DEPARTMENT OF THE AIR FORCE
AIR FORCE CIVIL ENGINEER CENTER
TYNDALL AIR FORCE BASE FLORIDA

21 NOVEMBER 2014

FROM: AFCEC/DD
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SUBJECT: **Engineering Technical Letter (ETL) 14-2 (Change 1): Preventing and Repairing Concrete Deterioration Under MV-22 and CV-22 Aircraft**

1. Purpose. This ETL provides guidance on Portland cement concrete (PCC) surface treatments to reduce or eliminate spalling, scaling, and other surface damage caused by heat and petroleum, oil, and lubricants (POL) from aircraft engines, and provides guidance on repairing PCC damaged by CV-22 or MV-22 operations.

Note: Use of the name or mark of a specific manufacturer, commercial product, commodity, or service in this ETL does not imply endorsement by the Air Force.

2. Application: All bases supporting MV-22 or CV-22 operations on PCC pavements. This includes bases subject to transient use or special project/operation use that exceeds six months or that anticipates over 90 shut-down and start-up operations on one spot within one year. It is best to apply these treatments before the areas are contaminated by POL; therefore, it is best to treat when in doubt as to the length or number of operations. Lack of treatment must not be used to deny or restrict operations of any aircraft, including CV-22s and MV-22s.

2.1. Authority:

- Unified Facilities Criteria (UFC) 3-260-02, *Pavement Design for Airfields*
- Air Force policy directive (AFPD) 32-10, *Installations and Facilities*
- AFPD 10-2, *Readiness*

2.2. Effective Date: Immediately

2.3. Intended Users:

- Major command (MAJCOM) engineers
- Base civil engineers (BCE)

2.4. Coordination:

- Naval Facilities Engineering Command Engineering and Expeditionary Warfare Center (NAVFAC EXWC)

3. Acronyms and Glossary:

FARP - forward area refueling point

NAVFAC EXWC	- Naval Facilities Engineering Command Engineering and Expeditionary Warfare Center
PCC	- Portland cement concrete
pH	- power of hydrogen
POL	- petroleum, oil, and lubricants
PPE	- personal protective equipment
TDS	- Technical Data Sheet
TSP	- trisodium phosphate
UFC	- Unified Facilities Criteria
UFGS	- Unified Facilities Guide Specification

4. References.

4.1. Air Force:

- AFPD 10-2, *Readiness*, http://www.e-publishing.af.mil/
- AFPD 32-10, *Installations and Facilities*, http://www.e-publishing.af.mil/
- ETL 02-7, *Preventing Concrete Deterioration Under B-1 and F/A-18 Aircraft*, http://www.wbdg.org/ccb/browse_cat.php?o=33&c=125

4.2. Navy:

- Naval Facilities Engineering Service Center (NFESC) Technical Data Sheet (TDS) 2058-SHR, *A Concrete Solution to the F/A-18 Parking Apron Problem*, September 1998
- TDS NAVFAC EXWC-CI-1403, *Mitigating Concrete Damage Caused by Engine Exhaust Surface Temperature below 500ºF*, December 2013 (supersedes TDS-2058-SHR)
- Malvar, L.J., Rossetti, P., Technical Report TR-2344-SHR, Naval Facilities Engineering Service Center, Port Hueneme, California, October 2010

4.3. Joint:

- UFC 3-260-02, *Pavement Design for Airfields*, http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4
- UFC 3-270-03, *Concrete Crack and Partial-Depth Spall Repair*, http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4
- UFC 3-270-04, *Concrete Repair*, http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4
- UFGS 32 13 13.43, *High-Temperature Concrete for Airfields with Applied Pavement Temperatures of 482 Degrees C (900 Degrees F) or Higher Using Lightweight and Traprock Aggregates*, https://www.my.af.mil/gcss-af/USAF/AFP40/d/s2D8EB9D637283B5601377B2CE4030666/Files/editorial/DRAFT%20UFGS%2032%2013%2013.43.pdf

4.4. New York State Department of Transportation Materials Bureau:

- NY 703-19 E (2008), *Moisture Content of Lightweight Fine Aggregate*

4.5. Industry:

- ASTM D5340, *Standard Test Method for Airport Pavement Condition Index Surveys*, http://www.astm.org/Standards/D5340.htm
- Anderson, John R., Marian P. Rollings, Michael Ayers, and Raymond S. Rollings, *Auxiliary Power Unit (APU) Resistant Concrete: State-Of-The-Art*. Transportation Systems 2000 Conference, San Antonio, Texas, 1 March 2000
- Hironaka, M.C., Malvar, L.J., "Jet Exhaust Damaged Concrete," *Concrete International*, vol. 20, no. 10, October 1998, pp. 32-35
- McVay, Michael, Jeff Rish III, Chris Sakezles, Shaik Mohseen, and Charles Beatty, "Cements Resistant to Synthetic Oil, Hydraulic Fluid, and Elevated Temperature Environments," *ACI Materials Journal*, March-April 1995, pp. 155-163

5. Background.

5.1. MV-22 and CV-22 engine exhaust can damage ordinary PCC pavements. The damage occurs in the form of scaling or spalling of the top 1 to 2 inches (25 to 50 millimeters) of the pavement. Pavement fragments from these surface scales have the potential to cause foreign object damage (FOD) to aircraft engines. The exhaust temperatures, coupled with spilled fluids (POL), damage ordinary PCC airfield pavements. The damage occurs progressively to the pavement surface under repeated thermal cycling and chemical reaction of the spilled aircraft fluids with the cement paste.

5.2. Testing by NAVFAC EXWC and the Air Force Research Laboratory (AFRL) (see reports in paragraphs 4.2 and 4.5) has shown that there are three primary mechanisms causing the damage: thermal fatigue, vapor pressure, and chemical degradation. Thermal fatigue has produced failures without the presence of POL. Damage due to vapor pressure has also been observed when the water vapor pressure cannot be relieved fast enough during the heating phase. Chemical degradation results in a significant loss of strength—up to 50 percent in some cases—which accelerates the failure. Chemical degradation by itself can result in raveling of the concrete, which has been observed under auxiliary power units (APU) for the B-1 and F-18; it does not produce scaling, but accelerates scaling.

5.3. There are three techniques to reduce damage from MV-22 and CV-22 exhaust.

5.3.1. Applying sodium silicate dramatically improves a concrete pavement's ability to resist damage from exhaust temperatures below 500 °F (260 °C). Applying sodium silicate is the most affordable way to reduce damage to existing undamaged pavement because reconstruction is not required.

5.3.2. When new construction is planned, a high-temperature aggregate such as an igneous traprock, expanded shale, or expanded slate can be used as the coarse aggregate in the concrete mix design. Unlike a concrete mix for an F-35 vertical landing pad (see UFGS 32 13 13.43, *High-Temperature Concrete for Airfields with Applied Pavement Temperatures of 482 Degrees C (900 Degrees F) or Higher Using Lightweight and Traprock Aggregates*), the fine aggregate can be a natural sand. For best results, sodium silicate must also be applied; however, the sealant must not be applied any earlier than 70 days after placement of the concrete.

5.3.3. Multifilament polypropylene fibers at a dosage of 3 pounds per cubic yard of concrete further improves concrete durability when subjected to exhaust.

5.4. In cases where existing pavement has been damaged, repairs in accordance with ETL 02-7, *Preventing Concrete Deterioration Under B-1 and F/A-18 Aircraft*, will provide a level of protection against further damage to the affected areas. For best results, a sealant can also be applied; however, the sealant must not be applied any earlier than 70 days after placement of the repair material.

6. Requirements.

6.1. The primary function of the airfield pavement is to provide the infrastructure necessary to launch, recover, maintain, and supply aircraft; therefore, this ETL must not be used to deny or restrict operations of any aircraft, including CV-22s and MV-22s. This ETL can be used to identify and establish projects and protocols to effectively support air operations.

6.2. Surface sealants such as sodium silicate must be applied no earlier than 70 days after the pavement has been placed.

6.3. Before applying surface sealants all contaminants such as POL, dust, curing compound, and moisture must be removed. If water is used to clean the pavement, the pavement must be dried and must be dry for 24 hours prior to any surface application.

6.4. It is recommended that steps to protect the pavement be initiated within six months of commencing operations. For locations subject to less than two operations per week, this time may be extended to 12 months. Surface treatments are most effective when placed prior to the application of heat loads and prior to any contamination by POL. Damage to PCC has been observed as early as six months and as late as 60 months after operations commence.

6.5. When possible, repair the following distresses within the treatment area prior to the placement of surface treatments: damaged joint and crack seals, spalls, and medium- and high-severity patches as defined by ASTM D5340, *Standard Test Method for Airport Pavement Condition Index Surveys*. Surface treatments can be applied before completing these repairs; however, retreatment of the surface within 6 inches (150 millimeters) of the repair area is recommended after completing the repairs. If the repair includes the placement of concrete or magnesium phosphate-based cements, the repair should not be resealed for 70 days.

6.6. There are some distresses that, if present, may reduce the effectiveness of the surface treatment; therefore, if you have shattered slabs, medium- or high-level durability cracking (D cracking), medium- or high-severity scaling, or medium- or high-level alkali-silica reaction (ASR) as defined in ASTM D5340, the surface treatment can be omitted. In rare cases where older pavements have had their entire surfaces scaled and additional scaling or surface cracking has ceased, surface treatments can increase the life span of the pavement and can be effectively applied. In general, parking/operation of the CV-22 or MV-22 on pavements with these types and levels of distresses may increase the rate of deterioration under the nacelles. Applying surface treatments to pavements with low-severity distresses of these types can effectively increase the service life of the pavement.

6.7. It is recommended to seal only those areas most susceptible to POL and direct exhaust, a circular area with a minimum 7-foot (2.1-meter) radius, centered where the engine exhaust is directed at parking, maintenance, and preflight check areas, including parking/maintenance ramps, forward area refueling points (FARP), and hot refuel/re-arm pads. Hold points do not require surface treatments at this time.

6.8. If constructing new or replacing existing pavement to support MV-22 parking, maintenance, FARP, or hot refuel/re-arm operations, a high-temperature aggregate such as an igneous trap rock, expanded shale, or expanded slate may be used as the coarse aggregate in the concrete mix design. Unlike a concrete mix for a vertical landing pad (see UFGS 32 13 13.43), the fine aggregate can be a natural sand. If the cost of the pavement using high-temperature aggregates is more than twice the cost of standard PCC then you should construct/repair the pavement using standard PCC. Sodium silicate should also be applied; however, the sealant must not be applied any earlier than 70 days after placement of the concrete repair material. Where practical, any PCC or PCC with high-temperature aggregates should include multifilament polypropylene fibers at a dosage of 3 pounds per cubic yard of concrete.

7. Methods. This section provides guidance on how to complete surface treatments.

7.1. PCC Sodium Silicate Surface Sealing. Do not apply to asphalt pavement.

7.1.1. The sodium silicate surface sealer is absorbed into the top 0.125 inch (3 millimeters) of the concrete, providing resistance to high exhaust temperatures and preventing POL stains. The sodium silicate will need to be reapplied if surface wear occurs.

7.1.2. The sodium silicate surface sealer should be a colorless, water-based solution containing 9 percent sodium silicate. While many manufacturers provide a product with this concentration, it often comes in 40 percent solutions. Higher-concentration products can be diluted to 9 percent sodium silicate. The 9 percent sodium silicate provides optimum concrete penetration with three applications. In order to dilute a 40 percent solution of sodium silicate to 9 percent, add 3.5 parts of water to 1 part of the 40 percent solution, i.e., for every gallon of 40 percent solution add 3.5 gallons of water. Eucosil (Euclid Chemical Company), Woodeze 5RU-146 (Rutland), or CARS Liquid Glass (Hubbard-Hall) are sodium silicate products that typically come in containers at 40 percent solution. The sodium silicate sealer is applied to PCC subject to the heat and POL from MV-22 and CV-22 engines. Use of higher concentrations can result in an excess buildup that will bubble and discolor under the heat load of the nacelles. If this occurs the excess material can be removed by washing the area with warm water. Use of a scrub brush and//or a high-pressure pump will speed the removal. In extreme cases you may need to use ultra-high-pressure rubber removal equipment. The portion of the sodium silicate that has combined with the concrete surface will remain in place.

7.1.3. Before application, clean the concrete with a rotary power washer/scrubber to remove tire rubber, curing compound, and POL. If heavy POL contamination is present or if the sodium silicate will not penetrate the surface, follow the procedures in paragraph 7.2 before applying the pavement sealant.

7.1.4. The sodium silicate must be applied no earlier than 70 days after the pavement has been placed. Testing has determined that sodium silicate applications prior to 70 days result in surface flaking of the PCC.

7.1.5. The pavement joints must be properly sealed before applying the sodium silicate. If the joint seals are not in good condition then they must be repaired or replaced before applying the sodium silicate.

7.1.6. All paint markings (including shadow markings) must be in place, in good condition, and contain no cracks or chips before applying the sodium silicate. Damaged markings must be repaired or replaced before applying the sodium silicate.

7.1.7. The concrete surface must be dry for 24 hours before applying the sodium silicate and after the pavement markings have been applied. Air temperature must be 40 °F (4.4 °C) or higher and relative humidity must be 80 percent or less, both during application and for 48 hours after application. It is acceptable to apply the sodium silicate over pavement markings and glass beads.

7.1.8. Apply three coats of the sodium silicate solution with low-pressure airless spraying equipment to ensure uniform application or use a roller with a 0.25-inch to 0.5-inch (6-millimeter to 13-millimeter) nap. Start applying the solution at the highest point in the pavement and continue downgrade. Each coat will cover no more than 200 square feet per gallon (4.9 square meters per liter). Avoid excessive application, as it may cause efflorescence and reduce friction. Allow the sodium silicate to penetrate for two hours then wash off any visible excess (ponded) solution. Allow the area to dry for at least 24 hours between each coat.

7.1.9. After allowing the last coat to dry for 24 hours, evaluate the surface for any excess silica or dusting. Wash off any excess silica or dusting as needed. Protect the application from any pedestrian or vehicular traffic until the last coat has dried.

7.2. Cleaning POL Contamination from PCC and PCC Joints.

7.2.1. If POL stains are present, treat the entire stain before sealing the pavement. Several methods to remove POL stains and, in the case of POL stains on joints, improve the bond to the joint surface are described below. Most stains require several applications and may require the use of more than one treatment method. By implementing all of these steps maximum removal will be achieved; however, one or more of the steps can be omitted to achieve acceptable results. Steam may be used; however, steam alone will provide some cleansing of the immediate surface but will not penetrate deep enough to provide a long-term result. Any POL-contaminated water, paste, or solids should be properly collected and disposed of.

7.2.1.1. Dawn (or Simple Green) Dishwashing Detergent and Hot Water. Apply to the stained area and scrub to develop a thick lather. Let set for five minutes then rinse with warm/hot water. Use of steam to pretreat the area and rinse may aid removal.

7.2.1.2. Trisodium Phosphate (TSP). TSP (also called sodium orthophosphate) is available in many hardware stores. **Note: Some states have banned this product because the phosphate can cause problems with nearby waterways. Check with the environmental office before using.** Mix one measure of TSP with six measures of water. Apply over the stain with a paintbrush and allow it to dry completely before scraping off the dried paste. Rinse the concrete surface and scrub with a stiff brush and clean water.

DO NOT MIX TSP WITH ANY ACID! A violent reaction can occur and release noxious gas. You can use both products but they must be used separately, with a thorough rinsing with water between applications.

Alternate application method: Dissolve 1 pound, 6 ounces of TSP in a gallon of water. Add enough finely ground calcium carbonate (also called whiting or agricultural lime) to make a thick paste. (Agricultural lime is available at garden supply stores.) Spread the paste over the stain and allow it to dry for a day, if possible. Brush off the dry paste with a stiff brush and scrub the concrete with water. The paste has a high pH so personal protective equipment (PPE) must be used and the paste should be kept away from aircraft. If it is windy, protect the treated area until the area is cleaned and rinsed to keep the caustic material from blowing around the apron.

7.2.1.3. Sodium Hyroxide. If TSP is not available or not allowed, use sodium hydroxide, such as Morado Super Cleaner (Zep Superior Solutions, http://www.zep.com/ZepSearch/singleproduct.aspx?search=0856&num=1&match=Exact&country=U?iframe=true&width=620&height=400). Make a solution of 5 percent sodium hydroxide (caustic soda: NaOH). Apply it over the stain with a paintbrush and allow it to dry for at least 24 hours. Rinse and scrub with clean water then repeat as required. This has a high pH so PPE must be used and the solution should be kept away from aircraft. If it is windy, protect the treated area until the area is cleaned and rinsed to keep the caustic material from blowing around the apron.

7.2.1.4. Church & Dwight Co., 03020 Arm & Hammer Super Washing Soda (http://www.armandhammer.com/fabric-care/laundry-boosters/Products/arm-and-hammer-super-washing-soda-detergent-booster.aspx), a sodium carbonate (washing soda), can be used as a substitute for TSP or sodium hydroxide; however, it does not work as well and may take more applications to remove the POL. Apply as directed. Rinse well with water. This is an organic salt. If it is windy, protect the treated area until the area is cleaned and rinsed to keep the salt from blowing around the apron.

7.2.1.5. Phosphoric Acid Cleaner. Apply Phosphoric Acid Cleaner (Miracle Sealants Company, http://miraclesealants.com/index.php?option=com_virtuemart&view=productdetails&virtuemart_product_id=133&Itemid=251) as directed. Rinse well with water and sodium carbonate (washing soda or soda ash) to neutralize the pH then rinse with clear water. This product will etch the concrete so do not leave it on too long and ensure the area is rinsed well to ensure no acid is left on the concrete.

7.2.1.6. Eximo or G Force. Eximo (CAF Environmental Solutions, http://mycaf.com/eximo.php) or G Force (Winsol Laboratories, http://www.winsol.com/G-Force.htm) are biological materials (bacteria) that consume POL. No matter what method is used to remove the stains, use of one of these products is recommended as a final treatment because the bacteria stays in the concrete and will eliminate any remaining POL over time. Follow the product directions.

7.2.2. If the contamination is too heavy then removal/repair of the area in accordance with ETL 02-7 may be required.

8. PCC Repair. Repairs to PCC damaged by MV-22 or CV-22 exhaust should be accomplished in accordance with ETL 02-7. In the event that an entire slab must be replaced, a high-temperature aggregate such as an igneous trap rock, expanded shale, or expanded slate should be used as the coarse aggregate in the concrete mix design. Unlike a concrete mix for a vertical landing pad (see UFGS 32 13 13.43), the fine aggregate can be a natural sand. If the cost of the pavement using high-temperature aggregates is more than twice the cost of standard PCC then you should construct/repair the pavement using standard PCC. Sodium silicate should also be applied; however, the sealant must not be applied any earlier than 70 days after placement of the concrete repair material. Where practical, any PCC or PCC with high-temperature aggregates should include multifilament polypropylene fibers at a dosage of 3 pounds per cubic yard of concrete.

9. Point Of Contact. Questions or comments about this ETL are encouraged and should be directed to the Pavements Subject Matter Expert, AFCEC/COSC, DSN 523-6495, commercial (85) 283-6495, afcec.rbc@tyndall.af.mil.

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