

# **TRI-SERVICE PAVEMENTS WORKING GROUP (TSPWG) MANUAL**

## **CONTINGENCY AIRCRAFT TIE- DOWNS IN PORTLAND CEMENT CONCRETE (PCC) PAVEMENTS**



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**TRI-SERVICE PAVEMENTS WORKING GROUP MANUAL (TSPWG M)**

**CONTINGENCY AIRCRAFT TIE-DOWNS IN PORTLAND CEMENT CONCRETE  
(PCC) PAVEMENTS**

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U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER CENTER (Preparing Activity)

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

<b>Change No.</b>	<b>Date</b>	<b>Location</b>

## **FOREWORD**

This Tri-Service Pavements Working Group Manual supplements guidance found in other Unified Facilities Criteria, Unified Facility Guide Specifications, Defense Logistics Agency Specifications, and Service specific publications. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the TSPWG Manual, the SOFA, the HNFA, and the BIA, as applicable. This manual provides option for the construction of aircraft tie downs in PCC pavement. The information in this TSPWG Manual are referenced in technical publications found on the Whole Building Design Guide. It is not intended to take the place of service specific doctrine, technical orders (TOs), field manuals, technical manuals, handbooks, Tactic Techniques or Procedures (TTPs) or contract specifications but should be used along with these to help ensure pavements meet mission requirements.

TSPWG Manuals are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction, maintenance, repair, or operations. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of this document. Technical content of this TSPWG Manual is the responsibility of the Tri-Service Pavements Working Group (TSPWG). Defense agencies should contact the preparing activity for document interpretation. Send recommended changes with supporting rationale to the respective service TSPWG member.

TSPWG Manuals are effective upon issuance and are distributed only in electronic media from the following source:

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

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

**TRI-SERVICE PAVEMENTS WORKING GROUP MANUAL (TSPWG M)  
NEW SUMMARY SHEET**

**Document:** TSPWG Manual 3-260-01.12-08, Contingency Aircraft Tie-Downs in Portland Cement Concrete (PCC) Pavements

**Superseding:** USAF ETL 12-8 Contingency Aircraft Tie-Downs in Portland Cement Concrete (PCC) Pavements

**Description:** This Manual provides guidance and methods for installing contingency aircraft tie-downs in Portland cement concrete (PCC) pavements.

**Reasons for Document:**

- Tie-downs are required in contingency environments by all services. The elimination of all USAF ETLs requires the content of ETL 12-8 be made available to DoD engineers through other documents such as TSPWG Manuals.

**Impact:** There is no cost impact. The following benefits should be realized.

- Supplemental information on the construction of tie-downs in contingency environments will be available to all services.
- Maintenance and/or upgrading of this supplemental information will include inputs from all services.

**Unification Issues**

None.

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

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## CHAPTER 1 INTRODUCTION

### 1-1 BACKGROUND.

The term *tie-down* refers to a mechanism for the purpose of securing an aircraft to the pavement surface. These systems are not intended for anchoring an aircraft during engine run-up.

### 1-2 PURPOSE AND SCOPE.

This manual provides access to information on the construction of aircraft tie-downs in PCC pavements during contingencies.

### 1-3 APPLICABILITY.

The information is applicable to all unit that must retrofit PCC pavement with tie-downs to support DoD aircraft. The information contained in this manual is not applicable to asphalt pavements.

### 1-4 GENERAL BUILDING REQUIREMENTS.

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

### 1-5 REFERENCES.

Appendix A contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

### 1-6 GLOSSARY.

Appendix C contains acronyms, abbreviations, and terms.

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## CHAPTER 2 OPTIONS FOR CONSTRUCTING TIE-DOWNS IN PCC

### 2-1 INTRODUCTION.

Appendix B contains options for the construction of aircraft tie-downs in PCC during contingencies.

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## APPENDIX A REFERENCES

### UNIFIED FACILITIES CRITERIA

[http://www.wbdg.org/ccb/browse\\_cat.php?o=29&c=4](http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4)

UFC 1-200-01, *DoD Building Code (General Building Requirements)*

UFC 3-260-01, *Airfield And Heliport Planning And Design*

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## APPENDIX B BEST PRACTICES

### **B-1           ARCHIVED USAF ETL 12-08**

A Copy of archived USAF ETL 12-08 Contingency Aircraft Tie-Downs In Portland Cement Concrete (PCC) Pavements is appended in the following pages.



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

18 JAN 2012

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

SUBJECT: **Engineering Technical Letter (ETL) 12-8: Contingency Aircraft Tie-Downs in Portland Cement Concrete (PCC) Pavements**

**1. Purpose.** This ETL provides guidance and methods for installing contingency aircraft tie-downs in Portland cement concrete (PCC) pavements.

**Note:** The use of the name or mark of any specific manufacturer, commercial product, commodity, or service in this ETL does not imply endorsement by the United States Air Force.

**2. Application:** All Department of Defense (DOD) organizations responsible for design, installation, and maintenance of aircraft tie-downs.

**2.1. Authority:** Air Force policy directive (AFPD) 32-10, *Installations and Facilities*.

**2.2. Coordination:** Major command (MAJCOM) pavement engineers.

**2.3. Effective Date:** Immediately.

**2.4. Intended Users:**

- Air Force Prime BEEF and RED HORSE units
- U.S. Army Corps of Engineers (USACE)
- U.S. Navy and Marine Corps
- Organizations performing DOD installation and maintenance of aircraft tie-downs

**3. Referenced Publications:**

**3.1. Air Force:** AFPD 32-10, *Installations and Facilities*, <http://www.e-publishing.af.mil/>

**3.2. DOD:** Unified Facilities Criteria (UFC) 3-260-01, *Airfield and Heliport Planning and Design*, [http://www.wbdg.org/ccb/browse\\_cat.php?o=29&c=4](http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4)

**4. Acronyms and Terms:**

AFCESA – Air Force Civil Engineer Support Agency  
AFPD – Air Force policy directive

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AFRL	– Air Force Research Laboratory
DOD	– Department of Defense
ETL	– engineering technical letter
HMA	– hot mix asphalt
hp	– horsepower
kg	– kilogram
kPa	– kilopascal
lb	– pound
m	– meter
mm	– millimeter
PCC	– Portland cement concrete
Prime BEEF	– Prime Base Engineer Emergency Force
psi	– pound per square inch
RED HORSE	– Rapid Engineers Deployable - Heavy Operations Repair Squadron
UFC	– Unified Facilities Criteria

**Note:** The term *tie-down* refers to a mechanism for the purpose of securing an aircraft to the pavement surface. These systems are not intended for anchoring an aircraft during engine run-up.

## 5. Introduction.

**5.1.** Aircraft tie-downs are an integral component of airfield aprons. An aircraft must be tied to a tie-down to ensure it remains stationary in the event of various weather phenomena such as high winds. Additionally, activities such as maintenance and loading require that aircraft remain stationary. In some instances, tie-downs also serve as static grounding points. This ETL focuses on tie-downs specifically designed to physically secure aircraft. The current guidelines characterize aircraft tie-downs by the following criteria: lightweight tie-downs are capable of an ultimate uplift resistance of 17,000 pounds (7711 kilograms [kg]) and heavyweight tie-downs are capable of an ultimate uplift resistance of 37,700 pounds (17,100 kg). Testing conducted by the Air Force Research Laboratory (AFRL) determined that two tie-down systems meet the lightweight criteria and one system meets the heavyweight tie-down criteria. During load testing, tensile forces were applied 90 degrees relative to the pavement surface, while in field environments aircraft tie-down cables are typically attached at angles between 20 degrees and 90 degrees relative to the pavement surface. The lightweight and heavyweight tie-downs detailed in this ETL are expected to meet the criteria regardless of the angle between the tie-down cable and the pavement surface.

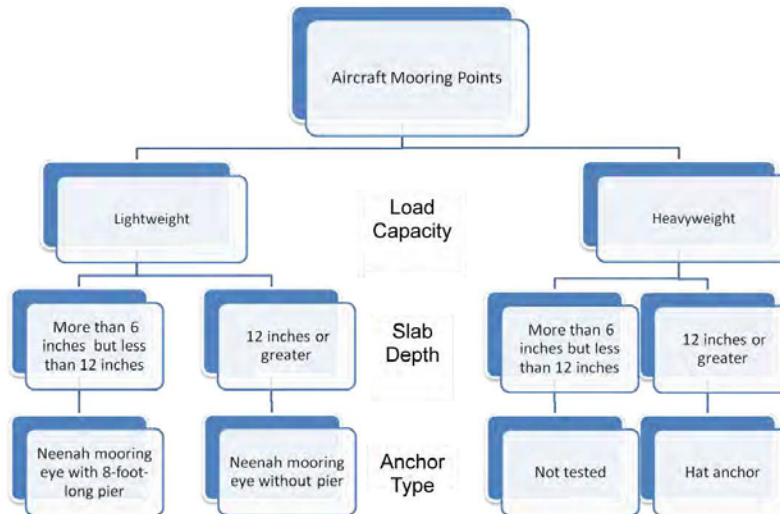
**5.2.** AFRL conducted strength tests on aircraft tie-downs. Tie-downs were installed in a section of jointed plain concrete 12 inches (305 millimeters [mm]) thick. Directly underneath the slabs was a 4-inch (102-mm) -thick crushed aggregate base course.

**5.3.** This ETL details tie-downs that satisfy the lightweight and/or heavyweight tie-down criteria: Neenah aircraft mooring eyes (with and without concrete pier) and hat-

type tie-downs. This ETL provides guidance concerning installation and load capacities of the two tie-down systems based on tests conducted in 12-inch (305-mm) -thick, jointed, plain concrete pavement. Neenah mooring eyes with 8-foot (2.4-meter [m]) -long concrete piers will meet the lightweight loading capacity in jointed, plain concrete sections less than 12 inches (305 mm) thick but at least 6 inches (152 mm) thick.

**5.4.** This ETL is not valid for tie-downs installed in hot mix asphalt (HMA) pavements. The exception is an HMA surface with a PCC underlay. This ETL criteria is valid when at least a 6-inch (152-mm) -thick PCC underlay is present, provided the HMA pavement thickness is disregarded and the tie-down selection and installation procedure is determined by the thickness of the PCC underlay. Tie-down installations for HMA/PCC pavements are discussed in paragraphs 6.2.1.7, 6.2.1.8 (lightweight tie-downs), and 7.3 (heavyweight tie-downs).

**5.5.** Additional information regarding tie-down spacing and layout is available in UFC 3-260-01, *Airfield and Heliport Planning and Design*. Figure 1 provides lightweight and heavyweight tie-down system installations in PCC pavements of various thicknesses.



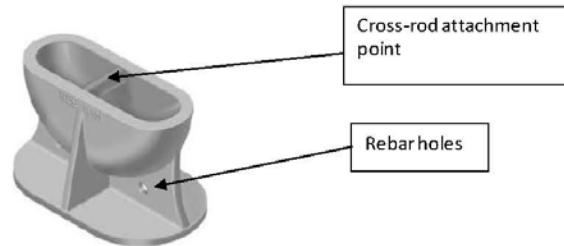
**Figure 1. Aircraft Tie-Down Systems.**

**6. Lightweight Tie-Downs.**

**6.1. PCC Pavement At Least 12 Inches (305 mm) Thick.** This section pertains to lightweight tie-down installation in PCC pavement at least 12 inches (305 mm) thick.



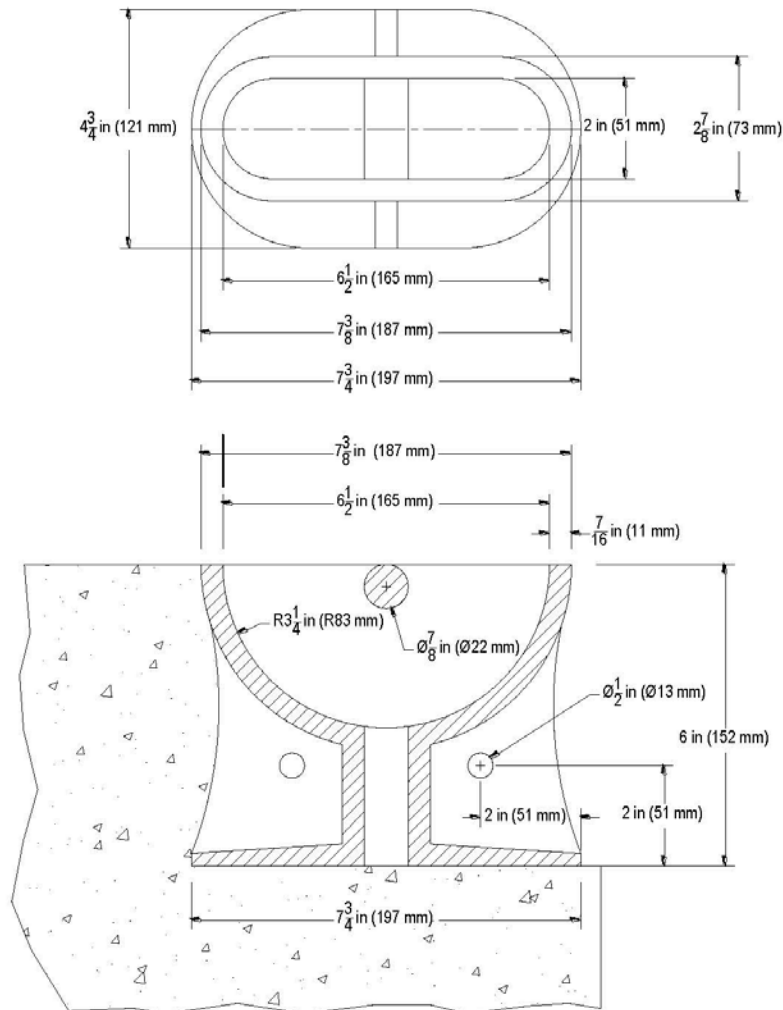
**6.1.1.** Neenah mooring eyes (Figure 2) are a commercially available product manufactured by the Neenah Foundry (<http://www.neenahfoundry.com>), Model No. R-3490-A. The dimensions for this mooring eye are provided in Figure 3. A Neenah mooring eye consists of an oval-shaped ductile iron casting with a cross-rod to which tie-down hooks can be attached. Neenah mooring eyes can be installed with or without concrete piers.



**Figure 2. Neenah Mooring Eye.**

**6.1.2.** AFRL load-tested four Neenah mooring eyes installed without concrete piers. Based on these experiments, the expected pullout capacity is 37,000 pounds (16,783 kg) (which provides a safety factor of 2 in relation to lightweight tie-down uplift capacity). This value is minimally short of meeting the heavyweight criteria. The observed failure mode for each mooring eye was a fracture of the cast-iron cross-rod. It is important to note that Neenah Foundry specifies a 9000-pound (4082-kg) capacity for the cross-rod. After testing, it is assumed this value roughly takes into account a 4:1 to 5:1 safety factor.

**6.1.3.** Figure 4 illustrates a Neenah mooring eye prior to PCC placement. It is important to note that the Neenah mooring eye is being installed without a PCC pier. The following steps pertain to Neenah installations with no PCC pier. Pier installation instructions and considerations are provided in paragraph 6.2.1.



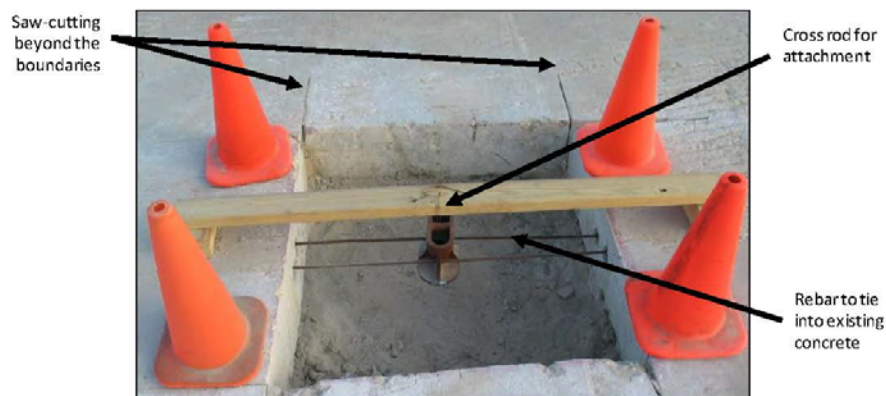
**Figure 3. Neenah Mooring Eye Dimensions.**

**6.1.3.1. Step 1—Concrete Removal.**

**6.1.3.1.1.** Remove the section of existing concrete that will serve as the tie-down location. The tie-down should be located as close to the center of the existing slab as possible. The cut-out dimensions measure approximately 3 feet by 3 feet (0.9 m by 0.9 m), but these dimensions may be altered at the

discretion of the facilities manager. It is important to note that the removed section must extend the entire depth of the concrete pad. Concrete cutting is most easily accomplished with the use of a walk-behind concrete saw. AFRL performed saw-cutting with a Husqvarna® 6600 model (66 horsepower [hp]), which accepts a 42-inch (1.1-m) –diameter, 0.187-inch (4.7 mm) -thick cutting blade. Similar walk-behind concrete saws may be employed, depending upon the equipment available at the facility, but alternative saws should meet the horsepower and blade size capacity provided by the Husqvarna 6600 model. The selected walk-behind saw must have the ability to adjust the blade depth to accommodate various concrete thicknesses and ensure the blade penetrates the entire depth of the slab. Examples of alternatives to the Husqvarna brand include MK Diamond and Core Cut.

**6.1.3.1.2.** Prior to cutting, accurately mark the section to be cut and removed. A 3-foot by 3-foot (0.9-m by 0.9-m) piece of plywood works well as a template. Place the template in the desired location and use spray paint to mark the boundaries. This allows accurate aligning of the saw during the cutting process. To ensure complete removal of the designated section of concrete, extend the length of the cut half the blade diameter beyond each boundary (Figure 4).



**Figure 4. Neenah Mooring Eye Prior to PCC Placement.**

**6.1.3.1.3.** The proper saw-cutting method consists of a series of passes, each pass increasing the overall saw blade depth penetration by approximately one-third of the total slab depth. For a 12-inch (305-mm) -thick slab, it is recommended that each pass increase the penetration depth by approximately 4 inches (102 mm) (e.g., pass one: 4 inches [102 mm]; pass two: 8 inches [203 mm]). It is required to know the slab depth prior to beginning the saw-cutting process. If the slab depth is not known, it can be determined by taking a core sample from a section of the concrete slab or

drilling through the concrete and measuring the length of the drill bit required to travel through the entire section.

**6.1.3.1.4.** Ensure the saw travels in a straight line to avoid binding the saw blade in the concrete. Additionally, it may be difficult to determine the proper saw blade depth on the final pass. The best method for ensuring the blade has penetrated the full depth is for the operator to observe the color change in the water discharged from the saw. Upon full penetration, the chalky white water discharge will typically assume a brown, muddy look. This change is due to blade penetration into the base course. Also, after penetrating the entire depth of the concrete slab and entering the base course, the saw blade resistance will typically noticeably decrease.

**6.1.3.1.5.** Following the saw-cutting process, remove the section. There are two options for removing the section.

**6.1.3.1.5.1.** The preferred method is to install an appropriately rated lifting point in the center of the section and lift the section out vertically as a single piece. A 12-inch (305-mm) -thick, 3-foot by 3-foot (0.9-m by 0.9 m) section weighs approximately 1,350 pounds (612.2 kg).

**6.1.3.1.5.2.** The second option for removing the section utilizes a skid steer equipped with an impactor. The impactor is used to break the cut-out section into smaller pieces. A 90-pound (40.8-kg) jackhammer, in conjunction with a 110 pounds per square inch (psi) (758 kilopascals [kPa]) air compressor, may also be used if the skid steer and/or attachment are not available. After adequately pulverizing the section, it is possible to remove the debris by hand. The debris should be placed in a loader with a bucket attachment for removal from the site. It is important that all debris is removed. This pulverization option should be the second resort due to the potential to damage the existing PCC surrounding the cut-out section. This is illustrated in the bottom left corner of Figure 4, which shows corner spalling of the surrounding PCC. The corners are particularly vulnerable after the cross-cutting procedure and the impacting process can cause spalling.

**6.1.3.2.** Step 2—Base Course Preparation. Adequately compact the base course with an engine-driven plate compactor, such as a Wacker Packer® (equivalent alternatives are available). Engine-driven plate compactors are for compacting backfill in trenches and other narrow excavations. It is important to note that plate compactors, such as the one shown in Figure 5, are only capable of compacting 2-inch (51-mm) -deep to 3-inch (76-mm) -deep lifts. When the plate compactor begins jumping violently, adequate compaction has likely been achieved.



**Figure 5. Engine-Driven Plate Compactor.**

**6.1.3.3. Step 3—Rebar Hole Drilling.**

**6.1.3.3.1.** Drill 1.5-inch (38-mm) -diameter rebar holes into the existing concrete. Unless the rebar holes on the Neenah mooring eye have been modified, a 0.375-inch (9.5-mm) -diameter section of reinforcement bar (#3 rebar) is recommended. Orient the rebar holes so the Neenah cross-rod will be perpendicular to the direction of the chain or cable used to connect the aircraft to the Neenah mooring eye. The locations of the drilled holes are dependent upon the configuration of the rebar holes located on the Neenah mooring eye. The horizontal spacing of the drilled rebar holes in the existing concrete should be equal to the horizontal spacing of the Neenah's rebar holes. The 1.5-inch (38-mm) -diameter rebar holes in the existing concrete should also be centered at a depth of 3.5 inches (89 mm) from the top surface.

**6.1.3.3.2.** It is important that each end of the rebar be fully tied into the existing concrete. This is accomplished by ensuring both ends of each piece of rebar extend 5 inches (127 mm) into the existing concrete. Each piece of rebar should be approximately 10 inches (254 mm) longer than the width of the removed section.

**6.1.3.3.3.** After marking the rebar hole locations, use a Hilti drill or dowel drill to drill the rebar holes. The 1.5-inch (38-mm) -diameter drilled rebar holes ensure the rebar holes are of sufficient diameter to be completely filled with concrete, eliminating air voids. The holes on one side of the removed section need to extend 1 foot (0.3 m) into the existing concrete. The holes on the opposite side should extend slightly more than 6 inches (152 mm) into the existing concrete. This allows for the rebar to be inserted into the deeper hole, lowered into the excavated section, and finally inserted into the shallower hole. Prior to lowering the rebar segment into the excavated section, slide the



rebar through the Neenah mooring eye holes. After rebar installation, the rebar segments should rest on the bottom of the drilled rebar holes. This provides a 1.125-inch (28.6-mm) gap between the top of the rebar segment and the top of the rebar hole, which is necessary to ensure free flow of the freshly placed PCC and eliminate air voids in the rebar holes.

**6.1.3.4. Step 4—Neenah Mooring Eye Protection.** Use duct tape to adequately seal the hole on the underside of the Neenah mooring eye. This will ensure that cement paste does not penetrate the ~~—bowl~~ of the Neenah. Also, fill the ~~—bowl~~ with sand or a rag (Figure 6) to keep concrete from spilling into the mooring eye, thus ensuring adequate space to attach tie-down connectors to the Neenah's cross-rod.



**Figure 6. Neenah Anchor Bowl Filled With a Rag.**

**6.1.3.5. Step 5—Neenah Mooring Eye Placement.** After inserting the rebar and Neenah mooring eye into the excavated section, attach tie-wire to the cross-rod of the mooring eye. Attach the other end of the wire to an improvised frame spanning the length of the excavated section. A 2-inch by 4-inch (51-mm by 102-mm) or 2-inch by 6-inch (51-mm by 152-mm) segment of lumber is recommended for the frame. The ends should rest on a smaller segment of lumber. Using the wire, adjust the mooring eye height so the top of the Neenah bowl is level with the existing pavement surface.

**6.1.3.6. Step 6—Concrete Placement.**

**6.1.3.6.1.** After securing the Neenah, place concrete into the excavated section. High-early-strength (Type III) cement is recommended. If Type III cement is not available, Types I and II cement are acceptable. However, Types I and II will increase the downtime before the mooring eye can be engaged. Allow the concrete to achieve a minimum compressive strength of

5,000 psi (34,474 kPa) before subjecting the tie-down to loading conditions. To expedite the process and decrease downtime, an increased compressive strength concrete mix design can be specified. A 6,000 psi (41,369 kPa) concrete with Type III cement could be loaded in 48 to 72 hours. Conversely, a 6,000 psi (41,369 kPa) mix with Type I or II cement cannot be loaded for 12 to 14 days. Alterations to the mix designs may be made at the facility manager's discretion. The aforementioned times allow for the different types of concrete to gain a minimum compressive strength of 5,000 psi (34,474 kPa) before loading. The wait times can be improved by using concrete mixes capable of gaining higher minimum 28-day compressive strengths (i.e.,  $f'_c(28) = 7,000$  psi [48,263 kPa]). Tables 1A and 1B provide guidance in predicting compressive strengths at various time intervals.

**Table 1A. Strength Gain Ratio.**

Cement Type	3-day strength ratio	7-day strength ratio	14-day strength ratio	28-day strength ratio
I, II	N/A	0.67	0.86	1
III	0.88	1	1	1

**Table 1B. Estimated Time for Various Mix Designs to Reach 5,000 psi (34,474 kPa) Compressive Strength.**

Specified $f'_c(28)$	Cement Types I or II	Cement Type III
5000 psi (34,474 kPa)	28 days	7 days
6000 psi (41,369 kPa)	12–14 days	3 days
7000 psi (48,263 kPa)	7 days	2 days

**6.1.3.6.2.** In regard to the coarse aggregate, a 0.75-inch (19-mm) minus mix is recommended. This mix refers to concrete mix designs incorporating coarse aggregate particles able to pass through a 0.75-inch (19-mm) sieve. A concrete vibrator is also required for concrete consolidation and the elimination of air voids.

**6.1.3.6.3.** During placement, maintain the position of the Neenah mooring eye to eliminate any vertical or horizontal movement. Strike off the surface of the PCC, being careful not to overfinish. Overfinishing may result in a weak surface that could spall or scale. After the initial set, trowel and brush the surface of the fresh concrete. After brushing, it is important to broom-finish the placed concrete to ensure a non-skid surface. For optimal curing conditions, maintain constant flooding of the section. Wet burlap sacks may be used to provide moist curing conditions, but this option should be a last

resort due to foreign object debris (FOD) potential. Additionally, chemical curing compounds may be utilized instead of flooding. These compounds, which reduce the evaporation of moisture from hydrating concrete by forming an impervious membrane between the freshly placed concrete and the external environment, are typically applied after final finishing of the freshly placed concrete. The airfield manager may specify to saw-cut and seal the joint between the new and existing concrete (particularly in freeze-thaw regions where the joint could open in cold temperatures).

**6.1.3.7. Installation Timeline (Without Concrete Pier).** Table 2 is an estimated timeline for installing one Neenah mooring eye without a concrete pier.

**Table 2. Neenah Mooring Eye Installation (Without Concrete Pier).**

Task	Time (minutes)
Saw-cutting	45
Impacting and debris removal	45
Base preparation	30
Drilling	45
Mooring eye placement	15
PCC placement	30
Total	210

**6.1.3.8. Equipment and Parts List.** The following list details the requisite equipment for a Neenah mooring eye (without concrete pier) installation:

1. Neenah mooring eye
2. #3 (0.375-inch [9.5-mm] -diameter) rebar
3. Rebar cutting tool
4. Hilti® drill (or equivalent) with 1.5-inch (38-mm) -diameter drill bit
5. Duct tape
6. Husqvarna Model 6600 (66 hp) walk-behind concrete saw (or equivalent)
7. Skid steer (or equivalent) with impactor and bucket attachments, or 90-pound (40.8-kg) jackhammer (with 110 psi [758 kPa] air compressor)
8. Plate compactor
9. Transit concrete mixer
10. Concrete vibrator
11. Hand tools (for concrete finishing)
12. Broom (for texturing)
13. Burlap or curing compound
14. Strike off screed
15. Lumber and wire



**6.2.** PCC Pavement at Least 6 Inches (152 mm) but Less Than 12 Inches (305 mm) Thick. This section pertains to lightweight tie-down installation in PCC pavement at least 6 inches (152 mm) but less than 12 inches (305 mm) thick.

**6.2.1.** Neenah Mooring Eye with Concrete Pier.

**6.2.1.1.** Neenah mooring eyes can be installed with concrete piers. Four tests were conducted on Neenah mooring eyes installed with an 8-foot (2.4-m) reinforced concrete pier. The expected pull-out capacity was 47,000 pounds (21,319 kg). This value meets the pull-out capacity required for heavyweight tie-downs. However, due to the failure mechanism of the mooring eye, a conservative approach is recommended. Therefore, this tie-down is not suggested to serve in a heavyweight loading role, but rather in a lightweight tie-down function, serving in rigid pavements less than 12 inches (305 mm) but at least 6 inches (152 mm) thick.

**6.2.1.2.** The observed failure mode for each mooring eye was a fracture of the cast-iron cross-rod. It is important to note that Neenah Foundry, the manufacturer of the Neenah aircraft mooring eye, specifies a 9000-pound (4082-kg) capacity for the cross-rod. After testing, it is assumed this value roughly takes into account a 4:1 to 5:1 safety factor.

**6.2.1.3.** Each pier measured 24 inches (610 mm) in diameter and extended 8 feet (2.4 m) below the top surface of the concrete pad. The recommended pier reinforcement consists of #4 (0.5-inch [13-mm] -diameter) rebar in mats in 1-foot (305-mm) grids. The required rebar cage diameter is 18 inches (457 mm).

**6.2.1.4.** Figure 7 illustrates the construction and placement of concrete pier reinforcement cages. The following section details procedures for installing a Neenah mooring eye with pier.

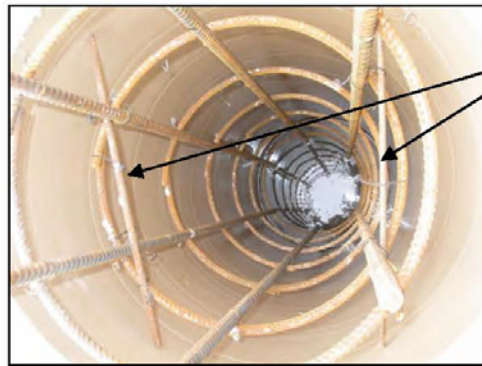
**6.2.1.4.1.** Step 1—Concrete Removal. Remove a section of the existing slab. For guidance regarding saw-cutting and debris-removal, see paragraph 6.1.3.1.

**Note:** When installing a Neenah mooring eye with a PCC pier, it is not necessary to drill rebar sleeves into the existing PCC because rebar is not required to secure the mooring eye to the existing PCC.

**6.2.1.4.2.** Step 2—Augering.

**6.2.1.4.2.1.** Auger a hole of adequate depth. A line truck with a 24-inch (610-mm) -diameter auger capacity is recommended. After augering, a sleeve (e.g., Sonotube<sup>®</sup>) may be inserted to serve as a concrete form. The sleeve is not required but may mitigate shaft cave-ins.

6.2.1.4.2.2. Following auger and sleeve placement, carefully insert the rebar cage into the excavated shaft. To eliminate cage movement during concrete placement, insert #3 (0.375-inch [9.5-mm] -diameter) rebar stabilizers into the soil surrounding the shaft. The rebar stabilizers basically serve as a wedge and the ends should extend slightly into the surrounding soil. Place the rebar stabilizer segments directly above the second rebar ring and attach them to the cage.



Rebar stabilizers  
inserted into the soil to  
eliminate cage  
movement during  
concrete placement

Figure 7. Rebar Cage for Neenah Anchor With 8-Foot (2.4-m) Pier.

6.2.1.4.3. Step 3—Neenah Mooring Eye Protection. Using duct tape and a rag (or sand), seal the mooring eye and position the tie-down in the appropriate location.

6.2.1.4.4. Step 4—Concrete Placement. Figure 8 shows a Neenah mooring eye with rebar cage prior to concrete placement. For guidance regarding concrete placement, see paragraph 6.1.3.6.



**Figure 8. Neenah Anchor With 8-Foot (2.4-m) Pier Prior to Concrete Placement.**

**6.2.1.5.** Installation Timeline (with Concrete Pier). Table 3 is an estimated timeline for installing one Neenah mooring eye (with 8-foot [2.4-m] -deep concrete pier).

**Table 3. Neenah Installation Timeline (With 8-Foot [2.4-m] Concrete Pier).**

Task	Time (minutes)
Saw-cutting	45
Impacting and debris removal	45
Hole auger	30
Rebar cage construction	360*
Sleeve and pier insertion	30
Mooring eye placement	15
Concrete placement	30
Total	555

\* Rebar cage can be constructed prior to installation.

**6.2.1.6.** Equipment and Parts List. The following list details the requisite equipment for a Neenah mooring eye installation with 8-foot (2.4-m) -deep concrete pier:

1. Neenah mooring eye
2. #3 (0.375-inch [9.5-mm] -diameter) rebar
3. Rebar cutting tool
4. Duct tape
5. Husqvarna Model 6600 (66 hp) walk-behind concrete saw (or

- equivalent)
6. Skid steer (or equivalent) with impactor and bucket attachments; or 90-pound (40.8-kg) jackhammer (with 110 psi [758 kPa] air compressor)
  7. Transit concrete mixer
  8. Concrete vibrator
  9. Hand tools (for concrete finishing)
  10. #4 (0.5-inch [12.7-mm] -diameter) rebar (various pieces)
  11. Rebar ties
  12. Line truck with 24-inch (610-mm) -diameter auger capability

**6.2.1.7.** HMA Pavements with PCC Underlay At Least 6 Inches (152 mm) but Less Than 12 Inches (305 mm) Thick. Neenah mooring eyes with 2-foot (0.6-m) -diameter, 8-foot (2.4-m) -deep concrete piers may serve as lightweight tie-downs in HMA pavements with a PCC underlay at least 6 inches (152 mm) but less than 12 inches (305 mm) thick. Installation requires full-depth removal of the HMA/PCC pavement with a walk-behind concrete saw (see paragraph 6.1.3.1). The augering process, subsequent pier and Neenah installation, and concrete placement procedures are the same as described in paragraph 6.2.1.4. (Due to pier construction, it is not necessary to use rebar segments to tie the Neenah mooring eye into the existing PCC.) The HMA pavement with PCC underlay cut-out section will be replaced with a monolithic PCC section.

**6.2.1.8.** HMA Pavements with PCC Underlay At Least 12 Inches (305 mm) Thick.

**6.2.1.8.1.** Neenah mooring eyes without concrete piers may serve as lightweight tie-downs in HMA pavements with a PCC underlay at least 12 inches (305 mm) thick. Installation requires full-depth removal of the existing HMA/PCC pavement with a walk-behind concrete saw (see paragraph 6.1.3.1).

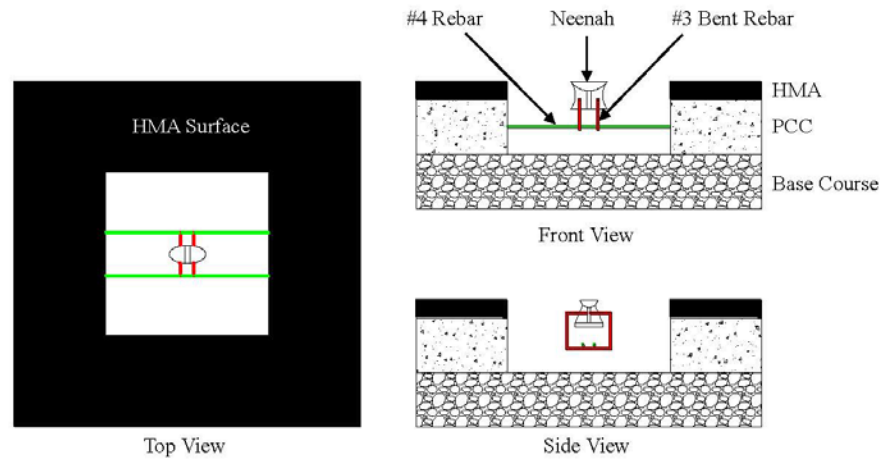
**6.2.1.8.2.** Drill four 1.5-inch (38-mm) -diameter rebar sleeves (holes drilled in the existing PCC pavement), two on each side of the cut-out section, at center position and center depth of the PCC underlay. Space the rebar segments as far apart horizontally as the rebar holes are spaced on the Neenah anchor. The sleeves on one side of the cut-out section should extend 1 foot (0.3 m) into the existing concrete, and the sleeves on the opposing side should extend 6 inches (152 mm) into the existing slab. Insert two 0.5-inch (12.7-mm) -diameter (#4) rebar segments into the rebar sleeves by sliding one end of the rebar into the deeper sleeve, lowering the segment into the cut-out area, and sliding the opposite end into the shallower hole. Ensure each rebar piece extends at least 5 inches (127 mm) into each rebar sleeve. (**Note:** These particular rebar segments will not be inserted through the rebar holes on the Neenah anchor.) The

rebar segments should rest on the bottom surface of the sleeve to ensure free flow of fresh concrete and to eliminate air voids in the rebar sleeves. The rebar sleeves should be constructed so the rebar segments will be perpendicular to the cross-rod of the Neenah anchor.

**6.2.1.8.3.** Slide a segment of bent #3 (0.375 inch [9.4 mm]) rebar through the rebar holes on the Neenah anchor. The opposite side of the bent rebar must wrap around the previously installed #4 rebar segments (Figure 9). This installation configuration, illustrated in Figure 10, guarantees the Neenah mooring eye is integrated into the existing PCC slab (**Note:** The bent rebar segment is not a common rebar configuration and will require special fabrication; the length will depend on the depth of the center of the PCC underlay). Attach the Neenah cross-rod to an improvised frame, ensure the top of the cross-rod is approximately 0.25 inch (6 mm) below the surrounding pavement surface, and proceed with concrete placement.



Figure 9. Neenah With Bent Rebar for Installation in HMA Pavement With Minimum 12-Inch (305-mm) -Thick PCC Underlay.



**Figure 10. Neenah Installation Schematic for HMA Pavement with Minimum 12-Inch (305-mm) -Thick PCC Underlay.**

**6.2.1.8.4. Equipment and Parts List.** The following list details the requisite equipment for a Neenah mooring eye installation in HMA pavements with a minimum 12-inch (305-mm) -thick PCC underlay:

1. Neenah mooring eye
2. #3 (0.375-inch [9.5-mm] -diameter) rebar
3. #3 (0.375-inch [9.5-mm] -diameter) bent rebar piece (two pieces per Neenah mooring eye)
4. Rebar cutting tool
5. Hilti drill (or equivalent) with 1.5-inch (38-mm) -diameter drill bit
6. Duct tape
7. Husqvarna Model 6600 (66 hp) walk-behind concrete saw (or equivalent)
8. Skid steer (or equivalent) with impactor and bucket attachments, or 90-pound (40.8-kg) jackhammer (with 110 psi [758 kPa] air compressor)
9. Plate compactor
10. Transit concrete mixer
11. Concrete vibrator
12. Hand tools (for concrete finishing)

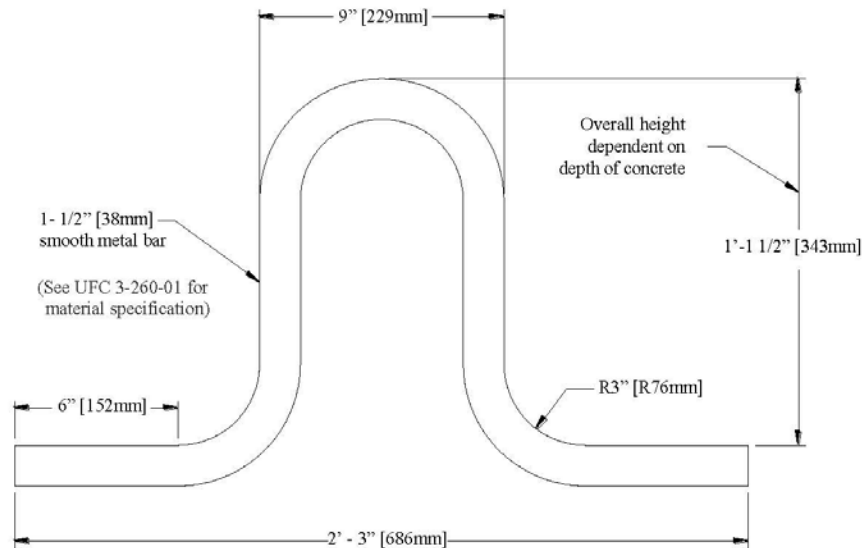
## **7. Heavyweight Tie-Downs.**

**7.1.** The hat-type tie-down was the only system deemed to meet the heavyweight-loading tie-down criteria in 12-inch (305-mm) -thick PCC pavement. This anchor was not tested in PCC pavements less than 12 inches (305 mm) thick and should not be utilized as a heavyweight or lightweight tie-down in PCC pavements less than 12



inches (305 mm) thick. Hat-type tie-downs are composed of a bent smooth metal bar, resembling the cross-section of a hat (Figures 11 and 12), that is integrated into the existing concrete. This anchor is not commercially available, but is similar to the Air Force rigid pavement tie-down described in UFC 3-260-01. Four hat-type tie-downs were tested by AFRL. Each tie-down was subjected to a 50,000-pound (22,680-kg) vertical load. None of the hat-type tie-downs failed or exhibited any measurable deflection.

**7.2.** There are two hat-type tie-down installation methods: method A—saw cutting; method B—coring. There is no performance difference between the two methods and installation times are similar. Each method (A and B) is discussed in detail in this ETL. The optimal installation method depends on equipment availability at each particular facility.



**Figure 11. Hat-Type Schematic.**





**Figure 12. Hat-Type Tie-Down.**

**7.2.1. Method A—Saw-cutting.** Method A entails saw-cutting the entire depth of a section of existing concrete (Figure 13). The width of the section is typically 1 foot (0.3 m) and the length is the length of the hat-type tie-down plus 10 percent (Example: hat-type tie-down length = 30 inches [0.76 m], cut-out section length = 33 inches [0.84 m]). Figure 11 shows the dimensions of a hat-type tie-down designed to be installed in 12-inch (305-mm) -thick PCC. The tie-down height, measured from the top of the bottom bar to the top of the hat, equals the PCC thickness plus 1.5 inches (38 mm), which will require the tie-down height to be increased if installed in pavement more than 12 inches (305 mm) thick.

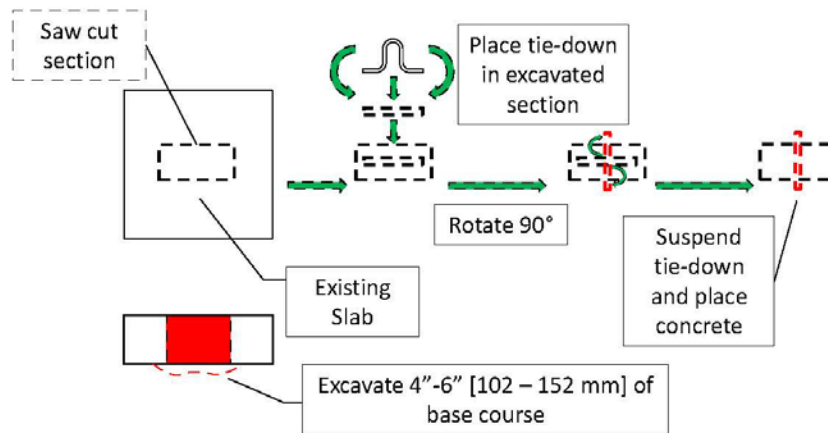


**Figure 13. Hat-Type Tie-Down Prior to Concrete Placement.**

**7.2.1.1. Step 1—Concrete Removal.** Saw-cut the section to be removed with

a walk-behind concrete saw. Guidance for concrete saw-cutting and debris removal is provided in paragraph 6.1.3.1. The hat-type tie-down should be installed so its final orientation will be perpendicular to the direction of the chain used to connect the aircraft to the tie-down.

**7.2.1.2. Step 2—Base Course Excavation.** Excavate the top 4 to 6 inches (102 to 152 mm) of base course material. It is important that the excavated portion extends several inches below the existing concrete. The installation procedure is illustrated in Figure 14.



**Figure 14. Hat-Type Tie-Down Installation (Saw-cutting Method).**

**7.2.1.2.1.** The recommended procedure for excavating the base course is to remove the bulk of the compacted material with hand tools. After removing as much of the material as possible with hand tools, water-jet the compacted base course material underneath the existing pavement to excavate a cavity beneath the slab. Water-jet only during the final stage of base course removal to keep the excavated section as dry as possible. A water distributor equipped with a high-powered water pump is suggested for the water-jetting procedure. It should be noted that the base course removal is a labor-intensive task.

**7.2.1.2.2.** Following the removal of the base course, completely clear the excavated section of water and debris. A small hand-held bucket is recommended for water and debris removal. After removing a majority of the standing water and solid debris, a shop vacuum (or equivalent) is suggested to complete the debris-removal process.

**7.2.1.2.3.** Before disassembling the water distributor and pump, ensure

the cavity is of sufficient depth and distance under the existing slab to allow the hat-type tie-down to be placed into the excavated section and rotated 90 degrees. Excavating 4 to 6 inches (102 to 152 mm) of the base course ensures the hat-type tie-down can be rotated into the proper position and there will be an adequate gap between the top of the tie-down's bottom bar and the bottom surface of the existing PCC. This gap prevents voids under the slab by allowing fresh PCC to flow unimpeded throughout the excavated section and specifically between the bottom bar of the tie-down and the bottom surface of the existing PCC.

**7.2.1.3. Step 3—Hat-Type Tie-down Insertion.** Place the hat-type tie-down into the cut and excavated section.

**7.2.1.4. Step 4—Hat-Type Tie-down Rotation.** Rotate hat-type tie-down 90 degrees so the ends of the bar sit under the existing concrete pad.

**7.2.1.5. Step 5—Hat-Type Tie-down Placement.** Suspend the top of the hat-type tie-down approximately 0.25 inch (6 mm) below the top surface of the existing concrete. The suggested method for suspending the hat-type tie-down incorporates a piece of lumber, with each end resting on an improvised base. Using tie wire, connect the top of the hat-type tie-down to the suspended lumber. Adjust the top of the bar height as necessary.

**7.2.1.6. Step 6—Concrete Placement.** See paragraph 6.1.3.6 for guidance regarding concrete placement. Ensure concrete is forced under the existing slabs to eliminate voids.

**7.2.1.7. Step 7—Recess Forming.** Before the concrete hardens, form a hemispherical recess around the top of the hat-type tie-down to allow room for the tie-down chain or strap to connect to the hat portion of the tie-down. The recess should be oval in shape and extend approximately 3 to 4 inches (76 to 102 mm) below the top of the bar and 9 inches (229 mm) horizontally in both directions. The hemisphere diameter is approximately 10 inches (254 mm) in the center, tapering off toward the horizontal edges. Make certain the recess allows enough space for connection attachments, such as shackles (Figure 15). Figure 16 shows the recommended hemispherical recess dimensions.

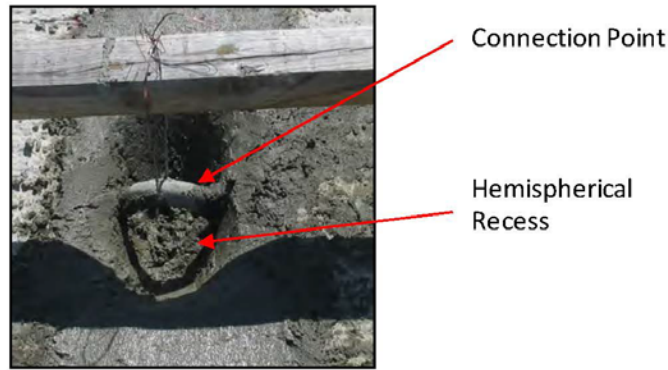


Figure 15. Installed Hat-Type Tie-Down.

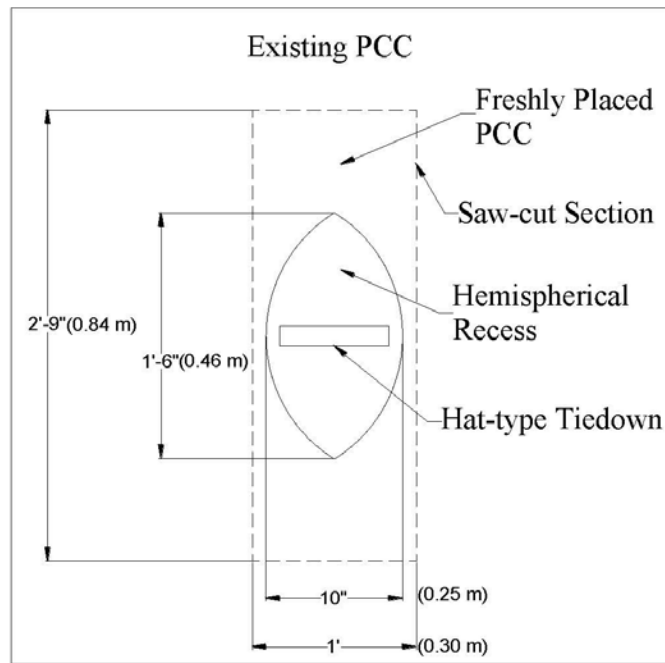


Figure 16. Hat-type Tie-Down Hemispherical Recess Dimensions.

7.2.1.8. Installation Timeline for Hat-Type Tie-Down—Method A. Table 4 is an estimated timeline for installing one hat-type tie-down (saw-cut method).

**Table 4. Hat-Type Tie-Down Installation Timeline (Saw-cut Method).**

Task	Time (minutes)
Saw-cutting	45
Impacting and debris removal	45
Base course excavation	60
Anchor placement	15
PCC placement	30
Total	195

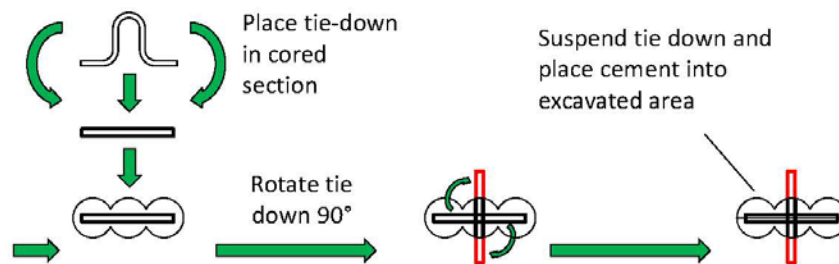
**7.2.1.9. Equipment and Parts List.** The following list details the requisite equipment for a hat-type tie-down installation (saw-cut method):

1. Hat-type tie-down
2. Husqvarna Model 6600 (66 hp) walk-behind concrete saw (or equivalent)
3. Skid steer (or equivalent) with impactor and bucket attachments, or 90-pound (40.8-kg) jackhammer (with 110 psi [758 kPa] air compressor)
4. Lumber (for suspending hat-type tie-down during concrete placement)
5. Transit concrete mixer
6. Concrete vibrator
7. Hand tools (for concrete finishing)
8. Water distributor and pump
9. Shop vacuum

**7.2.2. Method B—Coring.** Method B utilizes a series of three adjacent 12-inch (305-mm) -diameter cores through the entire concrete slab depth (Figure 17). The three adjacent cores eliminate the need to saw-cut the concrete slab. Method B reduces the equipment list by eliminating the walk-behind concrete saw and skid steer with impactor and loader (or 90-pound [40.8-kg] jackhammer and 110 psi (758 kPa) air compressor). However, Method B requires a coring rig capable of accepting a 12-inch (305-mm) -diameter coring bit, which may not be available at all facilities. Figure 18 provides an installation schematic for the coring method.



**Figure 17. Three Adjacent 12-Inch (0.3-m) Cores Allow for Insertion of the Hat-Type Tie-Down.**



**Figure 18. Hat-Type Tie-Down Installation Schematic (Coring Method).**

**7.2.2.1. Step 1—Coring.** Using a coring rig, collect three 12-inch (305-mm) -diameter cores adjacent to each other. The cores must extend the entire depth of the concrete.

**7.2.2.2. Step 2—Core and Debris Removal.** Remove the cores and completely remove any standing water from the core holes. The simplest method for removing water is using a shop vacuum with an extension small enough to easily fit into the core holes.

**7.2.2.3. Steps 3 through 7—Anchor and Concrete Placement.** See Method A, steps 2 through 7 (paragraphs 7.2.1.2 through 7.2.1.7). Figure 19 illustrates an installed hat-type tie-down prior to PCC placement.





**Figure 19. Hat-Type Tie-Down Installed Using Coring Method Prior to PCC Placement.**

**7.2.2.4.** Installation Timeline for Hat-Type Tie-Down—Method B. Table 5 is an estimated timeline for installing one hat-type tie-down using the coring method.

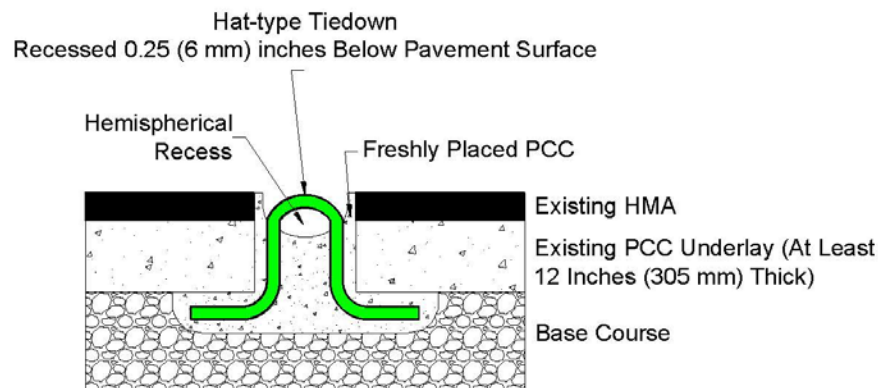
**Table 5. Hat-Type Tie-Down Installation Timeline (Coring Method).**

Task	Time (minutes)
Coring	60
Core extraction	5
Base course excavation	60
Anchor placement	15
PCC placement	30
Total	170

**7.2.2.5.** Equipment and Parts List. The following list details the requisite equipment for a hat-type tie-down installation (coring method):

1. Hat-type tie-down
2. Coring rig
3. Lumber (for suspending hat-type tie-down during concrete placement)
4. Transit concrete mixer
5. Concrete vibrator
6. Hand tools (for concrete finishing)
7. Water distributor and pump
8. Shop vacuum

**7.3. Hat-Type Tie-down Installations in HMA Pavements With at Least 12-Inch (305-mm) -Thick PCC Underlay.** Heavyweight capacity hat-type tie-downs may be installed in HMA pavements with a minimum 12-inch (305-mm) -thick PCC underlay. The installation requires a full-depth cut-out, or, depending on the installation method, adjacent 12-inch (305-mm) -diameter full-depth pavement core extractions of the HMA/PCC pavement section that will serve as the hat-type tie-down location. Each of these installation methods are described in detail in paragraphs 7.2.1 and 7.2.2. The required height of the hat-type tie-down, measured from the top of the bottom bar to the top of the hat, is determined by measuring the combined thickness of the HMA and PCC underlay and adding an additional 1.5 inches (38 mm). A sufficient volume of fresh concrete should be placed to fill the entire depth of the excavated area, including the thickness of the HMA layer, and create a level surface with the surrounding pavement (Figure 20).



**Figure 20. HMA/PCC Hat-Type Tie-Down Installation Schematic.**

**8. Point of Contact.** Recommendations for improvements to this ETL are encouraged and should be furnished to the Pavements Engineer, HQ AFCEA/CEOA, 139 Barnes Drive, Suite 1, Tyndall AFB, 32403-5319, DSN: 523-6439, Commercial: (850) 283-6439, FAX DSN: 523-6488, e-mail [AFCESAR@tyndall.af.mil](mailto:AFCESAR@tyndall.af.mil).

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## APPENDIX C GLOSSARY

### C-1 ACRONYMS

AFCEE	Air Force Center for Engineering and the Environment
BIA	Bilateral Infrastructure Agreement
DoD	Department of Defense
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HNFA	Host Nation Funded Construction Agreements
NAVFAC	Naval Facilities Engineering Command
SOFA	Status of Forces Agreements
UFC	Unified Facilities Criteria
U.S.	United States

**C-2            DEFINITION OF TERMS**

**Hat Type Tie-Down:** A tie-down consisting of a bar that is bent with one 180 degree bend and two 90 degree bends that generate a shape that resembles the cross section of a hat with a brim.