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TechData Sheet

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Mitigating Concrete Damage Caused by Engine Exhaust Surface Temperature below 500ºF

Supersedes TDS-2058-SHR

Technology Description

MV-22, AV-8B, and F/A-18 aircraft can damage your concrete pavements! Portland cement concrete pavements at locations where these aircraft are based are either already damaged or can be damaged. The damage occurs in the form of "scaling" of the top 1 to 2 inch of the pavement surface. Pavement fragments from these surface scales have the potential to produce foreign object damage (FOD) to aircraft engines. The elevated temperature exhaust gases from these aircraft coupled with spilled fluids damage ordinary Portland cement concrete airfield pavements. The damage occurs progressively to the pavement surface due to repeated thermal cycling and chemical reaction of the spilled aircraft fluids with the cement paste. Pavement damage from these aircraft has been observed in various locations.

MV-22 Landing

The Office of Naval Research and the Air Force Civil Engineer Support Agency sponsored an experimental investigation by the Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) to develop candidate pavement systems that would be resistant to the thermal/blast effects from the exhaust and the spilled liquids from these aircraft. Simulated high temperature exposure tests were conducted on candidate pavement systems at the NAVFAC EXWC Aircraft Engine Simulation Facility (AESF). This facility, which operates with natural gas, is capable of simulating the heat flux of various jet engine exhausts, from the F/A- 18 APU to the V-22, AV-8B and JSF F-35 aircraft main engines.

Three factors are considered to be the major contributing causes of the pavement failure. These factors are thermal fatigue, vapor pressure, and chemical degradation. Thermal fatigue is evidenced by the fact that failures have occurred without the presence of oils or fuels and that scaling failure planes have been observed to fracture aggregates. Vapor pressure could be detrimental in the case of saturated or partially saturated pores where 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% in some cases, which accelerates the failure. Chemical degradation by itself could result in raveling of the concrete but would not produce scaling. Chemical degradation alone could not reproduce the observed failures. In the experimental investigation, accurate simulation of the thermal fatigue was considered essential for proper reproduction of the failure mechanism. The experimental and numerical analyses were therefore focused on investigating thermal fatigue as a primary cause of failure. Engine oil was applied to the samples to evaluate the resulting strength degradation.

Cyclic exposure tests of the specimens were conducted in the AESF. The simulated jet was calibrated to replicate the heat flux from the MV-22 main engine exhaust on ordinary concrete pavements. That heat flux produces a concrete surface temperature of 450°F - 500ºF after ten minutes of exposure. The thermal gradients present during the pavement heating are enhanced if the initial pavement temperature is lower. To recreate the most conservative scenario, the test slabs were cooled down to just above freezing (38°F) before each exposure cycle.

The results of the experiments showed;


Field damage from an MV-22

1. Sodium silicate application dramatically improves a concrete pavements ability to resist damage from exhaust temperatures below 500ºF. Appling sodium silicate is the most affordable way to mitigate damage as it does not require reconstruction. It only requires the surface to be cleaned and proper sodium silicate application
2. A high temperature aggregate like an igneous traprock, expanded shale, or expanded slate should be used as coarse aggregate in new concrete mix designs. Unlike a concrete mix for a JSF, the fine aggregate can be a natural sand. However, sodium silicate must be applied. This option is intended when new construction is planned.
3. Multifilament polypropylene fibers at a dosage of 3lbs/ cubic yard of concrete add an extra layer of protection against damage when it is financially feasible to do so.

Value to the Warfighter

The value to the warfighter is increased readiness by having a land based platform for the MV-22.

Economics of the Technology: ROI or Payback

The use of sodium silicate, high temperature aggregate, and fibers will add to the initial cost of the concrete pavement. When the potential for FOD is considered these options become more attractive. The ROI will depend on the specific projects. For example, the ROI for a project that only involves cleaning a concrete pavement surface and adding sodium silicate will be much higher than a complete reconstruction project that includes bringing in special aggregate from hundreds of miles away.

Technology Transition Documentation

1. Pavement Materials Subjected to Simulated Aircraft Engine Exhaust - Final Report – (Draft)

Site Implementation and Specific Applications

Thus far MCAS Miramar and MCAS New River have used this guidance to build MV-22 parking aprons. The concrete mixes have performed well under laboratory testing and there have been no reports of damage. Please contact NAVFAC EXWC with any questions, comments, or concerns related to this topic.

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