3/_8$ in. thick	600
String line	1
Masonry nail, 3 in., box	1

Equipment	
Item	Quantity
*Masonry drill bit, 7/8 in. diameter**	4
*Wire brushes for ¾ in. diameter anchoring**	*
Threaded rod, steel, ¾ in. 10 diameter x 10 in. long	*
¾ in. washer, SAE, steel	*
Hex hut, ¾ in., steel	*
4½ in. diameter steel stone	10
Epoxy adhesive	6
*Additional mixing tubes for epoxy adhesive**	12
Shop towels, box/roll	6

* Varies by existing slab and prospective panel arrangement.

Italicized items are not included in a Standard USAF SuPR kit.

4. Demolition and panel installation for AC sections (2 work days, 11.9 hr total each day)

Install panels across entire 38 ft of runway width in need of tie-down anchoring per work day. Install the correct sequence of panels following the drawings in AFI 32-1043.

a. See Tables E-8 and E-9 for projected equipment, supply, and personnel needs before conducting work.
b. Demolish AC pavement within panel slot area (Figure E-28).
   (1) Remove the panel adjacent to the panel slot to prevent damage (panels previously installed from PCC section work).
   (2) Remove the asphalt concrete surface.
      (a) Use a backhoe or small excavator with an 18 in. wide bucket to rip and remove the asphalt from within the panel slot area. Place material to the side of the repair for removal.
      (b) Use a small jackhammer to demolish the asphalt within 1 ft of the ends of the panel slot area to minimize damaging the existing pavement or previously placed panel foundation.
      (c) Use the CTL to remove the demolished asphalt pavement and deposit it into a dump truck.
      (d) Trim any uneven portions of the remaining asphalt concrete with a cutoff saw (Figure E-29).

c. Remove soil sublayers to 36 in. below the pavement surface (Figure E-30).
    (a) Remove the soil within the panel slot area with a backhoe or small excavator.
    (b) Some handwork will be required at the ends of the trench and to square up the sides of excavation.
    (c) Monitor excavation depth over time to verify required depth is achieved.
    (d) Use the CTL or backhoe to dispose of removed soil and deposit in a dump truck.
d. Compact the bottom of the trench with the rammer compactor.
e. Backfill the trench with a flowable fill base.
    (1) Preposition supersacks of flowable fill near the project area for use with the forklift. Allow ample space to operate equipment and allow personnel to work.
        (a) The panel slot will require approximately 98 ft^3 of material with a conservative amount of waste (30 ft long and 25% waste). Assuming a typical supersack yields approximately 27 ft^3, approximately four units will be required for each work day.
        (b) Remove plastic wrapping and find/prepare lifting loops.
        (c) Have an additional supersack of material on hand in case the excavation is wider than expected. Do not remove plastic wrap until needed.
    (2) There are two options to place the flowable fill using typical ADR procedures: the wet method and the dry method.

Figure E-28. Pavement surface removal.

Figure E-29. Trimming the remaining pavement.

Figure E-30. Sublayer material removal.

(a) The wet method uses the simplified volumetric mixer to batch and mix dry materials and water together before placement. The dry method involves placing dry material directly into the excavation and adding a specific amount of water on top of the placed dry material that percolates through the dry material for hydration of the entire mass placed.

(b) If two volumetric concrete mixers are available, the flowable fill can be placed using the wet method. The wet method is expected to take longer to place material than the dry method since the material production/placement rate is much less; however, a better mixed and ultimately much more consistent material is produced that will gain strength much faster since water does not need to percolate through the loose material.

(c) If only one volumetric concrete mixer is available, the flowable fill must be placed using the dry method because the mixer will be needed to batch the concrete surfacing (Figure E-31). Project phasing and this instruction manual are based on use of the dry method to provide accelerated installation times to meet mission objectives.

(3) Make marks in the vertical faces of the soil 24 in. below the pavement surface around the perimeter of the trench.

Figure E-31. Placing flowable fill (dry method).

(4) Place layers of flowable fill by emptying individually supersacks within the trench to the 24 in. marks made (Figure E-31).

(a) Prepare a supersack for use in filling the excavation. Center the supersack over the trench, 3 ft from the end of the trench, using an extendable boom forklift.

(b) Cut the bottom of the bag and distribute material by moving the forklift boom back and forth. Keep the supersack low to the pavement to minimize dust.

(c) Rake and level the surface of the material placed.

(d) Add water to the trench.

i. Determine the flow rate of a water truck distributing water out its rear hose before the project begins. Calibration of the truck's flow rate consists of measuring the amount of time it takes to fill a 5 gal bucket at a constant engine speed (rpm). Determine the true value of water required to reach 5 gal within the bucket used since the total bucket volume will be larger (Figure 32).

$$Flow\ rate = \frac{5\ (gallons)}{Time\ to\ fill\ (\text{seconds})}$$

ii. Determine the total amount of water required to add to the placed flowable fill. For dry placed flowable fill, material is approximately batched at 0.0133 gal/lb of dry material. For standard 3,000 lb supersacks, approximately 40 gal is required.

$$Total\ Water = \#\ of\ supersacks\ used \times Supersack\ weight\ (lb) \times \frac{40\ gal}{3{,}000\ lb}$$

iii. Determine the amount of time to distribute water from the water truck.

$$Time\ to\ run\ water\ (seconds) = \frac{Total\ water}{Flow\ rate}$$

iv. Add water to the trench for the amount of time calculated by lightly spraying the water over the flowable fill area.

(e) Poke a grid of holes into the flowable fill layer to aid in water percolation through the lift of material. A 5 ft long piece of #5 rebar works well for this task. Center two holes longitudinally every foot transversely.

Figure E-32. Calibrating the water discharged from a water truck.

(f) Repeat steps (b) through (e) until the material within the trench reaches the 24 in. depth marks made earlier. Begin placing additional layers once all the water on the surface has soaked into the dry material.

(g) Smooth the surface of the flowable fill with rakes once all material is placed.

(5) Notable differences in the wet vs. dry backfilling methods are as followed.

(a) A volumetric concrete mixer is used with the wet method. Position the mixer approximately 4 ± 1 ft from the trench edge, but do not get closer because it could cause the trench to cave in. Place material from the shoulder to the interior of the runway. Ensure the mixer hopper stays at least one-quarter full to ensure a consistent product is produced.

(b) More water is used to batch flowable fill with the wet method. Approximately 70 gal of water per supersack is used for making flowable fill by the wet method. Material should have a flowability of 10 ± 1 in. by ASTM D6103.

(c) The fluid consistency of the wet-mixed material makes it self-leveling, and matching the cross-slope of the pavement will be difficult. The material will require tailoring by hand tools before the material sets to match the cross-slope of the pavement structure for drainage.

f. Allow the flowable fill to gain strength before continuing work within the excavation. The recommended strength to allow foot traffic for future reinforcement installation and concrete placement without damaging the flowable fill layer is 10 psi by ASTM D6133.

g. Place reinforcement grid in the trench (Figure E-33).

(1) Pre-construct the reinforcement grids to be used before the project begins.
(2) Place the reinforcement grid on a network of steel high chairs that set the grid approximately at the midheight of the constructed slab (Figure E-34).
    (a) Use a minimum of 14 chairs per pre-made grid. Additional chairs may be needed to prevent the grid from sagging.
    (b) Place transverse reinforcement on top of the chairs.
    (c) Tie all chairs to the reinforcement.
(3) Add lap splices to successive placements of reinforcement grids after placement within the trench. Center and tie the short segments of reinforcement to the placed grids to prevent movement, as shown in Figure E-33.

h. Backfill the trench with rapid-setting concrete (Figure E-35).
(1) Use a four-person concrete production team. One drives the truck that pulls the mixer, one operates the forklift that fills the mixer, one assists the forklift operator with bags and monitors the hopper material, and one operates the mixer controls at the rear.
(2) Use the forklift to pre-position supersacks of concrete near the project area but allow ample space to operate equipment and allow personnel to work.
(3) The panel slot will require approximately 180 ft^3 of material with a conservative amount of waste (38 ft long and 25% waste). Assuming a typical supersack yields approximately 25 ft^3, approximately eight units will be required for each work day.
(4) Spray the volumetric mixer auger and chute on the outside and inside with concrete release agent using a pump sprayer. Hand tools can also be sprayed to make cleanup easier.
(5) Ensure both mix water tanks are filled with water. Also, citric acid should be added to the water tanks as a retarding admixture to increase working time during hot weather. Recommended citric acid dosing rates are shown in Table E-7.
(6) Remove plastic wrapping from the supersack and find/prepare lifting loops.
(7) Position the volumetric mixer approximately 4 ± 1 ft from the trench edge, but do not get closer because it could cause the trench to cave in. Place material from the shoulder to the interior of the runway.

(8) Ensure the mixer hopper stays at least one-quarter full to ensure a consistent product is produced. Two additional super sacks must be added to the hopper as material is placed to allow the mixer to correctly produce material but will ultimately be wasted as unused material.

(9) Have a five-person finishing team construct the bedding layer.

(a) The rapid-setting concrete used is self-consolidating due to its fluid consistency. No vibration is required.

(b) Four people will screed and trowel the concrete; one person will direct material placement, move concrete as needed, and maintain site cleanliness.

(c) Place material from the shoulder to the runway interior. Use a square shovel to block and prevent concrete splatter.

(d) Screed the surface of the concrete to a depth of 1 5/8 in. below the pavement surface. Pass the screed multiple times to remove excess material and deposit material into low areas. Start the screed over previously placed areas to provide smooth transitions between placements.

Figure E-33. Reinforcement layout and dimensions.

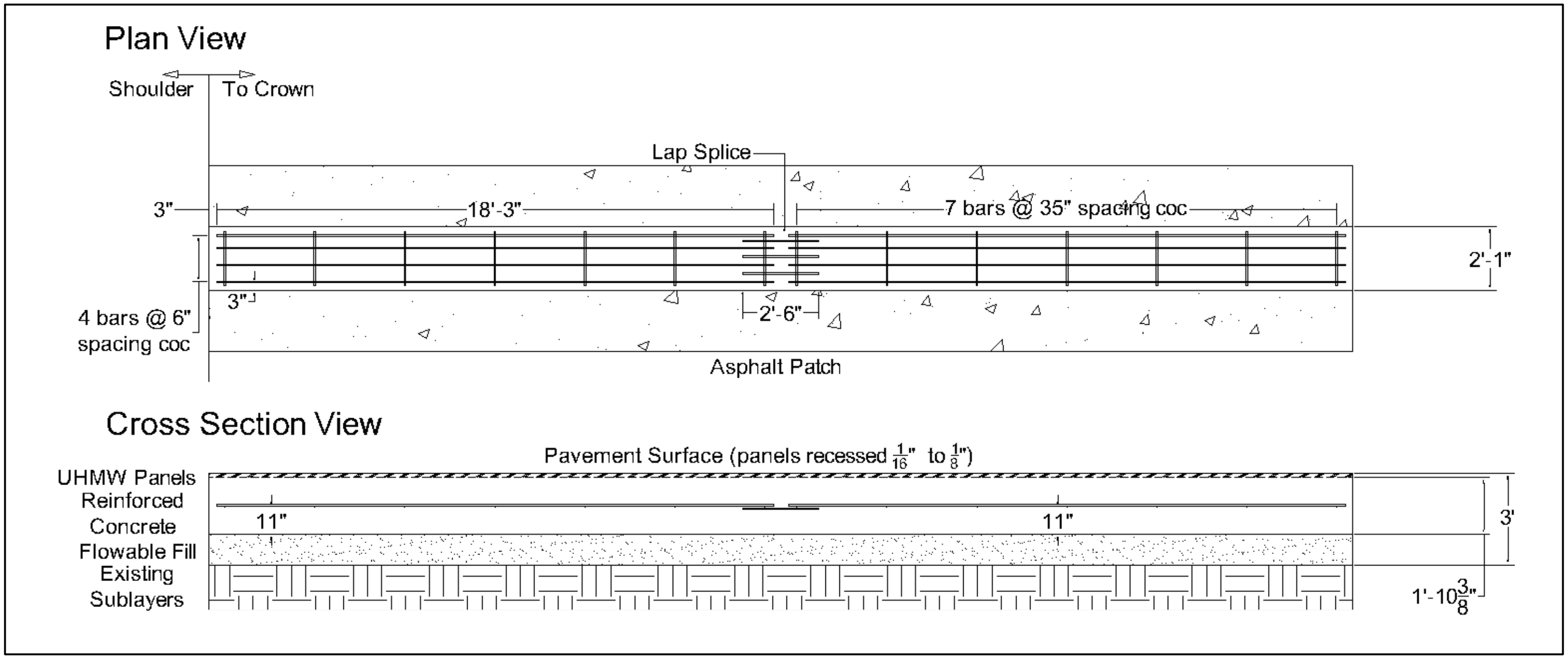


Table E-7. Citric acid dosing rate information.

Ambient Temperature (^{O}F)	Dosage (pounds per 50 gal of mix water)
Below 75	0
75-80	1
80-85	2
85 and above	3

Figure E-34. Reinforcement grids placed on chairs.

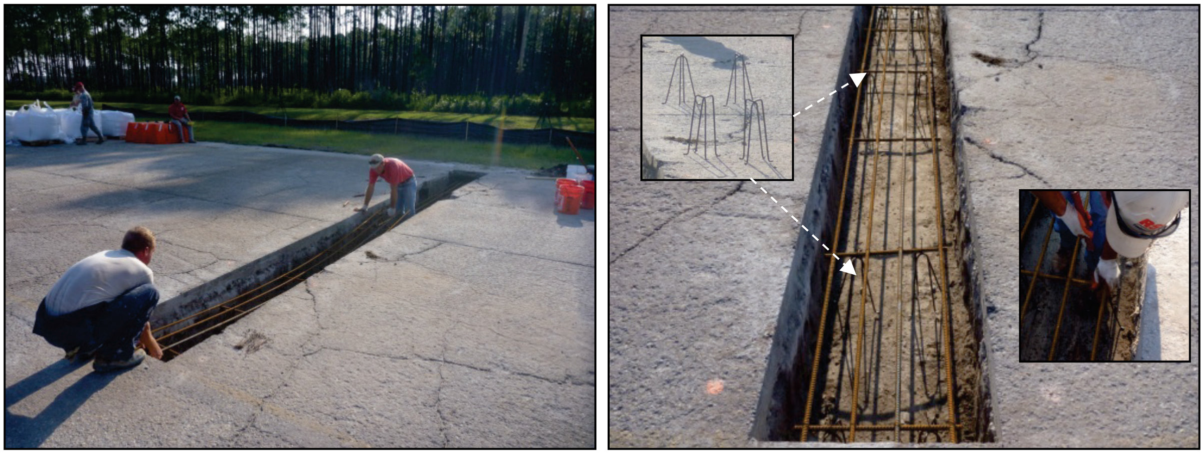


Figure E-35. Placing rapid setting concrete.

(e) Float and trowel the surface to make it flush and smooth. Allow the concrete to stiffen up slightly before working to allow for efficient finishing, since the placed concrete will be self-leveling in nature.

(f) Work fast and efficiently to ensure the material does not set up before work is complete. Remove excess material at the end of the placement and deposit it into an empty bucket for removal.

i. Allow the concrete to attain a compressive strength of at least 2,500 psi before continuing with work activities within the panel slot. Estimated time is approximately 90 min at 70°F, but refer to the manufacturer's provided information. Use a nondestructive Schmitt hammer testing device to monitor strength gain.
j. Arrange the panels near their prospective installation locations in the correct order for placement within the slab (Figure E-36).
   (1) See AFI 32-1043 for the correct panel sequence to ensure the panels with tie-down anchoring holes are positioned correctly.
   (2) Place panels approximate 5 ft away from the slot area to allow work to continue.
k. Inspect the depth of the panel slot. Ensure the surface is smooth and level so the panels lie correctly in the slot once completed (Figure E-37).
   (1) Begin verifying the surface while the concrete is gaining strength. Mark locations that require leveling with a lumber crayon.
   (2) Level marked locations with a small hand scabbler, handheld angle grinder with masonry disk, or demolition hammer/light jackhammer with a bushing bit after the surface reaches 2,500 psi compressive strength. Other appropriate equipment may be used if available.
   (3) Verify the final surface elevation in any areas modified.
   (4) Repeat steps (1) through (3) as needed.
l. Air blast the panel slot.
m. Cut the drain channels in to the interior of the concrete.
   (1) Use the walk-behind saw with two 18 in. diameter saw blades butted together.
   (2) Cut two slots transversely in the bedding layer ½ in. deep.
n. Water blast the completed panel slot to remove sawing slurry.
o. Vacuum the repair area. Straddle the slot with the airfield vacuum truck and vacuum the surface at least twice.
p. Heavily air blast the panel slot.

Figure E-36. Arranging panels.

Figure E-37. Final leveling of the panel slot.

q. Install panel anchoring (Figure E-38).
   (1) Drill holes into the concrete foundation using an appropriately sized masonry drill bit and hammer drill. Use the panel anchoring drill guide to ensure a vertical cut made to the correct depth. Use two drillers for increased speed, one on each side of the panel transversely.

(2) Clean the anchoring holes following the adhesive manufacturer's directions. Typical cleaning procedures include air blasting, wire brushing, and another round of air blasting to remove all loose material. Personnel requirements could include one airman, one brush cleaner or one airman, one brush cleaner, one airman. A three-person team requires an additional air compressor, hose, and blow gun not listed in the equipment requirements.

(3) Any holes that cannot be drilled full depth because of encountering embedded steel within the concrete should be marked. These locations will require a shortened anchor.

(4) Set out and prepare each anchor for installation (Figure E-39).

- (a) Anchors should be prepared with setting hardware and washers assembled before placement.
- (b) Set out any tie-down anchoring needed. Locate the center of the anchoring hole and mark its location with a lumber crayon.
- (c) Anchors requiring shortening should be trimmed with a portable band saw to an appropriate length to recess the rod below the panel surface (Figure E-40). Length determination includes these steps:
  - i. Place the anchor requiring modification into the indicated hole. Install the washer and hex nut on the rod.
  - ii. Twist the nut down within the countersunk hole to mark the maximum anchor length. Rotate the anchor an additional two turns to provide a void for adhesive at the hole depth.
  - iii. Remove the anchor without moving the hex nut. Cut the portion of the rod that extends above the panel surface flush with the top of the nut with the band saw.
  - iv. Remove the nut and replace on the uncut end of the anchor.

(5) Install anchoring hardware in each hole.

- (a) AFI 32-1043 describes the use of prepackaged adhesive packets for this task. Ensure the correct amount (or combination of packets if applicable) of adhesive is placed in the hole to ensure the necessary adhesive is provided for a good bond. Follow all manufacturer directions for correct use of the adhesive.

Figure E-38. Anchor hole production line.

Figure E-39. Layout anchors.

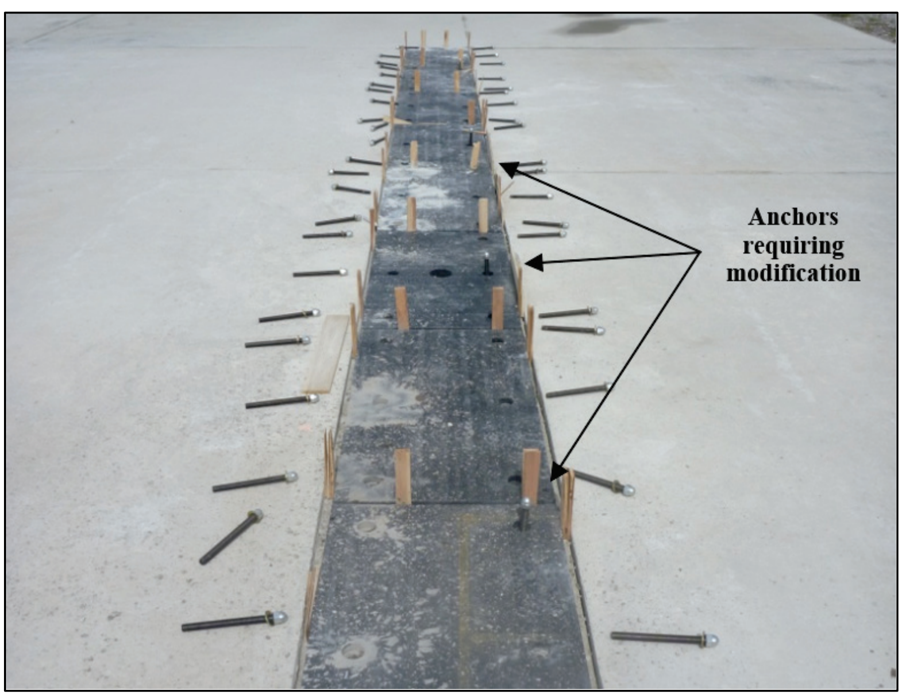


Figure E-40. Trimming a panel anchor.

(b) Bulk adhesive cartridges that use a mixing tube to premix adhesive before entering the drilled holes are highly recommended to ensure all adhesive is properly mixed at the correct ratio. Large cartridges with pneumatic handheld dispensing equipment are recommended to minimize time in changing cartridges.

i. Ensure enough adhesive is used to embed the anchor. Adjust the air regulator such that adhesive is deposited without leaving air voids but quickly enough to install all anchors in a timely fashion without clogging.

ii. The proper amount of adhesive has been dispensed when the adhesive is level with the bottom surface of the panel slot when the anchor is installed. Use the first couple of holes to determine the amount of adhesive needed.

iii. Clean any excess adhesive that enters the countersunk area with a paper towel before it hardens.

iv. Rotate the anchor back and forth while in the hole to ensure adhesive completely surrounds the anchor thread.

v. An off-site trial of this procedure is highly recommended to determine the proper equipment settings and filling times.

vi. Cool or heat adhesive to modify setting times as needed in extreme weather conditions.

r. Allow the adhesive to cure to full strength. This is temperature dependent: colder temperatures and base material (concrete foundation) require additional time than warmer environments. Do not activate the anchor until the cure time has been met.

s. Begin any cleanup efforts that do not disturb the anchoring adhesive. Remove the wooden wedges from the panels towards the end of the cure period.
t. Once the adhesive has cured, install the hardware on the panel anchoring.
    (1) Remove the setting hardware and install the hex nut on each anchor stud. Use a $1^1/_8$ in. socket and an impact hammer/ratchet to aid in removal.
    (2) Gross torque the hex nut on the panel anchoring with an impact wrench. A couple of short bursts are needed to spin the nut hand tight and begin torqueing the nut. Do not over torque the hex nuts.
    (3) Fine torque the hex nuts on the panel anchoring with a torque wrench set to 60 ft-lbs.
u. Verify the final anchor head elevations. Grind off any anchors that extend above the panel with an angle grinder. Be careful not to damage the panel.
v. Finalize site cleanup and sweep project area. Exit the runway.

Table E-8. Personnel needs and tasks for demolition and panel installation for AC sections activities.

Description	Task	Quantity
Demolition and Excavation		
Equipment operator	Operate CTL and backhoe, transport construction debris	2
Spotter / cleaner	Transport construction debris, clean small debris, fine tune trench dimensions with hand tools	2
Flowable Fill Placement		
Equipment operator	Drive forklift	1
	Operate water truck and dispense water	1
Spotter	Remove shrinkwrap, open supersacks, dispense dry material	1
Spreader	Level flowable fill to correct elevation, make percolation holes	3
Concrete Placement		
Equipment Operator	Tow volumetric mixer	1
	Operate volumetric mixer	1
	Operate forklift	1
	Operate airfield sweeper truck	1
Operator assistant	Remove shrinkwrap for supersacks, assist loading mixer	1
Concrete finisher	Screed and finish concrete	5
Demolisher	Jackhammer concrete, remove large debris pieces, level panel surface	4 (2 teams of 2)
Cleaner	Maintain site cleanliness, air blast slot area	1
Anchorage Installation		
Panel installer	Place and shim panels	4
Driller	Drill anchor holes	2
Cleaner	Clean anchor holes	2-3
Adhesive installer	Arrange and lay out anchors, trim anchors as needed, install anchors, assist adhesive dispenser	2
Adhesive dispenser	Install anchors	1
Everyone begins cleaning the site once complete.		
Hardware Installation		
Installer	Remove temporary and place permanent hardware	2
Cleaner	Collect removed temporary hardware	1
Fitter	Tighten nuts	3
Validator	Verify all anchors are recessed below panel surface, grind anchors that require recessing	1

Table E-9. Equipment and supply needs for demolition and panel installation for AC sections activities.

Equipment	
Item	Quantity
CTL	1
Cold planer attachment, 18 in. wide	1
Airfield sweeper truck	1
Water truck, 500 gal minimum	1
Impact hammer	2
1 1/8 in. socket	4
5,000 W generator	2
Backhoe or small excavator	1
Jackhammer, 40 lb max, with bits	1
Air hose, ¾ in. diameter x 50 ft	1
Air compressor, 100 cfm minimum	1
CTL with bucket	1
Cutoff saw with concrete blade	1
Dump truck	1
Measuring tape, 25 ft	1
Shovel, square	2
Shovel, round	2
Concrete rakes	2
Sand rakes	3
Wrecking/pry bar	2
Push broom	2
Rebar, #5 x 5 ft long	2
Telehandler forklift, 6 kip capacity minimum	1
Volumetric concrete mixer	1-2
Backpack sprayer	1
Airfield vacuum truck	1
Rebar tying tool	2
Handheld scabbler	2
Angle grinder	2

Equipment	
Item	**Quantity**
Demolition hammer/hammer drill, with bits	1
Knife	2
Concrete float, magnesium	3
Concrete trowel, steel	3
Depth tool guide/screed, $1^{5}/_{8}$ in. deep	4
Walk-behind saw	1
18 in. concrete saw blade	3
Pressure washer	1
Water hose	2
Hammer/maul	3
Rotary hammer drill	2
Small air compressor lance	2
Small air compressor hose, $^{3}/_{8}$ in. diameter	6
Small air compressor, 4 gal minimum, two outlets	2
Hammer drill	2
Portable band saw	1
Extension cords, 50 ft	8
Setting hardware	50
*Epoxy adhesive dispensing gun, pneumatic**	1
Electric drill, 6 amp	1
Panel anchor alignment tool	2
Dry core barrel, 4.5 in. diameter	1
Tie down anchor alignment tool	1
Torque wrench, ½ in. drive, 100 ft-lb capacity	2
Supplies	
Item	**Quantity/ work day**
#5 steel reinforcement, 20 ft	12
Rebar ties, 16 gauge, 8 in. long	100
Lumber crayons	4*

Equipment	
Item	**Quantity**
High chairs, 11 in. tall	14
4½ in. diameter masonry stone	10*
Rapid-setting flowable fill, 3,000 lb	6
Rapid-setting concrete, 3,000 lb	10
Citric acid, anhydrous powder form, 50 lb	1
Concrete release agent, 5 gal	1
Bucket, 5 gal	5
Measuring cup, 1 gal capacity	2
Steel brush attachment for angle grinder	2*
Wooden shims, 3/8 in. thick	600*
Stringline	1*
Masonry nail, 3 in., box	1*
Masonry drill but, 7/8 in. diameter	2*
Wire brushes for ¾ in. diameter anchoring pieces	4*
Threaded rod, steel, ¾ in. 10 diameter x 10 in. long	48
¾ in. washer, SAE, steel	48
Hex nut, ¾ in., steel	48
4½ in. diameter steel stone	10*
Epoxy adhesive	5
Additional mixing tubes for epoxy adhesive	2
Shop towels, box/roll	6

* Total quantity needed for all work days
** Varies by existing slab and prospective panel arrangement.
Italicized items are not included in a Standard USAF SuPR kit.

5. AC Patching (2 work days, 5.9 hr per day, both sides of each runway exterior section per day)
   a. See Tables E-10 and E-11 for projected equipment, supply, and personnel needs before conducting work.
   b. Mill the asphalt pavement between the sawcuts and foundation full depth with the CTL with cold planer attachment (Figure E-41). Complete work on one 38 ft exterior portion of the AC at a time.
      (1) Make passes in 1 in. depth increments. At least two passes per cut depth will be required. Maintain approximately 1 in. away from the edges to prevent damaging materials outside the boundaries.
      (2) Set one of the skis on the cold planer 1 in. deeper the other ski after the first pass is made. This will allow the cold planer to use existing pavement as a stable guide to control the cutting depth.
      (3) Have the airfield sweeper truck vacuum the patch slot after each pass of the CTL.
      (4) Complete milling on both sides of the panels before moving forward.
      (5) After milling is complete on each side, use a demolition hammer to remove the unmilled portions within the slot perimeter.
   c. Wet the exposed base material with water to prepare for compaction. Apply approximately ½ gal/yd^2 evenly across the base material.
   d. Remove the UHMW panels adjacent to the milled area from the runway.
   e. Compact the surface of the base layer with the steel wheel roller. Vibrate the soil to aid in compaction. Be careful not to over roll and damage the aggregates.
   f. Install st/eel asphalt formwork to the panel anchoring.
      (1) Install while the roller operates but in completed compacted areas.
      (2) Apply form release oil to the steel to assist in form removal.
      (3) Use an impact wrench to quickly tighten the forms to the concrete. Use a quick burst to prevent over tightening and damaging the anchorage points.
   g. Apply tack material to perimeter of asphalt surfaces Asphalt binder is recommended to prevent the need for water base emulsion products to break. Use a locally available material that best matches the grade of the existing asphalt concrete.
   h. Place asphalt and compact with the steel roller (Figure E-42).

(1) Place material within the patch. Grossly fill low spots and level high areas by hand, but minimize handwork to prevent segregation. Place loose material 1 in. higher than needed to account for compaction. Distribute enough loose material to provide 1 to 2 in. of head while screeding with the CTL.
(2) Roll loosely placed asphalt with the steel wheel roller. Follow guidance on ADR asphalt placement and materials.
(3) Monitor density with a nuclear density gage to ensure efficient compaction is achieved. Continue rolling as needed.

i. Watershock the overlay surface to accelerate cooling the asphalt placed.
(1) Distribute water over the surface of the asphalt overlay to help the material cool and gain strength. This can be done intermittently by hand (Figure E-42) or continuously with the help of a lawn sprinkler.
(a) Use of a cart-mounted lawn sprinkler is recommended for continuous cooling.
(b) When the lawn sprinkler is used, set up the sprinkler and water truck towards the runway crown end of the overlay and allow the water to flow to the shoulder. Set up equipment such that it lies on cool pavement and the water sprayed lands at 1 ft from the start of the overlay.
(c) Place sandbags over the cart wheels to prevent movement
(d) Two systems will be required for overlaid areas at the pavement crown.
(2) Monitor the surface temperature of the overlay with an infrared thermometer at 5 min. intervals. Take measurements in at least six random locations across the fresh patch.
(3) Stop cooling once the surface reaches 125 °F or is similar to the surrounding pavement.

j. Remove the steel formwork once the steel is safe to touch with gloves.

k. Replace the panels.

l. Finish cleaning the project area.

Table E-10. Personnel needs and tasks for AC patching activities.

Description	Task	Quantity
Milling		
Equipment operator	Operate CTL	1
	Operate airfield sweeper truck	1
Spotter	Guide CTL while milling, set milling head ski height	1
Base Recompaction		
Equipment operator	Drive water truck and apply water	1
	Operate plate compactor	1
Installer	Remove panels, collects hardware, install formwork	6 (2 groups of 3)
AC Placement		
Equipment operator	Deliver asphalt	1
	Operate CTL	1
	Operate roller compactor	1
	Operate water truck and watershock asphalt	1
	Operate airfield sweeper truck	1
Spotter	Guide CTL while screeding, set screed height	1
Paver	Apply tack material, place AC	4
Panel Reinstallation		
Installer	Remove temporary formwork, reinstalls panels	6 (2 groups of 3)
	Tighten nuts with torque wrench	2

Figure E-41. Milling the pavement for the patch.

Figure E-42. Asphalt placement.

Table E-11. Equipment and supply needs for AC patching activities.

Equipment	
Item	**Quantity**
CTL	1
Cold planer attachment, 18 in. wide	1
Airfield sweeper truck	1
Push broom	1
Demolition hammer, with bits	1
Extension cord, 50 ft	1
Generator, 3,000 W	1
Water truck, 1,000 gal minimum	1
Steel wheel vibratory compactor, CB14 or equivalent	1
Impact hammer	2
1 1/8 in. socket	2
5,000 W generator	1
Wrecking/pry bar	2
Custom steel formwork	*
Roofing brush	2
Asphalt screed attachment	1
Measuring tape, 25 ft	1
Shovel, square	2
Asphalt rake/lute	2
Water hose	4
Water sprinkler, wheeled	2
Sand bag, 25 lb	2
Infrared temperature gun	1
Torque wrench, ½ in. drive, 100 ft-lb capacity	2
Supplies	
Item	**Quantity/ work day**
Hot asphalt binder, gal	8
Hot mixed asphalt, airfield grade, ton	7**

* Varies by prospective panel dimensions.
** Assumes 4 in. patch is made with 25% waste.
Italicized items are not included in a Standard USAF SuPR kit.

6. Tie down anchoring construction (1 work day, up to 2.3 hr for eight locations)
   a. See Tables E-12 and E-13 for projected equipment, supply, and personnel needs before conducting work.
   b. Locate tie-down anchoring locations.
   c. Core the void for the anchor head with the rotary hammer drill and dry coring bit. (Figure E-43).
      (1) Center the core bit in the tie-down anchor hole and cut to a depth of 3 in.
      (2) Make one continuous cut if possible. Removing the core bit at any time in the process requires the hole to be cleaned before continuing to prevent clogging and to allow for additional cutting.
      (3) The dry core bit used in hammer mode should demolish the majority of the cored material. If material is still present, use a chisel or bushing bit to level the bottom of the core.
      (4) Air blast the core hole.
   d. Drill the tie-down anchor embedment hole. Use the tie-down anchoring drill guide to ensure a vertical cut is made to the correct depth.
   e. Clean the anchoring embedment hole following the adhesive manufacturer's directions.
   f. Install the tie-down anchor into the hole. Ensure the eye is aligned in the longitudinal direction.

Figure E-43. Tie-down anchorage installation.

Table E-12. Equipment and supply needs for tie-down anchorage installation activities.

Equipment	
Item	**Quantity**
Airfield sweeper truck	1
Impact hammer	2
1 1/8 in. socket	4
5,000 W generator	2
Measuring tape, 25 ft	1
Wrecking/pry bar	2
Demolition hammer/hammer drill, with bits	1
Hammer/maul	2
Rotary hammer drill	2
Small air compressor lance	1
Small air compressor hose, 3/8 in. diameter	3
Small air compressor, 4 gal minimum, two outlets	1
Extension cords, 50 ft	6
*Epoxy adhesive dispensing gun, pneumatic**	1
Electric drill, 6 amp	1
Dry core barrel, 4½ in. diameter	1
Tie down anchor alignment tool	1
Torque wrench, ½ in. drive, 100 ft-lb capacity	2
Supplies	
Item	**Quantity/ work day**
Bucket, 5-gal	5
Masonry drill bit, 1 1/8 in. diameter	2*
Wire brushes for 1 in. diameter anchoring pieces	4*
Epoxy adhesive	5
Additional mixing tubes for epoxy adhesive	2
Shop towels, box/roll	6
Eyebolt	4 or 8

* Total quantity needed for all work days.
** Varies by existing slab and prospective panel arrangement.
Italicized items are not included in a Standard USAF SuPR kit.

Table E-13. Equipment and supply needs for tie-down anchorage installation activities.

Description	Task	Quantity
Installer	Remove and replace panels and hardware	6
Driller	Drill anchor head void and hole	2
Cleaner	Clean anchor holes, level concrete	3
Anchor installer	Arrange and lay out anchors, install anchors, assist adhesive dispenser	1
Adhesive dispenser	Dispense adhesive	1
Equipment operator	Operate airfield sweeper truck	1

7. Joint sealing (1 work day, 7.0 hr)
   a. See Tables E-14 and E-15 for projected equipment, supply, and personnel needs before conducting work.
   b. Schedule a day when the weather will accommodate sealant placement.
   c. Air blast the panel joints and anchor holes.
   d. Install backer rod in all panel joints (Figure E-44).
      (1) Approximately 400 linear ft of backer rod is required.
      (2) For ½ in. wide joints and use of silicone based joint sealants, the backer rod should be placed ¼ in. below the panel surface.
      (3) Start with placing the long transverse pieces, followed with placing the shorter longitudinal pieces.
      (4) Install longitudinal pieces from the runway interior to the shoulders.

Figure E-44. Backer rod installed.

e. Install silicone sealant following manufacturer's directions (Figure E-45).
   (1) If a priming material is required, apply material before placing backer rod.
   (2) Installation of sealant with pneumatic applicator guns using large cartridges is recommended. Adjust regulator to appropriate pressure for best installation. Provide a recess of approximately $^1/_8$ in. below the panel surface.
   (3) Begin at the runway interior and work towards the shoulders. This will allow the sealant at the center portion of the runway to have the maximum amount of time to cure.

f. Allow sealant to cure to tack free. Finalize site cleanup and exit the runway.

Figure E-45. Joint sealant installation.

Table E-14. Personnel needs and tasks for joint sealing activity.

Description	Task	Quantity
Installer	Place backer rod	4 (2 teams of 2)
Sealant dispenser	Place sealant	2
Dispenser assistant	Assist sealant dispensers and maintain site cleanliness	1

Table E-15. Equipment and supply needs for joint sealing activity.

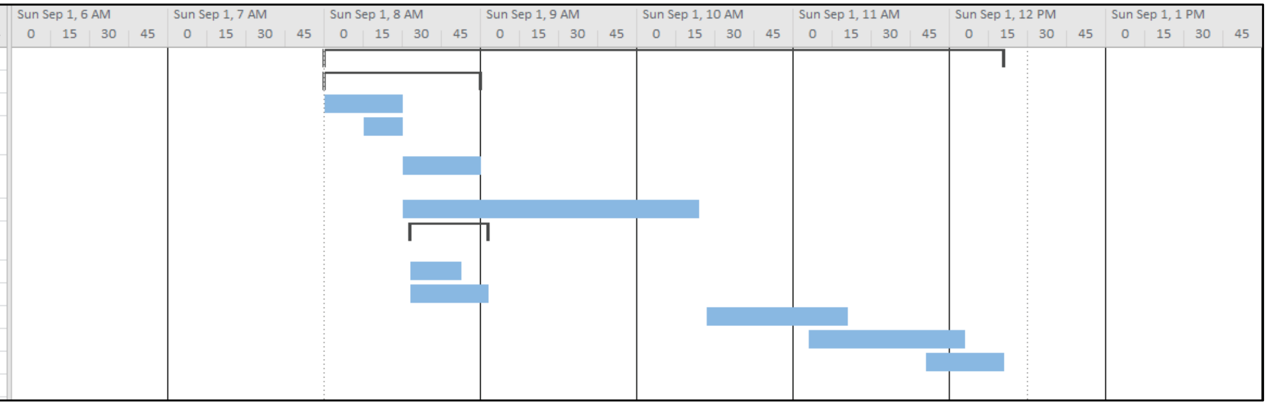
Equipment	
Item	**Quantity**
Small air compressor lance	2
Backer rod installation tool	2
Air compressor, 4 gal	1
Air hose, 3/8 in. diameter x 50 ft long	4
5,000 W generator	1
Sealant dispenser, 29 oz cartridges, pneumatic	2
Supplies	
Item	**Task**
Backer rod, HDPE closed cell, ¾ in. diameter	1 box (500 ft minimum)
Silicone sealant, airfield grade, 29 oz cartridge	42

Italicized items are not included in a Standard USAF SuPR Kit.

Figure E-46. Project Phasing Expedient UHMW-PE panel installation – Combination installation for new AC and PCC pavement construction.

1. Initial demolition - Transverse sawcutting

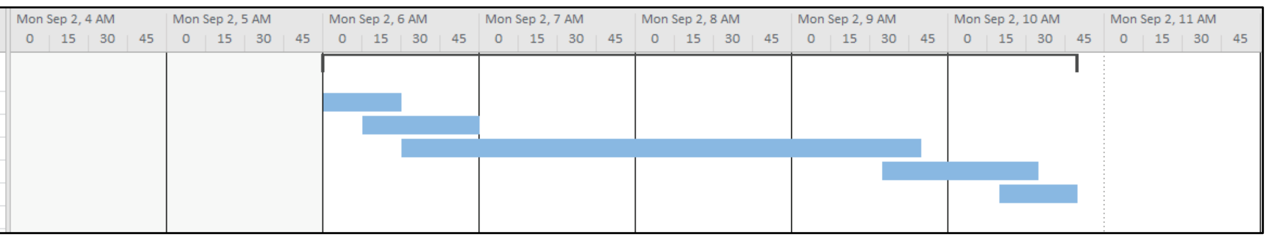
	Task Name	Duration
1	**Initial Demolition - Transverse Sawcutting**	**4.35 hrs**
2	**Panel Void Cuts**	**1 hr**
3	Mark panel slot perimeter	0.5 hrs
4	Snap chalk lines for slot perimeter (full width)	0.25 hrs
5	Snap chalk lines for transverse PCC relief cuts (partial width, center)	0.5 hrs
6	Make saw cuts for panel slot and relief cuts	1.9 hrs
7	**AC Section Patch Cuts (Partial Width, Exteriors)**	**0.5 hrs**
8	Mark additional cut locations	0.33 hrs
9	Snap additional chalk lines	0.5 hrs
10	Make sawcuts for AC patch	0.9 hrs
11	Wash saw slurry	1 hr
12	Clean work zone	0.5 hrs



(Sheet 1 of 1)

2. Initial demolition - Longitudinal sawcutting (PCC only)

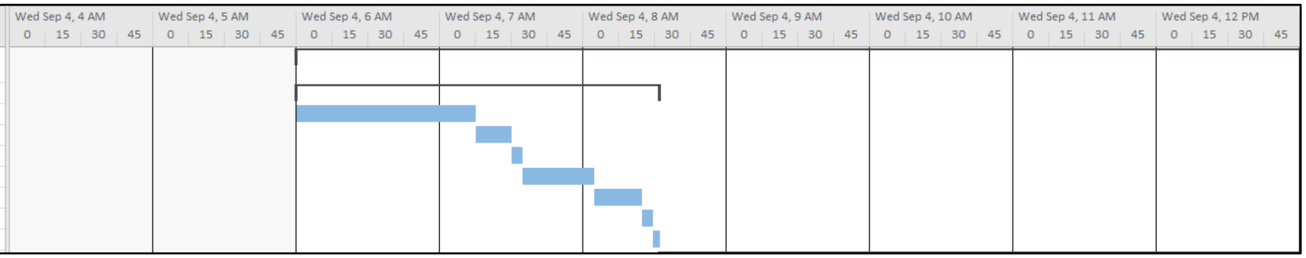
	Task Name	Duration
1	**Initial Demolition - PCC Section Relief Cutting**	**4.83 hrs**
2	Mark additional cut locations	0.5 hrs
3	Snap additional chalk lines	0.75 hrs
4	Make sawcuts	3.33 hrs
5	Wash saw slurry	1 hr
6	Clean work zone	0.5 hrs



(Sheet 1 of 1)

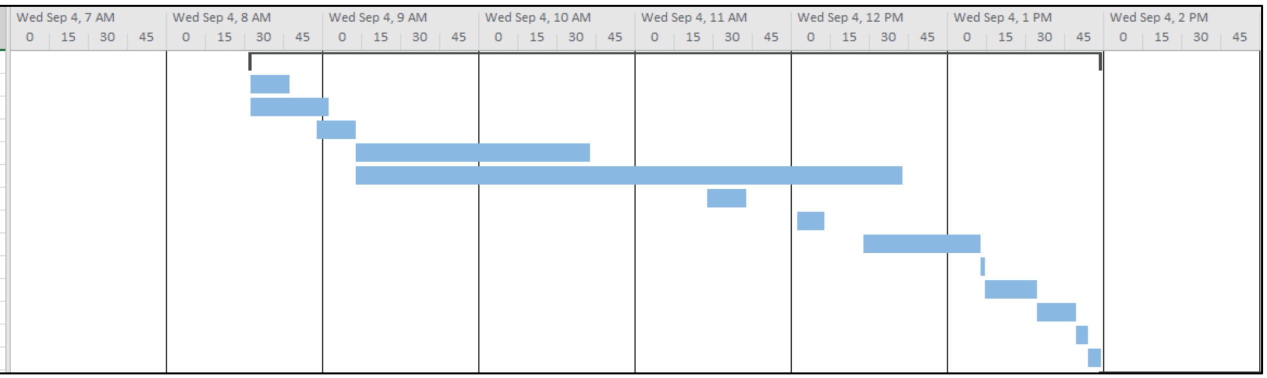
3. Demolition and panel installation – PCC sections

	Task Name	Duration
1	**Demolition and Panel Installation-PCC Portion (Partial width)**	**12.49 hrs**
2	**Complete Demolition**	**2.54 hrs**
3	Break surface	1.25 hrs
4	Mill panel slot void	0.25 hrs
5	Vacuum slot area	0.08 hrs
6	Perform final slot inspection	0.5 hrs
7	Water blast slot area	0.33 hrs
8	Vacuum slot area	0.08 hrs
9	Air blast slot area	0.05 hrs



Sheet 1 of 3)

	Task Name	Duration
10	**Bedding Layer Placement**	**5.44 hrs**
11	Install caulk along edge joints	0.25 hrs
12	Allow caulk to setup	0.5 hrs
13	Apply bonding agent	0.25 hrs
14	Place bedding layer	1.5 hrs
15	Allow concrete to gain strength	3.5 hrs
16	Cut joints in bedding layer	0.25 hrs
17	Clean slot perimeter	0.17 hrs
18	Perform final slot inspection	0.75 hrs
19	Air blast completed slot	0.03 hrs
20	Cut water drain holes	0.33 hrs
21	Water blast completed slot	0.25 hrs
22	Vacuum slot area	0.08 hrs
23	Air blast completed slot	0.08 hrs



(Page 2 of 3)

	Task Name	Duration
24	**Place and Install Panels**	**3.23 hrs**
25	Place and arrange panels	0.08 hrs
26	Shim panels	1.25 hrs
27	Drill anchoring holes	0.9 hrs
28	Clean anchoring holes	0.9 hrs
29	Set out anchors	0.25 hrs
30	Install anchors	0.9 hrs
31	Allow adhesive to cure	1.4 hrs
32	**Install Hardware on Panel Anchors**	**1.12 hrs**
33	Remove setting hardware	0.33 hrs
34	Install hex nuts	0.33 hrs
35	Gross torque hex nuts	0.33 hrs
36	Fine torque hex nuts	0.67 hrs
37	Verify panel anchors elevation	0.5 hrs
38	Remove shims and clean up	1 hr

(Sheet 3 of 3)

4. Demolition and panel installation – AC sections

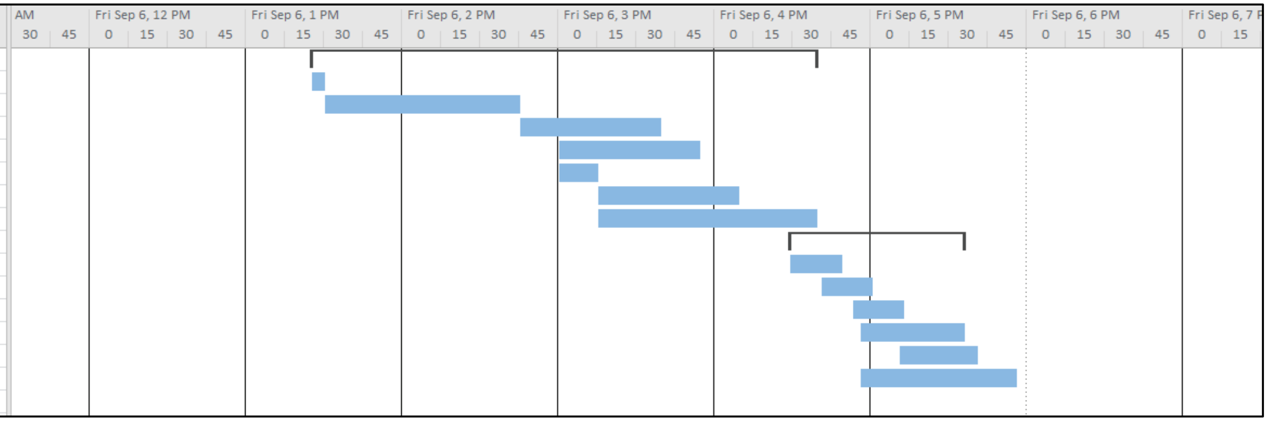
	Task Name	Duration
1	**Demolition and Panel Installation-AC Portion (Partial width)**	**11.94 hrs**
2	**Demolition and Excavation**	**1.62 hrs**
3	Remove surface pavement	0.2 hrs
4	Remove sublayer soil	1.25 hrs
5	Compact bottom of trench	0.17 hrs

(Sheet 1 of 3)

	Task Name	Duration
9	**Concrete Foundation Placement**	**4.79 hrs**
10	Install reinforcement grid	0.33 hrs
11	Place rapid-setting concrete	1.25 hrs
12	Allow concrete to gain strength	3.25 hrs
13	Perform final slot inspection	0.75 hrs
14	Air blast slot	0.03 hrs
15	Cut water drain holes	0.33 hrs
16	Water blast completed slot	0.25 hrs
17	Vacuum completed slot	0.05 hrs
18	Air blast completed slot	0.05 hrs

(Sheet 2 of 3)

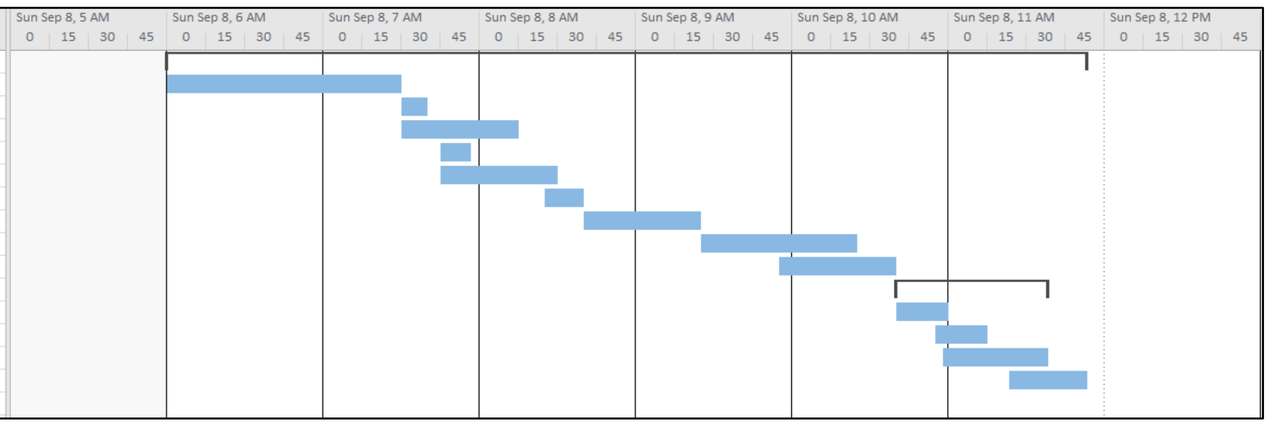
	Task Name	Duration
19	**Place and Install Panels**	**3.23 hrs**
20	Place and arrange panels	0.08 hrs
21	Shim panels	1.25 hrs
22	Drill anchoring holes	0.9 hrs
23	Clean anchoring holes	0.9 hrs
24	Set out anchors	0.25 hrs
25	Install panel anchor hardware	0.9 hrs
26	Allow adhesive to cure	1.4 hrs
27	**Install Panel Anchor Hardware**	**1.12 hrs**
28	Remove setting hardware	0.33 hrs
29	Install hex nuts	0.33 hrs
30	Gross torque hex nuts	0.33 hrs
31	Fine torque of hex nuts	0.67 hrs
32	Verify final anchor elevations	0.5 hrs
33	Remove shims and clean up	1 hr



(Sheet 3 of 3)

5. AC patching

	Task Name	Duration
1	**AC Patching (Half width, both sides of panel)**	**5.89 hrs**
2	Mill AC	1.5 hrs
3	Wet base	0.17 hrs
4	Remove panels	0.75 hrs
5	Compact base	0.2 hrs
6	Install steel formwork	0.75 hrs
7	Apply AC binder tack material	0.25 hrs
8	Place and compact AC	0.75 hrs
9	Watershock AC and allow pavement to cool	1 hr
10	Remove steel formwork	0.75 hrs
11	**Replace Panels**	**0.97 hrs**
12	Install panels and hex nuts	0.33 hrs
13	Gross torque hex nuts	0.33 hrs
14	Fine torque of hex nuts	0.67 hrs
15	Clean work zone	0.5 hrs

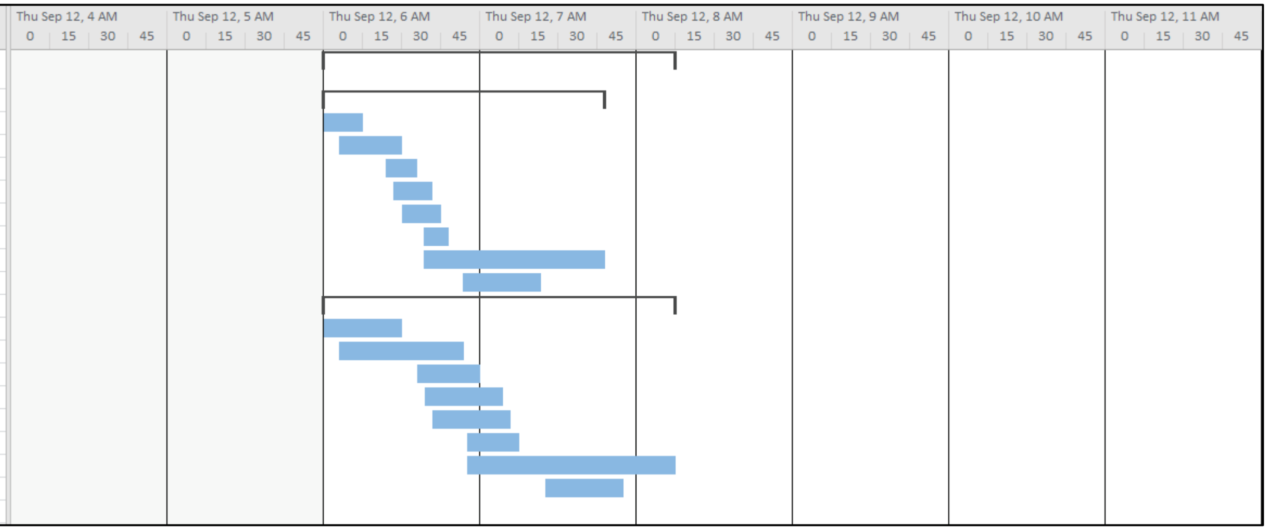


(Sheet 1 of 1)

6. Tie down anchorage installation

GANTT CHART

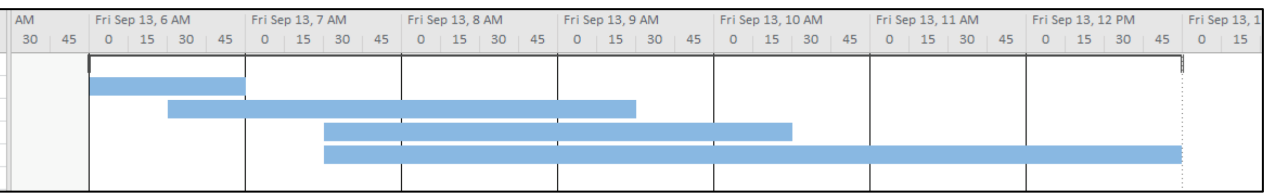
	Task Name	Duration
1	Install Tie Down Foundation Hardware (Full Width)	2.25 hrs
2	For 4 anchors	1.8 hrs
3	Dry core location	0.25 hrs
4	Remove core interior and level	0.4 hrs
5	Clean hole made	0.2 hrs
6	Drill anchor embedding hole	0.25 hrs
7	Clean hole made	0.25 hrs
8	Install tie down anchors	0.16 hrs
9	Allow adhesive to cure	1.16 hrs
10	Finish cleanup	0.5 hrs
11	For 8 Anchors	2.25 hrs
12	Dry core location	0.5 hrs
13	Remove core interior and level	0.8 hrs
14	Clean hole made	0.4 hrs
15	Drill anchor embedding hole	0.5 hrs
16	Clean hole made	0.5 hrs
17	Install tie down anchors	0.33 hrs
18	Allow adhesive to cure	1.33 hrs
19	Finish cleanup	0.5 hrs



(Sheet 1 of 1)

7. Joint sealing

	Task Name	Duration
1	Joint Sealing (full width)	7 hrs
2	Air blast joints and anchor holes	1 hr
3	Install backer rod	3 hrs
4	Install sealant	3 hrs
5	Allow sealant to cure, clean site	5.5 hrs



(Sheet 1 of 1)

Appendix F: Prototype Full-Depth PCC Repair Formwork Drawings

Figures F-1 through F-7 provide component and assembly drawings for the fabrication of prototype formwork used to cast the panel slot void within plastic concrete for the full-depth PCC installation method.

Figure F-1. Column and gusset plate components drawing.

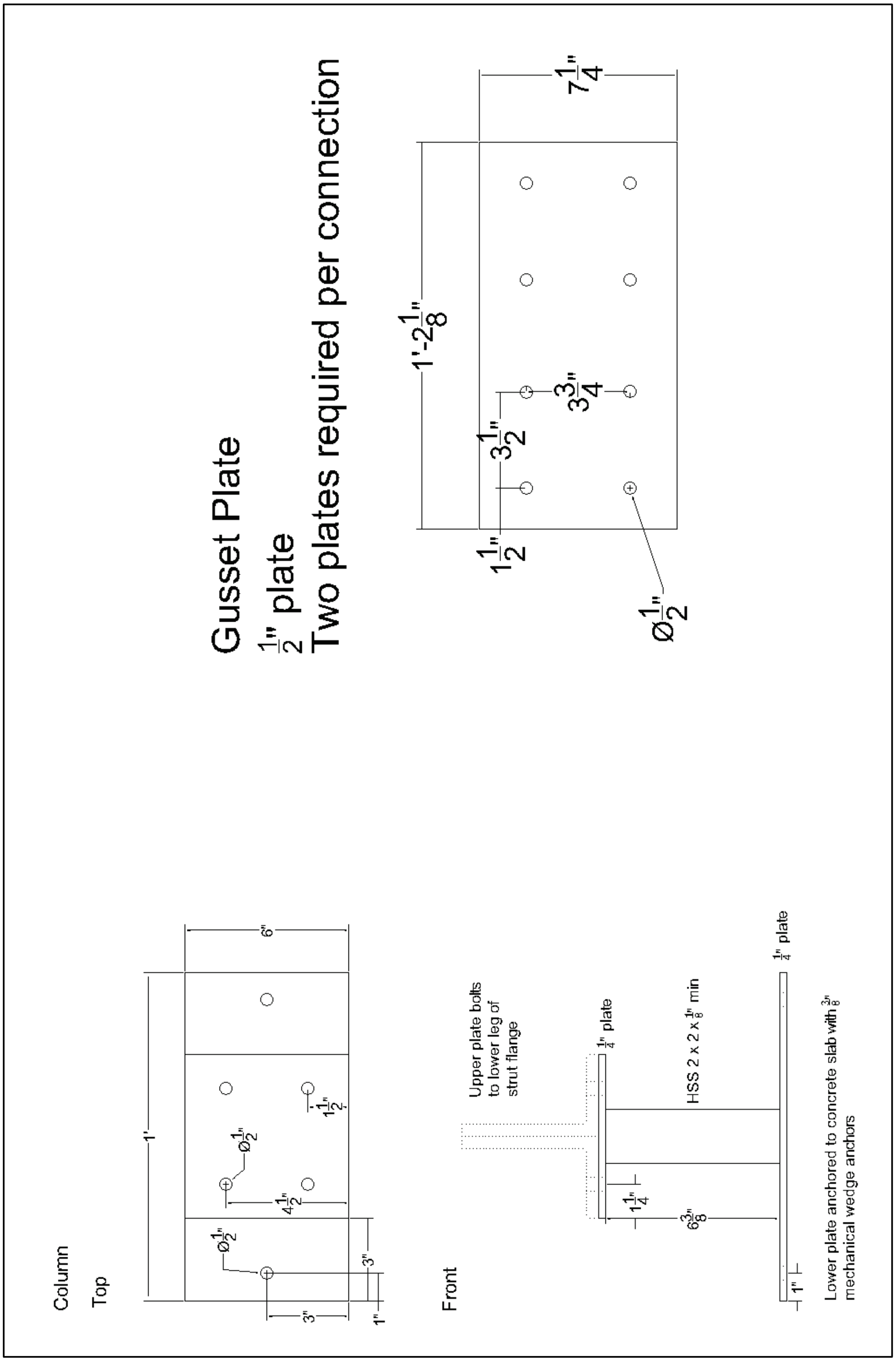


Figure F-2. Strut formwork component drawing.

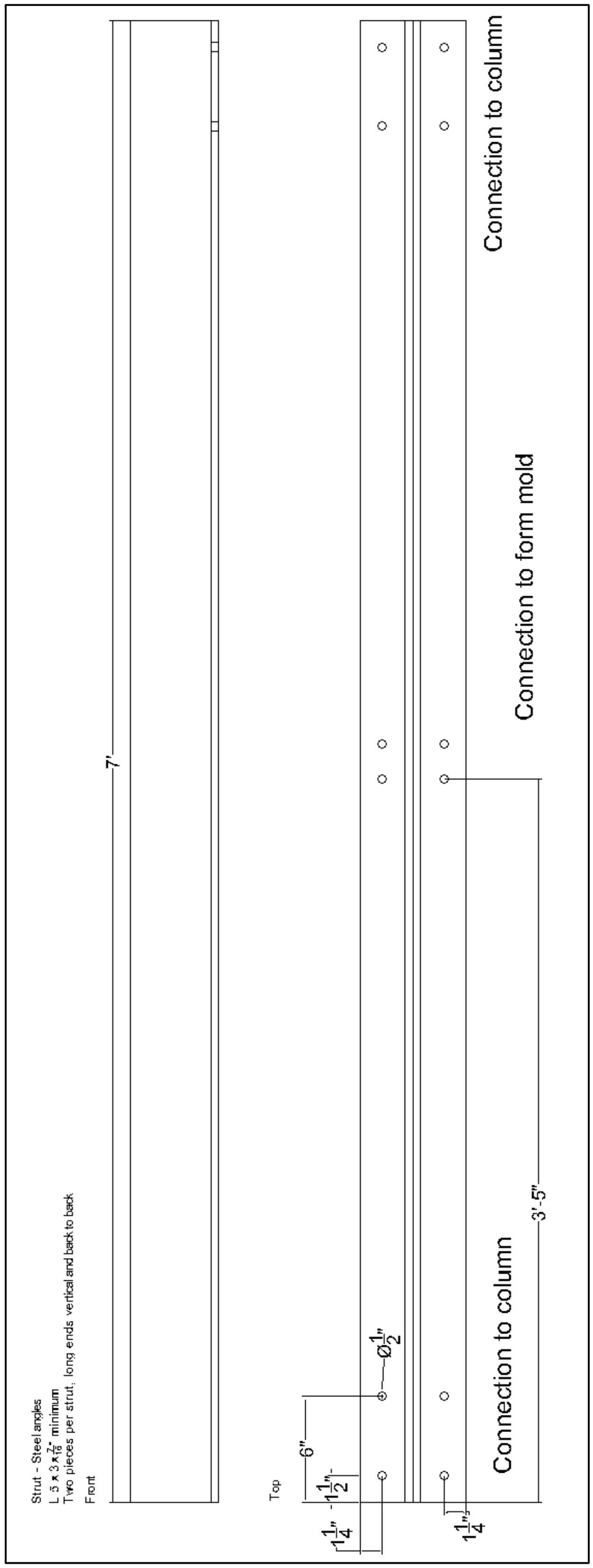


Figure F-3. 5-ft form mold component drawing.

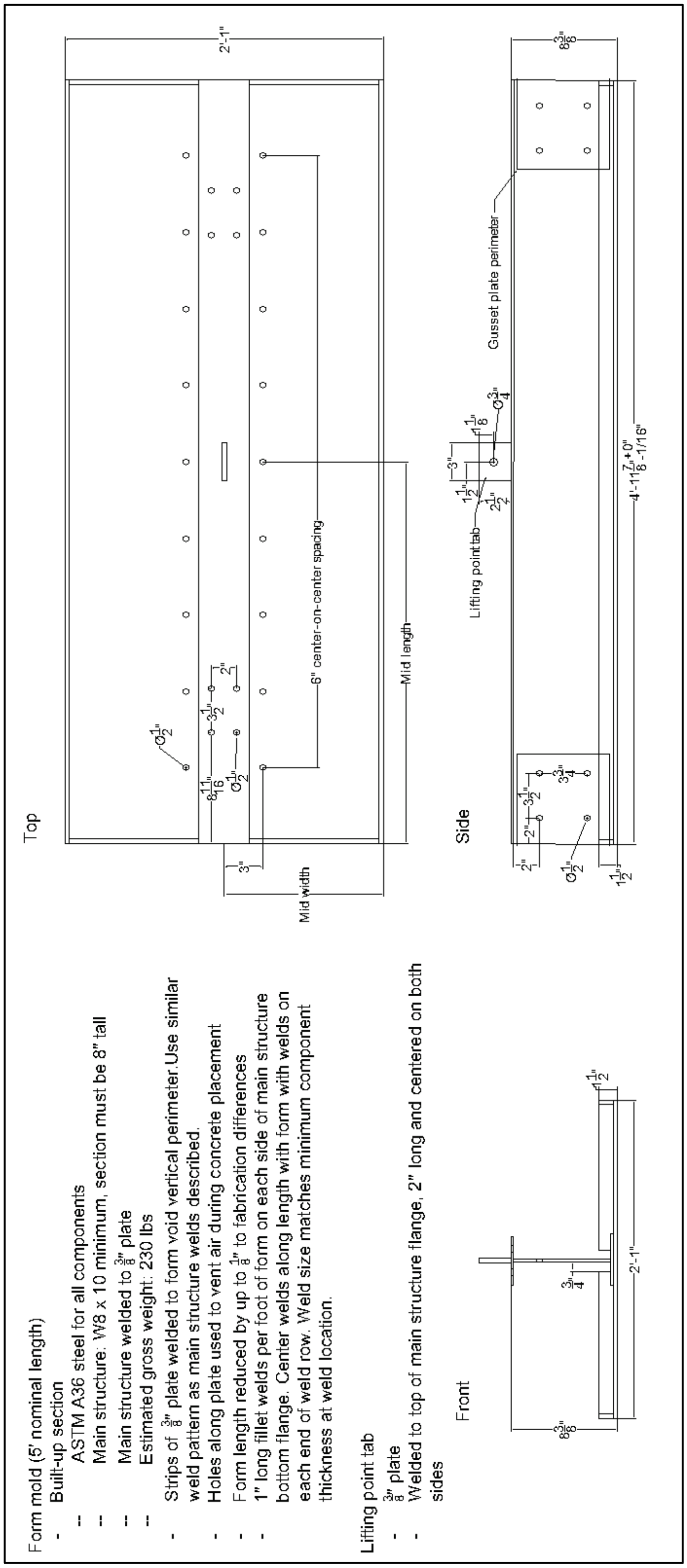


Figure F-4. 3.75-ft form mold component drawing.

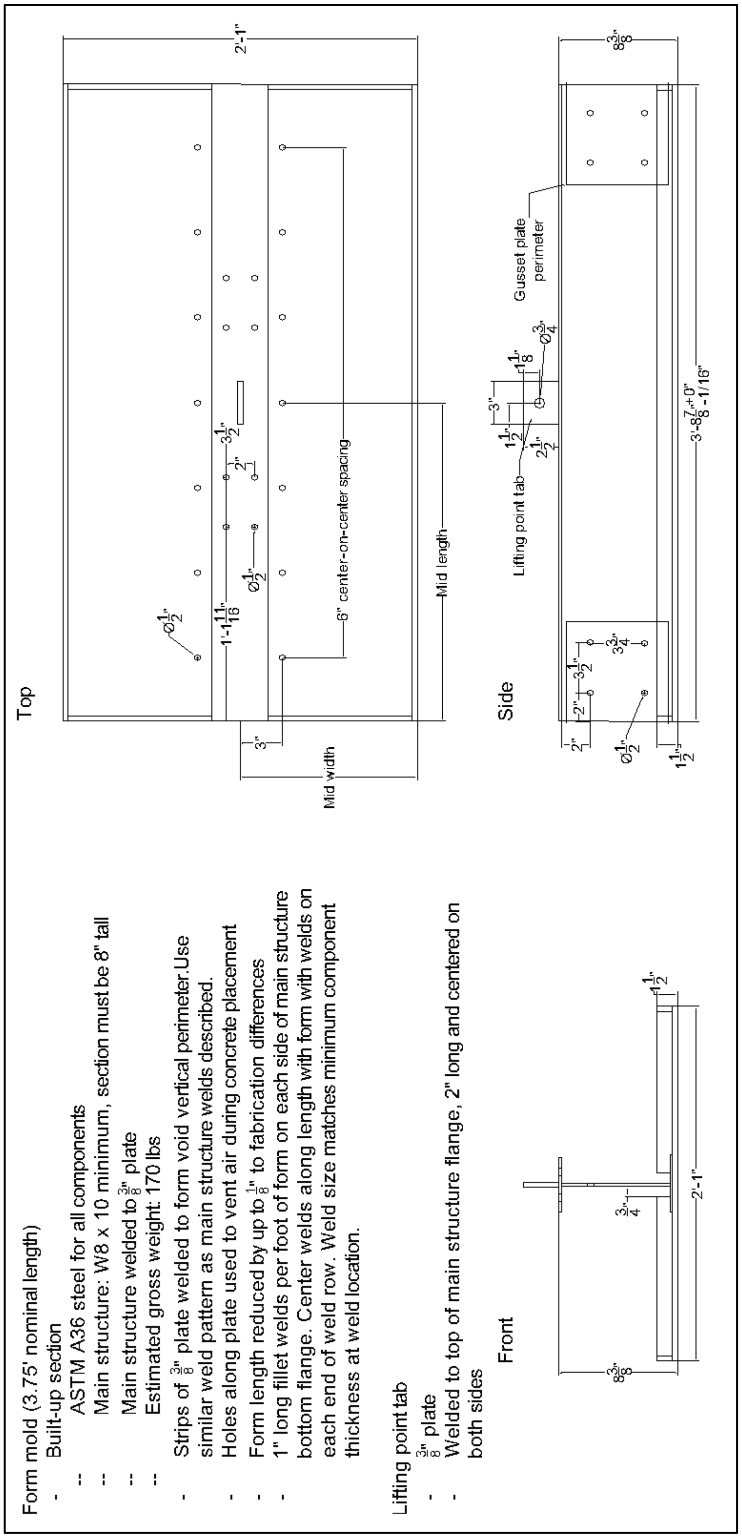


Figure F-5. 2.5-ft form mold component drawing.

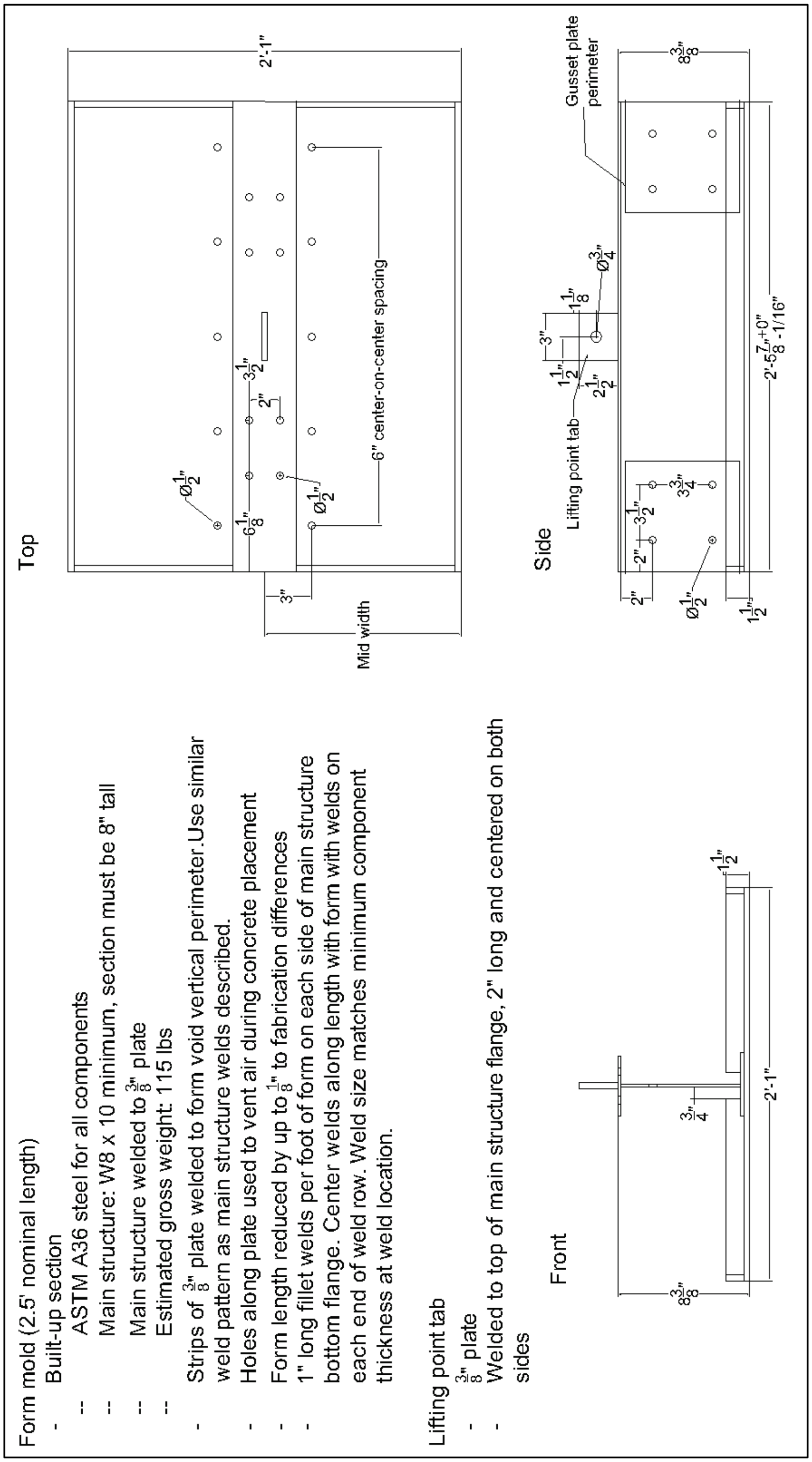


Figure F-6. Formwork assembly diagram.

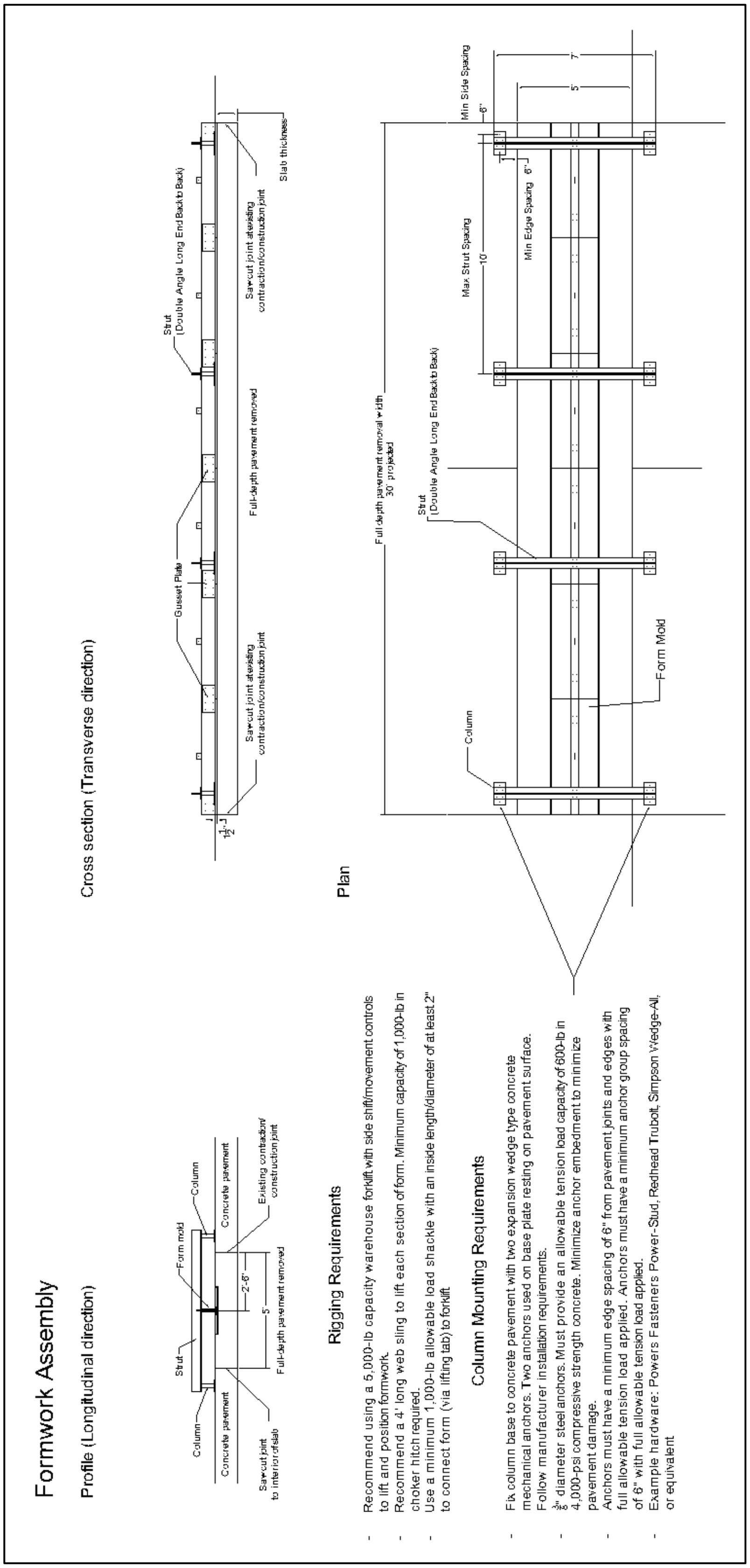
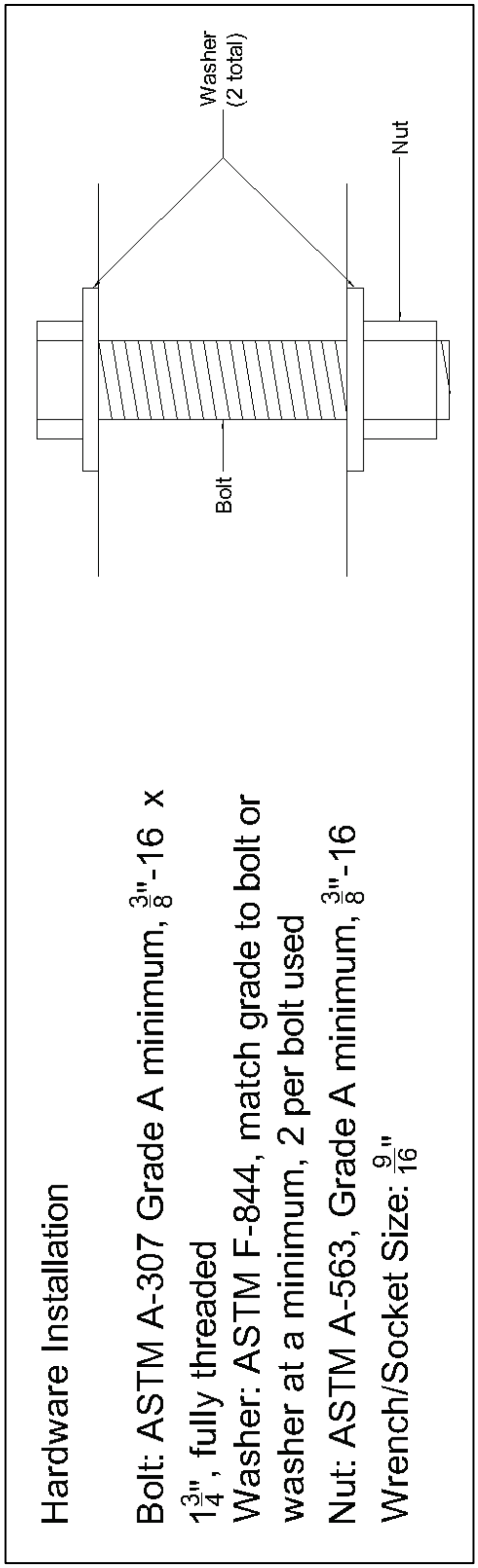


Figure F-7. Formwork hardware assembly diagram.



Appendix G: Prototype Panel Form for Helical Anchoring Tie-Down Foundation Drawing

Figures G-1 through G-4 provide component and assembly drawings for the fabrication of prototype formwork used to construct tie-down foundations for helical soil anchorage.

Figure G-1. Strut section component drawing.

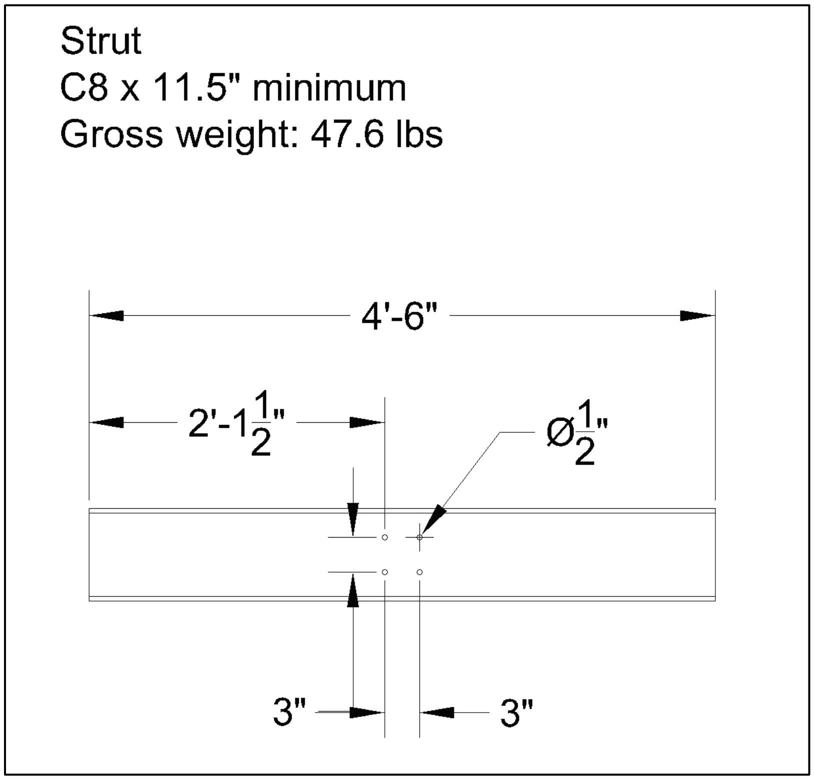


Figure G-2. Formwork hardware assembly diagram.

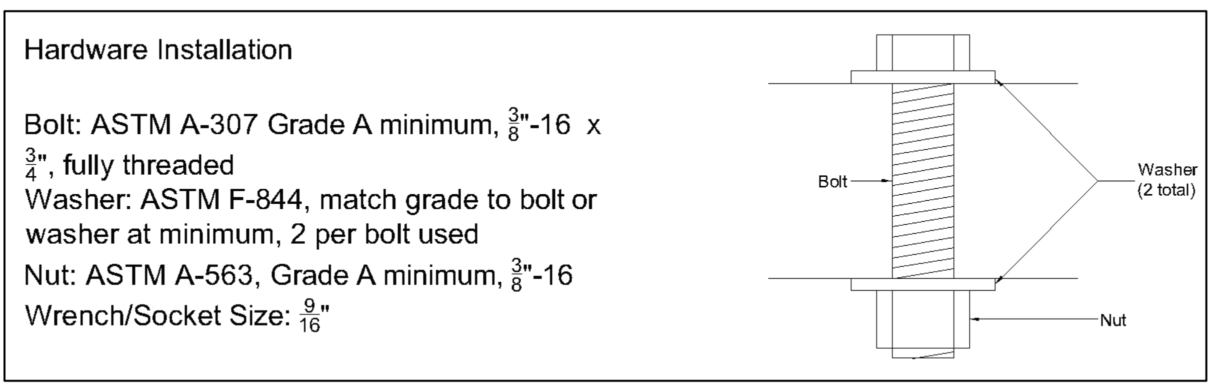


Figure G-3. Form mold component drawing.

Panel mold

Bottom plate: $\frac{1}{4}$"
Upper (mounting) plate: $\frac{1}{8}$"
Filler HSS 2" x 2" x $\frac{1}{8}$"
Gross weight: 90 lbs

1" long fillet weld by plate thickness wide centered on all filler section faces for both upper and lower plates.

Weld $1\frac{1}{4}$" tall by $\frac{3}{8}$" thick strips of plate steel around perimeter.

Profile

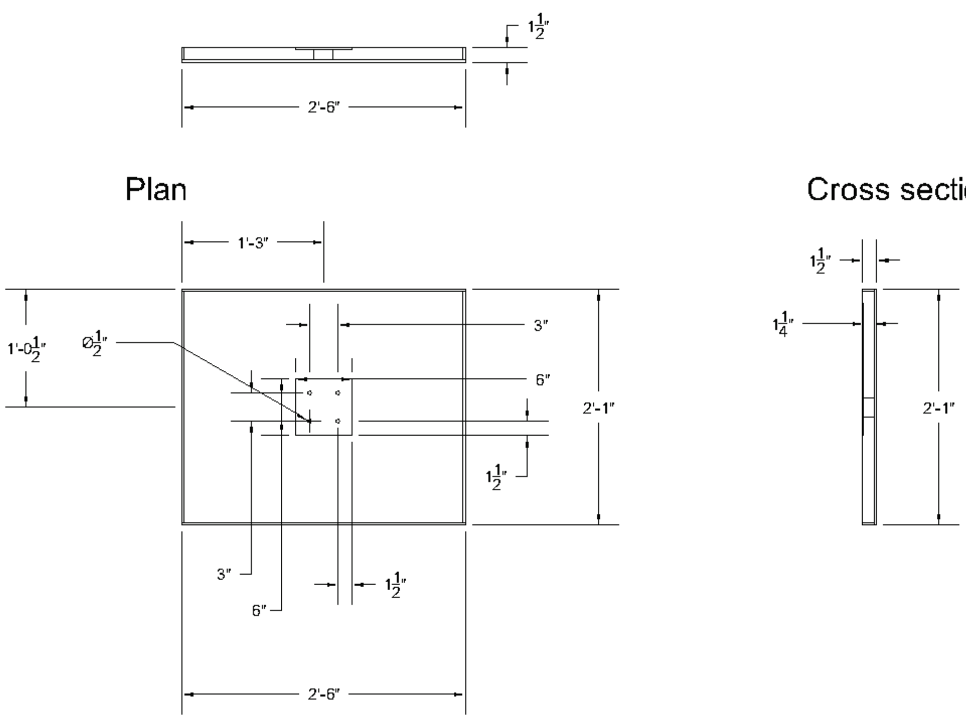
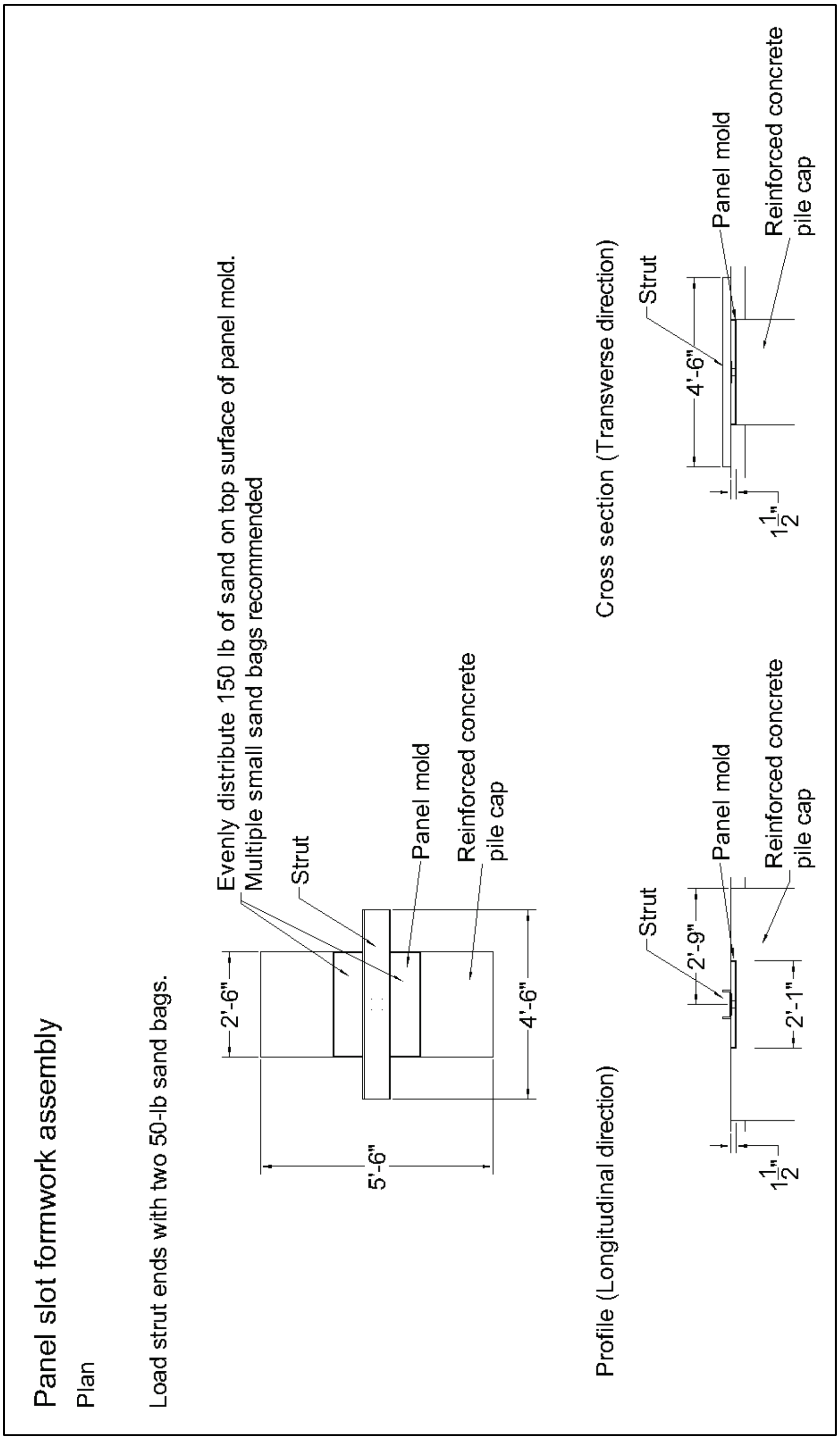


Figure G-4. Formwork assembly diagram.



Unit Conversion Factors

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
inch-pounds (force)	0.1129848	newton meters
knots	0.5144444	meters per second
microinches	0.0254	micrometers
microns	1.0 E-06	meters
miles per hour	0.44704	meters per second
ounces (mass)	0.02834952	kilograms
pounds (force)	4.448222	newtons
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
square feet	0.09290304	square meters

Acronyms and Abbreviations

AAS	aircraft arresting system
AC	asphalt concrete
ADR	airfield damage repair
AFCEC	Air Force Civil Engineer Center
AFI	Air Force Instruction
CTL	Compact track loader
DoD	Department of Defense
ERDC	US Army Engineer Research and Development Center
FOD	foreign object damage
FRP	fiber-reinforced polymer
MARES	Mobile Airfield Repair Equipment Set
NDT	non-destructive testing
PCC	portland cement concrete
RED HORSE	Rapid Expeditionary Deployable Heavy Operation Repair Squadron Engineers
SSD	saturated surface dry
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specifications
UHMW	ultra-high molecular weight
USAF	US Air Force

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14. ABSTRACT
The US Army Engineer Research and Development Center conducted an evaluation of different procedures to install ultra-high molecular weight polyethylene panels beneath pendant-based aircraft arresting systems (AAS). Currently employed techniques were modified or new techniques were developed to increase productivity and installation accuracy, aid in system constructability, and reduce logistical concerns when compared to AAS requirements and pavement repair guidance. Procedures for both asphalt concrete and portland cement concrete surfaced runway pavement were evaluated.
The field evaluation was conducted from July to August 2013 at the Silver Flag Training Site, Tyndall Air Force Base, FL. The evaluation consisted of timing various procedures using a six- to eight-man installation crew. Equipment and supplies currently in Air Force inventories were preferred, but outside items were not prohibited if performance gains could be achieved and the new items were deployable using typical military cargo aircraft. Required work tasks were organized and grouped together to efficiently complete the panel installation work within multiple short-term runway closure windows without any long-term closures greater than 12 hours to allow for aircraft operations during the installation process.
This report summarizes the timed field trials and the pertinent conclusions based on the results. Recommendations for implementation including additional equipment, supplies, and personnel needs are provided.

15. SUBJECT TERMS
Anchorage (Structural engineering)—Testing, Arresting gear, Panels, Polyethylene, Runways (Aeronautics)

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