



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

19 DEC 2007

FROM: HQ AFCESA/CEOA
139 Barnes Drive, Suite 1
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SUBJECT: **Engineering Technical Letter (ETL) 07-2: Anchoring a Fiberglass Mat Assembly in Asphalt Concrete (AC) Pavement**

1. Purpose. This ETL provides an alternate method of installing a Type 3 polymer plug anchor to anchor fiberglass mats in asphalt concrete (AC) pavements as defined in Technical Order (T.O.) 35E2-3-1, *Folded Fiberglass Mats for Rapid Runway Repair*. Specifically, this ETL revises paragraph 7.6 of T.O. 35E2-3-1 and provides a method to reconfigure/modify the anchor bolt and a choice of anchor-setting materials, thereby providing performance that is equal or superior to previous methods for anchoring in AC 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. This ETL is applicable to all organizations with responsibility for performing folded fiberglass mat (FFM) assembly repairs on AC airfield pavements.

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

2.2. Effective Date: Immediately.

2.3. Intended Users: Air Force base civil engineers (BCE), RED HORSE squadrons, and other units responsible for the planning, design, construction, maintenance, and repair of airfield pavements; U.S. Army Corps of Engineers (USACE) and Navy offices responsible for emergency airfield design, construction, and repairs.

2.4. Coordination: Major command (MAJCOM) pavement engineers.

3. References.

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

4. Acronyms and Terms:

AC	- asphalt concrete
AFB	- Air Force Base
AFRL	- Air Force Research Lab
C	- Celsius
ETL	- Engineering Technical Letter
F	- Fahrenheit
FFM	- folded fiberglass mat
ft	- foot
HQ AFCESA	- Headquarters, Air Force Civil Engineer Support Agency
in	- inch
kN	- kilonewton
lb	- pound
m	- meter
MAJCOM	- major command
ml	- milliliter
mm	- millimeter
OD	- outside diameter
oz	- ounce
RED HORSE	- Rapid Engineers Deployable Heavy Operations Repair Squadron Engineers
RRR	- rapid runway repair
T.O.	- Technical Order
UFC	- Unified Facilities Criteria

5. Recommended Procedure to Install FFM Anchor in Thin Asphalt.

5.1. Modify the standard concrete wedge anchors (use the type that is standard with the FFM kit). Use anchors that are approximately 9.5 inches (241 mm) long and 0.5 inch (12 mm) in diameter (measured across the threads).

5.1.1. Modify each anchor by removing the nylon collar section, expansion sleeve, and cone at the bottom of the bolt and replacing them with three 1.375-inch (35 mm) outside diameter (OD) washers with a spacer about 0.5 inch (12 mm) tall between them and one threaded coupling nut with a hexagon outer shape and a piece of tape on the end of the coupling. The coupling should be long enough (about 1.5 inches [38 mm] long) to ensure the end of the bolt does not extend below the bottom of the coupling. Oversized nuts can be used as spacers.

5.1.2. Before final assembly, place each bolt in an FFM bushing and then add the washers, spacers, and coupling nut.

5.1.3. Ensure the junction of all parts (sleeve, washer, spacer, and coupling) is tight and that you cannot see the threads of the bolt along the length of the

modified bolt. This is important to ensure the bolts can be removed and reinserted after the anchors have been in service.

5.2. Place the FFM on the ground in the desired location.

5.3. Use a hammer drill to drill a 1.5- to 2-inch (38 to 50 mm) -diameter hole to a depth of 10 to 11 inches (254 to 279 mm).

5.4. Use a shop vacuum to remove loose material from the hole.

5.5. Wash the asphalt portion of the shaft with a small amount of water.

5.6. Ensure the bolt is in the FFM bushing.

5.7. Ensure the bolt and bushing fit properly in the mat and the hole by placing it in the hole and then removing it.

5.8. Keep the bushing on the bolt.

5.9. Place Power-Fast[®] + or Liquid Roc 500 in the hole to a level approximately 0.5 inch (12 mm) from the pavement surface.

5.9.1. Note: At high temperatures (above 90 °F [32 °C]) the epoxy can set in two to three minutes, so have all materials ready and available. Have an extra tube of epoxy available at all times.

5.9.2. If temperatures are below 60 °F (16 °C), use AC100 Plus™ or Hilti HIT ICE.

5.9.3. If temperatures are above 95 °F (35 °C), use Liquid Roc 500, not Power-Fast +.

5.10. Insert the bolt into the hole. Ensure the adhesive flows around the washers and avoid creating air pockets.

5.11. Seat the bushing in the transition and ensure the bolt is flush with the bushing.

5.12. Open to traffic after one hour of cure time above 70 °F (21 °C) (using Power-Fast + or Liquid Roc 500); two hours if 40 to 70 °F (4 to 21 °C) (using AC100 Plus, Hilti ICE, or Power-Fast + above 60 °F [16 °C]).

6. Background.

6.1. T.O. 35E2-3-1 describes the use of part number R-256 NSN 8030-01-376-7248, a two-part polymer kit which is no longer available from the manufacturer. Furthermore, T.O. 35E2-3-1 provides instruction on anchoring mats to AC pavements thicker than 10 inches (254 mm); however, there is a need to anchor

mats to AC pavements that are significantly thinner than this. Testing by the Air Force Research Laboratory (AFRL) at Tyndall AFB, Florida, and the U.S. Army Engineer Research and Development Center (ERDC) at Vicksburg, Mississippi, has resulted in a suitable replacement for the polymer kit recommended in the T.O. and a method has been developed to anchor the mats to thinner AC pavements.

6.2. Anchors were placed by drilling a 1.5-inch (38-mm) -diameter hole approximately 10 inches (254 mm) deep. The hole was cleared of debris and filled with epoxy. The modified bolt was inserted into the hole. After allowing the epoxy to cure, the bolts were loosened and retightened to ensure the repair could be maintained if needed. The bolts were then pull-tested to determine the pull-out strength.

6.3. AFRL obtained the best results using a water-insensitive two-part structural epoxy. A double-tube container containing a total of 22 oz (650 ml) of epoxy will fill a single hole. Adhesives packaged this way can be applied manually, pneumatically, or with a power-operated injection tool. The epoxy is proportionally mixed through a static element mixing nozzle.

6.4. Additionally, if drills, mixing paddles, and potable water are available, fast-setting grouts using 2-inch (51-mm) -diameter holes can also be employed. Fast-setting grouts behave similarly to the epoxies, with faster cure times in hot weather and longer set times in colder climates. Using heated water can improve cure times in cold conditions. The grout is typically packaged in dry form in a 5-gallon (18.9-liter) bucket. The materials examined herein required 1 gallon (3.7 liters) of water to produce approximately 2 gallons (7.5 liters) of grout. This volume of grout can be used to install approximately five to seven anchor bolts. Once poured, the material can be screeded and finished in a manner similar to concrete. Adding slightly more or less water (only a few ounces or as recommended by the manufacturer) will produce a thinner or thicker grout respectively, but should not affect the finished strength.

7. Modified Anchor System.

7.1. Epoxy.

7.1.1. Characteristics.

7.1.1.1. Required: Working time of 3 to 5 minutes at 75 °F (24 °C); cure time less than 120 minutes at 75 °F (24 °C); water-insensitive; temperature range will differ depending on the climate where the mat will be applied. The usual range is from 40 to 95 °F (4 to 35 °C). Some are designed for high temperatures up to 140 °F (60 °C) and some are designed for temperatures as low as -10 °F (-24 °C); however, none have been found to be effective over the full temperature range from -10 to 140 °F (-24 to 60 °C). Many epoxies will not set in temperatures below 40 °F (4 °C).

7.1.1.2. Desired: Formulated for underwater applications.

7.1.1.3. When selecting an epoxy for cold weather applications, you should consider the cure time and viscosity (pumpability) characteristics. AC100 Plus and HIT ICE performed well in all our tests.

7.1.2. Specific Epoxies Tested.

7.1.2.1. Superstick Hi-Mod Gel #590 (E-Bond Epoxies, Inc.): This product was extremely sensitive to moisture. Any moisture in the subgrade will affect the materials even when the pavement surface is dry. This product had a long cure time (8 to 24 hours) even at room temperature, which is unacceptable for most rapid runway repair (RRR) applications.

7.1.2.2. Concrete Welder (PERCOL Polymerics, Inc.): This product was extremely sensitive to moisture. Any moisture in the subgrade will adversely affect the materials even when the pavement surface is dry, which is unacceptable for most RRR applications.

7.1.2.3. Liquid Roc 500 (MKT/Gunnebo Fastening Corp.): This product provided satisfactory performance. This product can be placed/cured underwater. (<http://www.mktfastening.com/>)

7.1.2.4. Power-Fast + (Powers Fasteners): This product provided satisfactory performance. This product can be placed/cured underwater. (http://www.powers.com/adhesive_foam.html)

7.1.2.5. Epcon A7 Acrylic (fast-set formula) (Red Head): This product provided satisfactory performance.

7.1.2.6. AC100 Plus (Powers Fasteners): This product provided satisfactory performance at low temperatures (35 °F [2 °C]). This product can be placed/cured underwater. (http://www.powers.com/adhesive_foam.html)

7.1.2.7. HIT ICE (Hilti): This product provided satisfactory performance at low temperatures (35 °F [2 °C]). This product can be placed/cured underwater. (<http://www.hilti.com>)

7.2. Fast-Setting Water-Based Grouts.

7.2.1. Characteristics.

7.2.1.1. Required: Working time of 10 to 15 minutes at 75 °F (24 °C); cure time less than 60 minutes at 75 °F (24 °C); water-insensitive and can be used in a submerged condition similar to concrete; temperature range will differ

depending on the climate where the mat will be applied. The usual range is from 40 to 95 °F (4 to 35 °C), but temperatures above 95 °F (35 °C) will shorten work and cure times, while in the lower temperature range (approximately 50 °F [10 °C] and below) work and cure times will increase. Anchor holes require minimal preparation and grout is insensitive to dust or moisture in the hole; the grout should be a non-shrink, non-metallic type material.

7.2.2. Specific Grout Tested: HARD-ROK™ Anchoring Cement (Adhesives Technology Corp.) provided satisfactory performance.

7.3. Modified Anchor Bolt.

7.3.1. Existing Anchor Bolts. The anchors are Hilti HSL M12/50 expansive anchors (Hilti Corp.). Hilti HSL 3 bolts are similar and a suitable substitute. The anchors are approximately 9.5 inches (241 mm) long and 0.5 inch (13 mm) in diameter. The sleeve has a 0.75-inch (19 mm) outside diameter. They are designed for use in cracked concrete. Figure 1 shows the anchor and its components. The anchor comes with a shoulder bolt, a washer, a steel sleeve, a nylon collar section, an expansion sleeve, and a cone.

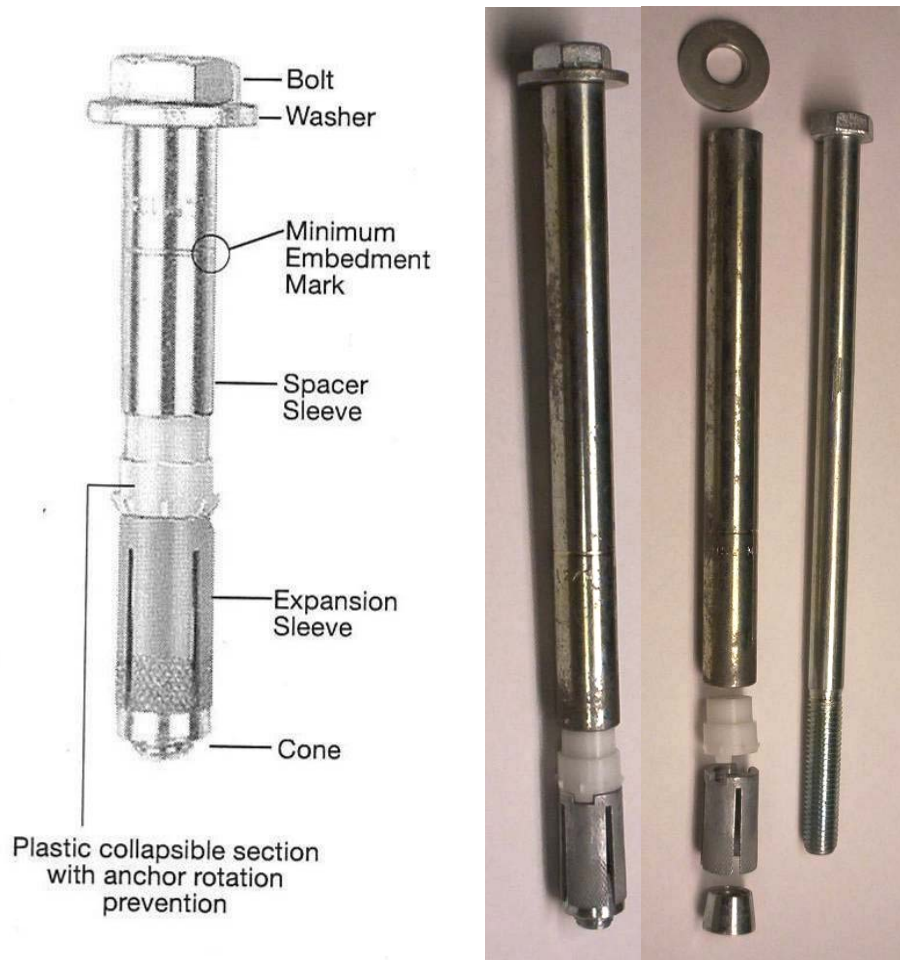


Figure 1. M12/50 Expansion Anchor

7.3.2. Modifications. The standard anchor was modified by removing the nylon collar section, expansion sleeve, and cone, and replacing them with three 1.375-inch (35-mm) OD (outside diameter) washers, two 0.5-inch (13-mm) spacers, one threaded coupling nut with a hexagon outer shape, and a piece of tape on the end of the coupling. The coupling was a metric class 5.8 zinc-plated steel coupling nut M12 screw, 1.5 inches (38 mm) in length, 0.625 inch (16 mm) in width, with a 0.069-inch (1.75-mm) pitch. The tape on the end of the coupling is needed to ensure epoxy does not enter the coupling and precludes the bolt from being removed and reinserted after the epoxy has cured. The spacers consisted of two 0.625-inch (16-mm) ID (inside diameter) nuts which allowed the threaded portion of the 0.5-inch (13-mm) bolt to easily pass through. The nuts were approximately 0.5 inch (13 mm) tall. Spacers made from sections cut from the sleeve were also tried; however, epoxy was able to pass between the spacers and the washers due to the clearance between the bolt and the washer relative to the thickness of the spacer wall.

Figure 2 shows the anchor components. Figure 3 shows the components assembled.



Figure 2. Modified Anchor Components



Figure 3. Assembled Modified Anchor

7.4. Test Setup and Procedures.

7.4.1. The tests were conducted on asphalt pavement that was 4.75 inches (121 mm) to 5.75 inches (146 mm) thick. The asphalt was placed over a crushed stone base that was approximately 9 inches (229 mm) thick. The temperature ranged from 75 °F (24 °C) to 100 °F (38 °C). A 1.5-inch (38-mm) -diameter hole was drilled 10 to 11 inches (254 to 279 mm) deep. Excess debris at the bottom of the hole was removed using a standard shop vacuum cleaner. The adhesives were tested in both wet and dry environments. The holes were cleaned with a variety of methods, including washing the surfaces with water, while several holes were tested without any cleaning. The epoxy was injected in each hole and an anchor with a loading plate was placed in and over the hole.

7.4.2. The anchors were tested at one hour, six hours, and 24 hours after placement. The anchors were pulled vertically using a forklift and a front-end loader. The maximum pulling force was recorded using a Dillon 100,000 lb force (445 kN) load cell.

7.4.3. Three tests were also conducted on pavements and subgrades at 35 to 39 °F (1.6 to 3.8 °C). The temperature of the pavement and subgrades was monitored using thermal couples. The anchors were tested at 45 minutes and 6 hours.

7.5. Test Results. Tests on anchors placed in temperatures above 75 °F (24 °C) resulted in strengths in excess of 5,000 lbs force (22 kN). A total of twenty-seven tests using Liquid Roc 500 resulted in a minimum pull strength of 5,000 lbs force (22 kN), a maximum of 15,000 lbs force (67 kN) and an average of 10,000 lbs force

(44 kN). The pull test strengths appeared to be insensitive to moisture, cure times over one hour in length, and surface preparation. It should be noted that the ultimate pullout force is a function of the pavement structure and material characteristics in which the anchor is embedded. Less competent pavement structures would be expected to provide lower ultimate pullout strengths, approaching the lower end of the range tested or 5,000 lbs force (22 kN). For example, tests completed at the ERDC site using the recommended system with a 4.5- to 6.0-inch (114- to 152-mm) -thick AC surface, but a poor quality base, produced an average pullout strength of 6,500 lbs force (28.9 kN). In contrast, more competent pavements, which include increased asphalt thicknesses or higher-strength materials, will provide anchor pullout strengths near the maximum values reported. Thus, in extremely thin or weak asphalt pavements, additional anchors may be required to provide the same pullout resistance for the foreign object debris (FOD) cover.

7.5.1. Some epoxies such as AC100 Plus and HIT ICE are designed to be placed at low temperatures. These products set within several minutes and cured sufficiently within 45 minutes to attain pull strengths of 15,000 pounds force (67 kN) when placed and cured at 35 °F (2 °C). It should be noted that the lower temperatures significantly increased the stiffness of the pavement which had caused a significant increase in the strength of the anchor system.

8. Point of Contact. Recommendations for improvements to this ETL are encouraged and should be furnished to HQ AFCESA/CEOA, 139 Barnes Drive, Suite 1, Tyndall AFB, FL 32408-5319, Pavements Engineer, HQ AFCESA/CEOA, DSN 523-6439, commercial (850) 283-6439, internet AFCESAReachBackCenter@tyndall.af.mil.

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