POLYMER CONCRETE MICRO-OVERLAY FOR FUEL AND ABRASION RESISTANT SURFACING: LABORATORY RESULTS AND FIELD DEMONSTRATIONS

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INTRODUCTION

E-Krete Polymer Concrete Micro-Overlay (PCMO) technology refers to applying thin-layers of polymer concrete for sealing/surfacing paved surfaces. E-Krete PCMO is manufactured by Polycon, LLC of Jackson, MS. PCMOs are polymer-modified concretes containing Portland cement (or other types of hydraulic cements), proprietary additives (pozzolans, plasticizers, air-entraining agents, etc…), and aggregate placed in similar fashion to asphalt and coal tar slurries. E-Krete PCMO can be applied to asphalt, concrete, or coal tar surfaces. Thickness can range from 2-6mm (1/16-1/4 inch) depending on aggregate size and number of applications. E-Krete PCMOs can have different physical and chemical-resistant properties depending on the formulations used. They can be pigmented for pavement markings, to yield an aesthetic surface, for increasing conspicuity for visual reference, or for coating dark asphalt or coal-tar surfaces to reduce the “heat island” effect for expanses of pavement.

The E-Krete PCMOs described in this paper represent two basic products having similar formulations; a fuel resistant sealer/slurry paving product and a pavement marking product which are composed of very similar materials. A surface sealer (either solvent or water-based) may be applied to the E-Krete PCMO to enhance the fuel/oil/chemical resistance in areas where an additional level of protection is warranted. E-Krete PCMO pavement marking is the same basic material as PCMO but is pigmented, contains a finer grade of filler and can have reflective beads imbedded in the surface for retroreflectivity. No laboratory testing was conducted on PCMO pavement marking but it was placed in several field test locations.

The laboratory analysis of E-Krete PCMO consisted of resistance to fuels and abrasion testing conducted in comparison to a standard unmodified coal tar emulsion formulated as a typical fuel resistant sealer (FRS) for an airfield pavement. The unmodified coal tar emulsion was formulated with 2 different amounts of sand.

The field demonstrations were based upon the outcome of the laboratory testing. Given the performance of the E-Krete PCMO in the laboratory, field trials were initiated. The first test section was placed at the US Army Engineer Research and Development Center (ERDC) with subsequent sections placed at 7 more locations around the country. Those locations are: Norfolk Naval Station (Norfolk, VA), MacDill AFB (Tampa, FL), Tyndall AFB (Panama City, FL), Forbes Field (Topeka, KS), McConnell AFB (Wichita, KS), North Island NAS (San Diego, CA), and Edwards AFB (Barstow, CA).

LABORATORY TESTING

Laboratory samples of E-Krete PCMO were prepared by weighing out the proper proportions of dry powder to liquid E-Krete resin, hand mixing for 5 minutes and pouring onto the substrate. A template was used to achieve the desired thickness of application. Typically, thickness for testing was 3.2mm (1/8 inch) placed in a single lift. Double layers were placed in two 1.6mm (1/16 inch) lifts using templates. Samples were allowed to cure 1 week before testing. The 4 configurations of PCMO are: unsealed (EKU), sealed (EKS), sealed with 1 layer of broadcast sand (EKSS), and 2 layers of PCMO with broadcast sand (EKSS2). The results of the testing were compared with 2 configurations of a commercial RT-12 coal tar emulsion (CTE) differing only in the amounts of sand. CTE2 was prepared using 0.24 kg (2 pounds) sand and CTE4, 0.48 kg (4 pounds) sand per gallon, respectively, added to the coal tar emulsion.

For simulated weathering, samples were placed in a carbon-arc type apparatus as detailed in ASTM Practice G23. Samples were prepared on roofing paper for the wet track abrasion test and placed in the weatherometer. The aging regimen was according to Method I in G23. Total time in the weatherometer was 160 hours with each hour consisting of 51 minutes of light exposure without water and 9 minutes with light and water. Temperature in the chamber was 60°C (140°F) and 50 percent humidity.

Fuel Resistance Testing (ASTM D2939) Chemical Resistance Testing (ASTM C-2299) Resistance to Deicing Chemicals (ASTM C-672)

Twelve tiles of Polycon E-Krete PCMO were prepared (3 of each of the 4 types) and 6 tiles of CTE (3 of each of the 2 types). The uncured thickness of each material was 3.2mm (1/8 inch). The CTEs were placed in 2 layers of 1.6mm (1/16 inch) each. A small reservoir was fixed by epoxy or silicone sealant to the surface of each tile and filled with kerosene. The EK sample reservoirs were filled with kerosene that had been discolored by addition of a small amount of asphalt. This was necessary because coal tars typically discolor the kerosene indicating some kerosene soluble components and is necessary to detect whether the kerosene penetrated the fuel resistant layer to the tile substrate. The ASTM procedure requires that the fluid be left in contact with the surface for 24 hours. After 24 hours, the CTE4 sample had allowed the kerosene to penetrate. The CTE2 and EK had not allowed kerosene to breach the surface. However, the CTE samples had noticeable discoloration of the surface and the kerosene pool. The coal tar surface appeared mottled and wrinkled indicating some swelling and penetration of the fuel into the coal tar. The reservoirs were refilled and left for an additional 96 hours. After an additional 96 hours of kerosene in contact with CTE2, the surface was stained and darkened in comparison to areas not in contact with fuel but the fuel had not breached the coating and the PCMO was not effected. No effect of the kerosene on any of the EK samples was noted after 120 total hours of kerosene in contact with the surface. Additional chemical resistance testing to same tiles resulted in no effect to the E-Krete PCMO tile samples. Further Chemical resistance testing to E-Krete PCMO tiles for resistance to deicing chemicals (ASTM C-672) resulted in no effect to the PCMO tiles.

Modified Wet Track Abrasion Testing (Non-standard)

A modified form of the Wet Track Abrasion test described in ASTM D 3910 “Standard Practices for Design, Testing, and Construction of Slurry Seal” was employed. The modification involved replacing the rubber hose with a small wire brush (#1960 from Wright-Bernet, Inc.) to increase the abrasive action. This test is conducted on surface treatment samples placed on a substrate of asphalt roofing paper to simulate adhesion to an asphalt surface. The test is performed on samples submerged in water under a 5-pound mass load using a Hobart C-100 Mixer. The surface of the pavement coating is placed in contact with the abrader for 5 minutes. The abraded surface is then dried and weighed to determine weight loss. The results are reported in Figure 1 and Table I before and after aging in the weatherometer. Only selected samples were chosen for weatherometer aging.

The results of the abrasion testing indicate that the unsealed PCMO material is approximately 8 to 10 times more abrasion resistant than a standard coal tar emulsion. The sealed PCMO is approximately 2 times more abrasion resistant than the CTE. The difference between the sealed and unsealed PCMO indicates that the surface sealer is abraded more rapidly than the PCMO base. Although the abrasion resistance of the CTE’s is higher after aging due to embrittlement, it is well documented that these materials exhibit severe “chicken-wire” or “map” cracking with age and must be resealed every 2-5 years (Shoenberger, 1993 and Saraf et al., 1992). There is no statistical loss in abrasion resistance after aging of the E-Krete PCMO material.

FIELD DEMONSTRATIONS

In the Fall of 2008, demonstrations of E-Krete PCMO and PCMO pavement markings were placed at 8 sites under the guidance of the US Army ERDC. The demonstrations were intended to place the products

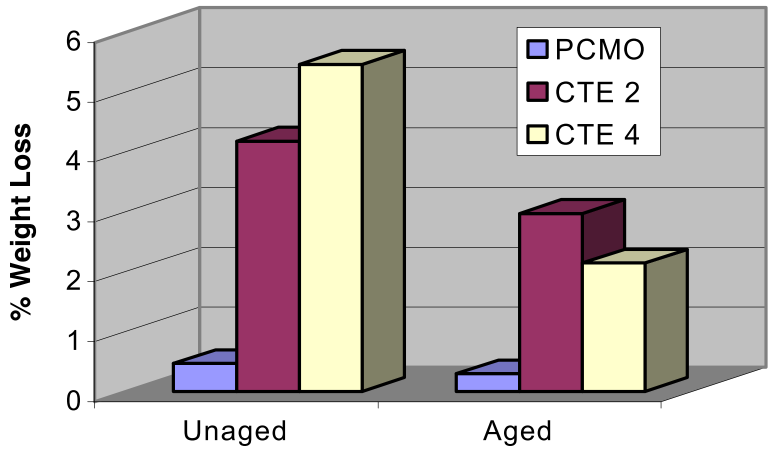

Figure 1. Abrasion resistance of E-Krete PCMO compared to coal tar emulsion using a modified form of the wet track abrasion test.

under a wide range of environmental conditions with aircraft loads (where possible) and fuel/hydraulic fluid spills. The products were often placed on severely cracked and failing surfaces with the intention of yielding some information pertaining to the envelope under which these materials would fail. In the fall of 2012, all 8 sites were visited to conduct condition assessments, and measure adhesion (ASTM D4541 using the Elcometer), and frictional resistance in terms of the British Pendulum Number (BPN) according to ASTM E303 using the British Pendulum Tester (Table 2.)

US Army Engineer Research and Development Center, Vicksburg, MS

The E-Krete PCMO was placed in late morning of August 25, 2008 under clear skies in temperatures ranging from 29-35°C (85-95 ^{o}F) and 50-70 percent relative humidity. Pavement temperatures were above 50°C (122°F) at the start of the demonstration. Pavement preparation consisted of blowing off the loose material on the pavement surface. The materials were mixed on-site in a mortar mixer and placed in approximately 2 hours. The area covered was approximately 140 sq.m. (1500 sq.ft.). The E-Krete PCMO material (pigmented black) reached a non-tacky condition within 25 minutes. No particular problems were encountered during the placement. The test area is in a remote location at ERDC and receives very little traffic.

On Friday, August 28, 2008 an M-60 tank (approximately 106,000 lbs gross weight or 53 tons) was employed as a test vehicle (Figure 2). Tracked vehicles (with rubber pads) cause significant raveling of aggregate particles from the surface of asphalt pavements while conducting “pivot steers”, in which the vehicle spins while remaining in one location.

Ten total pivot steers were conducted on the E-Krete PCMO surfaces with no delamination from the underlying asphalt. The damage to the PCMO surface was some scuffing of the surface in areas with a surface layer of broadcast sand. The sand had sheared loose from the surface and caused scuffing under the tank treads. No delamination of the PCMO was noted. The tank testing ended prematurely with the rupture of a fuel line on the tank spilling 2-3 gallons of diesel onto the PCMO surface. After 2 days, no residue of the fuel or staining of the E-Krete PCMO was apparent.

In addition, a section of latex-modified coal tar emulsion was subjected to similar traffic conditions. After 2 complete pivot steers, the coal tar surface appeared polished and smooth and some aggregate particles from the underlying asphalt were visible in the trafficked area. A strong odor of coal tar was also apparent after the surface was trafficked.

In October 2012, the PCMO section at Vicksburg displayed no cracks reflecting from the underlying asphalt. No cracks were smaller in width than the underlying cracks in the asphalt. Scuff marks from the tank testing were still visible although not distinctive (Figure 3). BPNs were on the order of those from typical asphalt. The adhesion tests showed excellent adhesion to the asphalt. The asphalt pulled apart (cohesive asphalt failure) rather than the PCMO pulling away from the asphalt surface (adhesive failure). This indicates strong adhesion to the asphalt.

MacDill AFB, Tampa, FL

Two E-Krete PCMO sections, each approximately 23m by 23m (75 ft by 75 feet) were placed near Fuel Pit 25. The weather was good with temperatures ranging from 22°C (72°F) in the morning to 33°C (90°F) in the afternoon. Pavement temperatures ranged from 27°C (81°F) to 55°C
(130°F). Humidity was 55-70 percent. Winds were light. E-Krete PCMO was mixed in a mortar mixer and placed by hand using a combination squeegee/broom to coat the pavement surface. The E-Krete PCMO was placed on the surface of 12-year old coal tar that was severely deteriorated and missing in many areas. There were numerous cracks in the coal tar surface that extended down into the underlying asphalt. The E-Krete PCMO reached a non-tacky condition in 30 minutes for the first section (placed about 10:00 am) and 25 minutes for the second section (placed at 2:00 PM). The primary aircraft operating on the PCMO and PCMO pavement marking surfaces is the KC-135 tanker.

A PCMO pavement marking line approximately 30 feet long was placed on Taxiway L. The PCMO pavement marking was placed on top of the existing paint and reached a non-tacky condition within 30 minutes. The PCMO pavement marking was sprayed using a proprietary device designed specifically for application of PCMO pavement marking. A mask was used to prevent overspray. Reflective beads were placed on the surface by hand. The thickness of the PCMO pavement marking line was estimated at approximately (152 microns) 60 mils. In November, 2012 the PCMO and PCMO pavement marking sections were in excellent condition. In the E-Krete PCMO area, reflective cracks had propagated up from a severely map-cracked underlying coal-tar surface (Figures 4 and 5) and a small area (approximately 2 sq.m. or 3 sq.yd.) was stained with some type of aircraft fluid. The fluid had caused no noticeable softening of the E-Krete PCMO and is most likely a synthetic jet turbine lubricant.

that many of the reflective cracks in the coal-tar layer did not propagate up through the PCMO layer. In several locations along the edge of the E-Krete PCMO sections, cracks in the coal-tar were visible running up to the edge but did not proceed into the overlying E-Krete PCMO layer. Adhesion tests pulled up the underlying coal-tar and the frictional resistance was similar to asphalt. The PCMO pavement marking line was in excellent condition when compared to the distressed conventional paint striping (Figure 6).

Tyndall AFB, Panama City, FL

A E-Krete PCMO section was placed at the fuel depot on the west end of the runways at Tyndall AFB in October 2008. Black E-Krete PCMO was placed on the surface of the concrete because the original location suggested by Air Force personnel was asphalt. Placement conditions were mild with temperatures of approximately 28°C (83°F) under cloudy skies and occasional breezes. Humidity at the start of the demonstration was approximately 65 percent. The E-Krete PCMO was placed over concrete in a fuel station servicing light-duty government vehicles, however, heavy trucks carrying aviation fuel must pass over the PCMO section as well. To prevent the PCMO from cracking over the expansion and control joints already present in the concrete, masking tape was used to cover the joints while the coating was applied. After the E-Krete PCMO had reached a non-tacky condition (approximately 45 minutes), the tape was removed, leaving the joint intact.

A PCMO pavement marking stopbar was placed in the entrance to the parking lot of the Air Force Civil Engineering Service Center (AFCESA) and hand-sprinkled with reflective beads. The primary traffic in this area is personal vehicles (cars and trucks). Retroreflectivity measurements were obtained using a Mirolux 12 retroreflectometer. Measurement of the reflectivity immediately after placement yielded readings of 325, 348, 320, 333, 373 at 2 foot intervals along the stopbar for an average of 340 millicandelas/square meter/lux.

The condition of the E-Krete PCMO test site in October, 2012 was excellent with some oil-stains and scuffing from recent construction activity. However, a marking crew placed standard road marking paint over the top of the PCMO pavement marking in September, 2010 so no assessment of that feature is given. Base personnel commented on the ease of cleaning the PCMO surface with simple detergent, water, and a broom. Stains from fuel and oil spills were easily removed in this manner. Testing with the Elcometer demonstrated that adhesion was good, with the PCMO exhibiting a cohesive failure (the PCMO pulled apart rather than losing adhesion and pulling off the concrete surface). Frictional resistance was similar to asphalt as measured by ASTM E303.

Norfolk Naval Station, Norfolk, VA

An E-Krete PCMO area approximately 30m by 30m (100ft by 100ft) with PCMO pavement marking around the aircraft tie-downs was placed in October 2008. The materials were placed under clear skies with temperatures between 25-30°C (77-85°F). Winds were light. Pavement temperatures were approximately 40-49°C (104-120°F) during placement. The demonstration section is located just south of Hangar LP-33 and east of the control tower in the VAW-120 apron on the on the edge of the pavement adjacent to a field. The demonstration section contained a small concrete island in the middle. The asphalt surface of the section exhibited severe joint reflection cracking from old concrete underlying the asphalt. The E-6 aircraft provide most of the traffic to this section.

Table 1. Wet Track Abrasion test results.

Sample	**Percent Weight Loss ± 95 percent Confidence Level**
Before Aging	
EKU	0.49 ± 0.07
EKS	1.16 ± 0.17
EKSS	1.78 ± 0.44
EKSS2	2.26 ± 0.19
CTE2	4.18 ± 1.49
CTE4	5.36 ± 1.62
After Aging	
EKU	0.29 ± 0.26
EKS	1.19 ± 0.20
CTE2	2.97 ± 1.18
CTE4	2.14 ± 0.24

Table 2. Average adhesion values for Elcometer testing and British Pendulum Numbers (BPN) for the field demonstration sites.

Location	Air Temperature, °C (°F)	Average Adhesion[a], kPa, (psi)	Average Adhesion[b], kPa (psi)	Average BPN[c]
ERDC	24 (75)	620 (90)[1]	---	72
MacDill AFB	30 (85)	793 (115)[1]	2344 (340)[2]	70
Tyndall AFB	30 (85)	---	1724 (250)[3]	72
Norfolk Naval Station	16 (60)	862 (125)[1]	---	68
Forbes Field	13 (55)	1379 (200)[1]	1896 (275)[3]	66
McConnell AFB	---	---	---	---
North Island NAS	22 (72)	689 (100)[1] 172 (25)[2]	---	72
Edwards AFB	16 (60)	620 (90)[1]	---	---

[a] ASTM D4541 using 1.5” diameter dolly on asphalt
[b] ASTM D4541 using 1.5” diameter dolly on concrete
[c] ASTM E303, asphalt BPN generally ranges from 60-80
[1] cohesive failure within the asphalt or coal tar substrate, average of 3 readings
[2] adhesive failure (pulled PCMO from the underlying substrate)
[3] cohesive failure within the PCMO

As of October, 2012, the E-Krete PCMO was in excellent condition. Numerous fuel and oil/ hydraulic fluid spills had occurred, however, the overall condition was excellent with considerable staining and some pooling of oil/hydraulic fluid evident. The joint reflection cracks had propagated up through the PCMO surface. The PCMO pavement marking displayed slight delamination in some areas where oil/hydraulic fluid was evident. This was likely due to wicking of pooled hydraulic fluid under the tie-downs. No softening of the PCMO was noted in these areas. Adhesion tests in areas not soaked with fluids pulled up the underlying asphalt. Frictional resistance was similar to asphalt as measured by ASTM E303.

Edwards AFB, Barstow, CA

In November, 2008, an E-Krete PCMO area approximately 6m by 6m (20 ft by 20 ft) was placed in the parking lot of the Civil Engineering office and PCMO pavement marking markings were placed on some roadways. The materials were placed under clear skies with temperatures between 27-30°C (80-85°F). Winds were light. Pavement temperatures were approximately 43-49°C (110-120°F) during placement.

In October, 2012, the condition of the E-Krete PCMO was excellent aside from the reflective cracks from the underlying asphalt. The reflective cracking is not related to the PCMO. Some minor raveling from the crack faces had occurred where there is noticeable unevenness in the substrate and in areas where the underlying asphalt cracks were about ½ inch wide. Some cracks have also reflected through the white arrow. The color of the E-Krete PCMO is darker than the surrounding pavement and is holding the color well. There is a white arrow of PCMO pavement marking in the middle of this section that was placed directly on top of the PCMO. This section receives car and light truck traffic only. Frictional resistance was not measured since traffic was present during the inspection. Adhesion tests conducted on the Krete PCMO section pulled up the underlying asphalt.

A yellow E-Krete PCMO pavement marking centerline was placed on Rosemond Avenue (a 4-lane highway), across from the northern CE exit. It is a double yellow line with one side being their conventional yellow paint. The section is about 200-ft. long and at 2 locations the lines are covered with black paint, where traffic crosses. Both the PCMO pavement marking and the paint appear to be in good condition. The paint is approximately 1 year old. PCMO pavement marking was placed on one side of a pedestrian walkway across Rosemond Ave. at the CE building. The paint is beginning to fade somewhat from wear; it is of course somewhat thinner. Generally, a paint stripe is 19-38 microns (7-15 mils) thick and PCMO pavement marking from 76-152 microns (30-60 mils) in thickness. The PCMO pavement marking is somewhat darker in the wheel paths from dirt or grime from traffic. "Stop" and "Stop Ahead" pavement markings had been placed on Rosemond Ave. approaching N. Muroc Street. They alternated the markings made of Polycon and those painted between each lane; doing 1 of each type at every location. The markings of both types are still in relatively good condition. The only distress noted was in areas where the underlying pavement had cracked, the pavement markings had also cracked. The only cracks observed were reflective.

North Island NAS, San Diego, CA

November, 2008 in an area approximately 15 m by 15 m (50 ft by 50 ft). The materials were placed under clear skies with temperatures between 24-27°C (75-80°F). Winds were light.

Pavement temperatures were approximately 38-43°C (100-110°F). A 203 cm wide (8 inch) PCMO pavement marking white line surrounds the perimeter and a 152 cm (6 inch) yellow PCMO pavement marking line splits the middle of the section. The section was placed on severely aged and cracked asphalt and receives traffic from light-duty aircraft (C-12s) only.

The condition in November, 2012 was excellent except for the reflective cracks from the underlying asphalt. Skid resistance was similar to the surrounding asphalt. Adhesion measurements taken on one side of the section were consistent with measurements taken at other locations (see Table I).

The overall condition of the pad is better than the surrounding pavement. A white discoloration is noticeable on the PCMO, in areas adjacent to hairline cracking.

condition was noted on one of the PCMO sections at Forbes Field. There were only a few areas where raveling had occurred from the crack faces and these were in areas with large underlying cracks. Generally, most of the cracks vary from hairline up to 3mm (1/8 inch). The largest cracks are up to 6mm (¼ inch) wide. These types of cracks, while widespread, did not cover the entire pad. The yellow center strip did not appear to have any cracks in it and is holding color well with little apparent fading. Most of the cracks were reflecting up from the underlying asphalt.

Forbes Field, Topeka, KS

In November 2008, 2 PCMO and 1 PCMO pavement marking areas were placed. The materials were placed in poor conditions under clear skies and temperatures between F 4-10°C (40-50°). Winds were high and gusting. Pavement temperatures ranged from 10-24°C (50-75°F). These conditions were not ideal but could not be avoided due to scheduling. The PCMO pavement marking area was placed on concrete in a "Red Carpet" area for dignitaries as they exit aircraft. The "Red Carpet" area was placed in late morning. Figure 7 shows the area from October, 2012. One PCMO area is approximately 23m by 15m (75 ft by 50 ft) and was placed on severely map-cracked coal tar. Section 1 was placed in the morning when pavement temperatures were well below 16°C (60°F). The second PCMO section was placed on severely delaminating coal tar. This section was placed later in the afternoon when pavement temperatures were above 16°C (60°F). This section is approximately 6m by 6m (20 ft by 20 ft). The condition of all the sections was excellent although reflective cracking had occurred.

Whitening of the PCMO surface adjacent to the cracks has occurred in Section 1. This may be related to "effervescence" in the PCMO. This does not seem to have affected the performance. Many of the cracks from the coal tar substrate have reflected up through the PCMO. However, this only occurred with the larger cracks. The adhesion tests conducted over the concrete failed cohesively with the PCMO pulling apart rather than delaminating from the concrete. Adhesion tests pulled up the underlying coal tar. Frictional resistance was similar to asphalt.

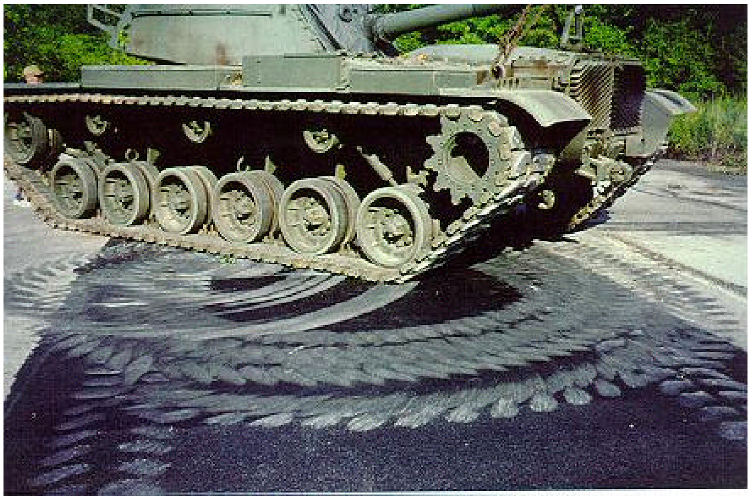

Figure 2. 106,000 lb M-60 tank conducting pivot steers on PCMO surface at US Army ERDC.

Figure 3. PCMO surface in October 2012. Some scuffing of the surface from the tank testing in August 2008 is apparent.

Figure 4. PCMO surface in October 2012 at MacDill AFB. The adjacent pavement is coal tar that is approximately 14 years old and is severely deteriorated.

Figure 5. PCMO section at MacDill AFB showing reflective cracking. Note that the crack has not widened or displayed any raveling from the crack face.

Section 2 was a small area placed over severely delaminating coal tar. The purpose was to determine if the PCMO was able to encapsulate the existing coal tar. It appears to have accomplished this by preventing further adhesion loss of the coal tar from the asphalt (Figure 7).

McConnell AFB, Wichita, KS

In November, 2008, 3 PCMO "pads" approximately 15 ft by 15 ft in diameter were constructed at B-1 aircraft parking areas B10, B11, and B12. The materials were placed in poor conditions under clear skies and temperatures between 7-16°C (45-60°F). Winds were between high and gusting. Pavement temperatures ranged from 10-27°C (50-80°F). B10 was overlaid with 3 coats of PCMO to a total thickness of approximately 3mm-5mm (1/8-3/16 inch). Two layers of PCMO with a fuel-resistant clear topcoat sealer were placed on B11. Two layers of PCMO only were placed on B12. All 3 were placed on relatively new concrete about 2 months old but with substantial hydraulic fluid staining and were pressure washed only before PCMO placement. No detergent or solvents were used to clean the surface. The concrete joints were covered with masking tape during application.

The conditions under which the PCMO must perform in service at McConnell AFB are extreme. The B-1 is a high-performance aircraft that loses considerable amounts of hydraulic and lubricating fluid. The B-1 aircraft has an auxiliary power unit (APU) exhaust port approximately 1m (3-4 feet) above the pavement surface. The exhaust gases impinge upon the pavement at an approximate angle of 45°angle and can heat the surface to near 204°C (400°F). The combination of heat and jet turbine fluid chemistry destroys the cement paste resulting in severe spalling and cracking (Anderson et al. and McVay et al, 1995) after a few years.

Two months after placement of the PCMO it was noted that delamination was occurring in some areas. A visit to the site and inspection of the areas revealed that the delamination was progressing from the concrete joints towards the center of the slabs. After discussions with Polycon representatives and the PCMO placement crew, it was discovered that the masking tape covering the joints was not removed until well after the PCMO had began to harden. During removal of the tape some of the coating stuck to the tape and pulled away from the slab. It was in these areas that delamination was occurring. Additionally, it was also in these areas where the hydraulic fluid had stained the concrete before application of the PCMO. Thus, it was surmised that the hydraulic fluid on the concrete had prevented a proper bond of the PCMO to the concrete substrate. Removal of the masking tape from the joints pulled up some of the coating because it was prevented from bonding to the concrete by the hydraulic fluid.

In November, 2012, a detailed inspection of the B1B pads was conducted. The overall condition of the PCMO was described as good. Approximately 10 percent of the PCMO surface has delaminated, with severe staining from hydraulic fluid. In pads B10 and B12 the PCMO had turned rubbery. This rubbery condition is due to swelling of the polymer within PCMO by synthetic jet turbine fluid. The condition of the PCMO on pad B11 was better than B10 and B12 but some rubbery areas were noted. Despite this condition, the PCMO has prevented the aircraft fluids from causing serious damage to the underlying concrete substrate. Given that concrete replacement under the B1B aircraft generally occurred every 3 years, the demonstration of the PCMO coating was considered successful.

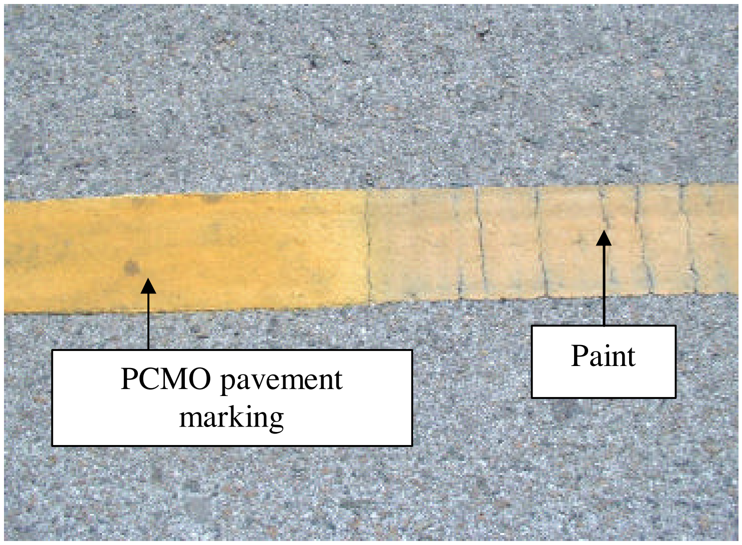

Figure 6. PCMO pavement marking line at MacDill AFB in October 2012 after 4 full years in service. Note the transverse cracking in the conventional airfield pavement marking paint. The marking paint is approximately 3 years old in this picture.

Figure 7. "Delaminated coal tar area before (2008) and after sealing with PCMO (2012) at Forbes Field, Topeka, KS.

Estimated Life of Coal Tar and PCMO

Studies conducted by both the FAA (Saraf et al., 1992) and ERDC (Shoenberger, 1993) have shown that average functional life of a coal tar based fuel resistant sealer (FRS) is 2-5 years. In most cases, the severity of cracking is such that the sealer has lost its fuel resistance in 2-3 years. Thus, the expected functional life of a coal tar based FRS is approximately 3 years. In practice, resealing typically occurs every 5-6 years because the funds are not available to reseal on a 2 or 3-year cycle.

Estimating the service life a new product such as PCMO is not simple. US Army ERDC has nearly 4 years of field experience with this product. Other pavement sections that have been sealed with PCMO for more than 5 years have been found to be in excellent condition. Based on the experiences with coal tar FRS, severe abrasion from aircraft traffic is not a significant form of distress. The majority of the PCMO demonstration sites have not had significant traffic and given that PCMO has been shown to more abrasion resistant than coal tar, high amounts of traffic should not significantly affect performance. Based on the performance of the demonstration sites an estimation of 10 years service life is not unreasonable.

Life Cycle Cost Analysis (LCCA)

A life cycle cost analysis (LCCA) for the PCMO products will be presented here compared to a typical coal tar emulsion. The life cycle cost comparison will be accomplished using net future value which estimates the life cycle cost based on the costs at the time resealing is conducted. The annual inflation rate is assumed to be 3%.

$$\text{Net Future Value} = \sum_{0}^{n} \text{Initial Cost} \times (1 + r)^{n}$$

Assume that a 41,806 sq.m. (50,000 sq.yd.). parking area is sealed with a coal tar emulsion that costs $1.26/sq.m.($1.05/ sq.yd. or $.12/sq.ft.) the resulting total initial project cost is $52,500. An average *functional* life of the coal tar is assumed to be 3 years and is based on field observations (Shoenberger, 1995 and Saraf, 1992). In 6 years, the parking area would need retreating 2 times for a cost based on future value of approximately $172,500 to maintain a viable fuel resistant surface. In 10 years, the costs for resealing would be over $240,500. The same area sealed with PCMO at $4.84/sq.m. ($4.05 sq.yd.) would cost $202,500. Using the estimated life of PCMO PCMO of 10 years, the cost compared to coal tar sealing over the ten-year period is substantially lower and requires less interruption to aircraft traffic.

SUMMARY

The Polycon E-Krete materials are approved for modified applications on Military Airfields Military Bases. Further approvals include US Government installations were necessary applications for the Polycon E-Krete are warranted.

The results indicate that the fuel and abrasion resistance of the PCMO product exceeds that of a typical unmodified coal tar emulsion. PCMO is resistant to hydraulic fluid but has been shown to soften in contact with some synthetic jet turbine fluids. The abrasion resistance is greater for PCMO PCMO compared to an unmodified coal tar emulsion. The laboratory data and field data both suggest that the material is durable and resistant to weathering.

The field demonstrations have been very successful with performance at or above expectations at all sites. However, although the performance has been rated as excellent, this is based on only 3-4 years of experience with these products. Several of the demonstrations were placed on severely cracked asphalt or coal tar and many of those cracks have reflected through the PCMO surface. No significant forms of environmental or load-related distress that are directly related to the PCMO product have been observed to date. Based on the observations at McConnell AFB and MacDill AFB, the PCMO will soften under prolonged exposure to certain types of synthetic jet turbine lubricants.

Overall, the PCMO product appears to be an excellent alternative to conventional coal tar FRS. Based on the performance of demonstration sites and inspection of other sites over 5 years old, it is estimated that the minimum service life of PCMO will be 10 years in areas with light traffic. The PCMO product exhibits a high resistant to weathering and can be expected to be extremely durable.

Although the initial cost is higher than coal tar, the estimated life cycle costs for PCMO are substantially lower assuming an average functional life of coal tar sealer to be 3 years and that of the PCMO to be 10. For a 41,806 sq.m. (50,000 sq.yd.) parking area sealed with PCMO PCMO that costs $4.84/sq.m. ($4.05/sq.yd. or $0.45/sq.ft.) compared to coal tar at $1.26/sq.m. ($1.05/ sq.yd. or $.12/sq.ft.), the cost savings realized over a 10 year period are over $35,000 assuming an inflation rate of 3 percent.

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