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E-Krete™ Polymer Composite Micro-Overlay for Airfields: Laboratory Results and Field Demonstrations

J. Kent Newman and James E. Shoenberger

November 2003

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E-Krete™ Polymer Composite Micro-Overlay for Airfields: Laboratory Results and Field Demonstrations

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Final report

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Prepared for Polycon, Inc.
300 Industrial Drive South
Madison, MS 39211

Under CRDA-9804-E-C242

ABSTRACT: The results indicate that the fuel and abrasion resistance of the E-Krete™ product exceeds that of a typical unmodified coal tar emulsion. E-Krete™ is resistant to hydraulic fluid but has been shown to soften in contact with synthetic jet turbine fluids. Use of an appropriate surface sealer will delay E-Krete™ from softening in areas where jet turbine fluids may be spilled. The abrasion resistance is approximately 8 to 10 times greater for unsealed E-Krete™ and 2 times greater for sealed E-Krete™ compared to a typical unmodified coal tar emulsion sealer. No freeze-thaw damage occurred to E-Krete™ with deicing fluid after seven freeze-thaw cycles. The laboratory data and field data both suggest that the material is durable and resistant to weathering.

The field demonstrations have been successful with performance at or above expectations at all sites. However, although the performance has been rated as excellent, this is based on only 2 to 3 years of experience with these products. Field conditions are reported from observations conducted in November 2000. Several of the demonstrations were placed on severely cracked asphalt and many of those cracks have reflected through the E-Krete™ surface. No significant forms of distress that are directly related to the E-Krete™ product have been observed as of November 2000. Based on the observations at McConnell Air Force Base and MacDill Air Force Base, it appears that the E-Krete™ will soften if exposed to synthetic jet turbine lubricant spills.

Overall, the E-Krete™ product would appear to be an excellent alternative to conventional coal tar fuel resistant sealer (FRS). Based on the performance of demonstration sites and inspection of other sites over 5 years old, it is estimated that the service life of E-Krete™ will be approximately 10 years in areas with light traffic. Life cycle cost analysis indicates that the costs of E-Krete™ based on an estimated 10 year E-Krete™ life and using resealing of a coal-tar surface every 3 years.

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PREFACE

The research reported herein was sponsored by Polycon, Inc., Madison, MS, (601) 898-1024, as part of the Cooperative Research and Development Agreement (CRDA), CRDA-9804-E-C242, and the U.S. Army Engineer Research and Development Center (ERDC), Geotechnical and Structures Laboratory (GSL), Engineering Systems and Materials Division (ESMD), Airfields and Pavements Branch (APB). Mr. John Edwards is POC at Polycon, Inc.

This study was conducted under the direct supervision of Dr. Gary Anderton, Acting Chief, APB, and Mr. Don Alexander, P.E., Chief, APB, while under the general supervision of Dr. Albert Bush, Chief, ESMD, and Dr. David W. Pittman, Acting Director, GSL. Project principal investigator (PI) was Dr. J. Kent Newman, APB. The authors of this report were Dr. Newman and Dr. James E. Shoenberger.

Commander and Executive Director of ERDC was COL James R. Rowan, EN. Dr. James R. Houston was Director.

EXECUTIVE SUMMARY

This report details the results of an evaluation of a water-based polymer composite overlay produced by Polycon, Inc. Testing and demonstrations in this report most closely correspond to the BD-2000, TOL 3000, TOL 3002, and ROL 4000 in the E-Krete™ family of products manufactured by Polycon Systems, Inc. These data described were collected and the field evaluations conducted were accomplished between June 1998 and November 2000.

The laboratory results indicate that the fuel and abrasion resistance of the E-Krete™ product exceeds that of a typical coal tar emulsion. E-Krete™ can be expected to be resistant to hydraulic fluid, gasoline, kerosene, and aviation fuels such as JP-8, however, some synthetic jet turbine fluids may cause softening of E-Krete™. The laboratory data and field data both suggest that E-Krete™ is durable and extremely resistant to weathering.

The field demonstrations have been successful with performance at or above expectations at all sites. However, although the performance has been rated as excellent, this is based on only 2 to 3 years of experience with these products based on observations of field performance as of November 2000. No significant forms of distress that are directly related to the E-Krete™ product have been observed as of November 2000.

Overall, the E-Krete™ product would appear to be an excellent alternative to conventional coal tar fuel-resistant sealer (FRS). Based on the performance of demonstration sites and inspection of other sites over 5 years old, it is estimated that the service life of E-Krete™ will be approximately 10 years in areas with light traffic. The E-Krete™ product exhibits good weathering resistance and can be expected to be extremely durable. In areas with high traffic where abrasion occurs, it may be necessary to occasionally reapply in the trafficked areas when significant wear has occurred.

Although the initial cost is higher than coal tar, the estimated life cycle costs are lower assuming an average functional life of coal tar sealer to be 3 years, that resealing with coal tar occurs every 3 years, and that the functional life of E-Krete™ is 10 years. Compared to conventional unmodified coal tar emulsion slurry, the cost savings over a 10-year period are estimated to be 14 percent using an inflation rate of 3 percent. This life cycle cost analysis was conducted using actual costs for application of a coal tar sealer containing polymer additive at MacDill Air Force Base, Tampa, FL, used in 1999.

INTRODUCTION

In February 1998, Mr. Jack Wilson from Polycon, Inc. (Madison, MS), visited the U.S. Army Engineer Research and Development Center (ERDC) (formerly the Waterways Experiment Station) to introduce his products to the Airfields and Pavements Division within the Geotechnical Laboratory. Polycon, Inc. manufactures nonpetroleum and noncoal tar containing water-based polymer latex pavement coatings. Mr. Wilson was interested in having the U.S. Army Corps of Engineers (USACE) test his products for application to aviation facilities. At the close of the meeting it was agreed to form a Cooperative Research and Development Agreement (CRDA) with Polycon, Inc. The goal of the CRDA was to test Polycon's products in the laboratory to determine some select properties as compared to coal tar-based fuel-resistant sealer (FRS). In May of 1998, the CRDA was finalized and testing of the products began.

Polycon manufactures two basic products having similar formulations, E-Krete™ and PermaStripe™, which are composed of very similar materials. The E-Krete™ is a water-based polymer latex composite coating containing aggregate. The E-Krete™ products are designed to provide a wearing surface that is durable, abrasion, and fuel resistant for sealing pavement surfaces. E-Krete™ is applied using a flooding/squeegee/brush application which can be followed by an aggregate chip layer (if desired). A surface sealer (either solvent or water-based) may be applied to the E-Krete™ to enhance the fuel/oil/chemical resistance in areas where an additional level of protection is warranted (such as aircraft parking areas or parking garages). PermaStripe™ is the same basic material as E-Krete™ but is pigmented for pavement marking, contains a finer grade of filler, and can have reflective beads imbedded in the surface for retroreflectivity. No laboratory testing was conducted on PermaStripe™, but it was placed in several field test locations. The laboratory testing performed in this report should apply to the PermaStripe™ as it is similar in formulation to the E-Krete™.

The laboratory analysis of E-Krete™ consisted of resistance to fuels, deicing chemicals, freeze-thaw, and abrasion testing, some of which was conducted in comparison to a standard unmodified coal tar emulsion. The unmodified coal tar emulsion was formulated with two different loading of sand. The laboratory tests proved the E-Krete™ material to be superior to coal tar in fuel and abrasion resistance.

The field demonstrations were based upon the outcome of the laboratory testing and, given the excellent performance of the E-Krete™ in the laboratory, field trials were initiated. The first test section was placed at ERDC in August 1998 with subsequent sections placed at seven 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).

EXPERIMENTAL

The E-Krete™ and PermaStripe™ products are 2-component as received: a dry mix containing cement, sand, and other fillers and a liquid containing a proprietary blend of emulsified polymer resin. The two are mixed in the correct proportions for the particular application and applied by a squeegee and brush system. The squeegee and brush system are also proprietary, having been designed and optimized specifically to result in a thin applications of between 3 and 8 mm (1/8 to 1/4 in.) in thickness.

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

Samples were aged in a carbon-arc type apparatus as detailed in the American Society for Testing and Materials (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 hr with each hour consisting of 51 min of light exposure without water and 9 min with light and water. Temperature in the chamber was 60 °C (140 °F) and 50-percent humidity.

Fuel Resistance Testing (ASTM D2939)

Twelve tiles of E-Krete™ were prepared (three of each of the four types) and six tiles of CTE (three of each of the two types). The uncured thickness of each material was 1/8 in. The CTE's were placed in two layers of 1/16 in. each. A small reservoir was fixed by epoxy to the surface of each tile and filled with kerosene. The E-Krete™ (EK) sample reservoir was 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 hr. After 24 hr, none of the samples (either EK or CTE) exhibited complete penetration of fluid to the tile substrate. 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 hr. After the additional 96 hr of kerosene in contact with CTE2, the surface was notably softened and darkened in comparison to areas not in contact with fuel. For CTE4, the kerosene had penetrated the surface to the tile underneath. No effect of the kerosene on any of the EK samples was noted after 120 total hours of kerosene in contact with the surface. In all of

the CTE samples, there was noticeable discoloration of the kerosene in contact with the surface of the coal tar, indicating that the fuel indeed dissolves a portion of the coal tar. The dissolution of components of the coal tar is likely to have an effect on the physical properties of the coal tar sealant, especially upon repeated exposure to fuels. No such effect should be present with E-Krete™.

Resistance to Deicing Chemicals (ASTM C 672)

A modified version of ASTM C 672 was employed to assess the resistance of EK surfaces to deicing chemicals. The test is designed for Portland cement concrete (PCC) materials and EK contains a significant portion of Portland cement. Block samples of asphalt concrete were employed as the testing substrate. EK is normally applied to asphalt concrete (AC), although PCC can also be resurfaced by EK. Each AC block was cleaned and EK applied in a minimum uncured thickness of 3 mm (1/8 in.). A small reservoir was constructed of silicone sealant about the perimeter of the EK. A solution of 4 percent calcium chloride deicing fluid was poured into the reservoir to a depth of approximately 6 mm (1/4 in.). The AC block was then placed in a freezer between -18 and -15 °C (0 and 5 °F) for 16 to 18 hr. This process was repeated for seven cycles. Overall, none of the samples tested demonstrated any observable adverse effects as a result of the deicing fluid.

Modified Wet Track Abrasion Testing (Nonstandard)

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 lb mass load using a Hobart C-100 Mixer. The surface of the pavement coating is placed in contact with the abrader for 5 min. The abraded surface is then dried and weighed to determine weight loss. The results are reported in Figure 1 and Table 1 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 E-Krete™ material is approximately 8 to 10 times more abrasion resistant than a standard coal tar emulsion. The sealed E-Krete™ is approximately two times more abrasion resistant than the CTE. The difference between the sealed and unsealed E-Krete™ indicates that the surface sealer is abraded more rapidly than the E-Krete™ base. Although the abrasion resistance of the CTE's is higher after aging because of the embrittlement, it is well documented that these materials exhibit severe "chicken-wire" or "map" cracking with age and must be resealed every 3 to 6 years (Shoenberger 1993 and Saraf, Majidzadeh, and Kumar 1992). There is no statistical loss in abrasion resistance after aging of the E-Krete™ material. The reduced variation in the test results for E-Krete™ indicates the consistency of the product.

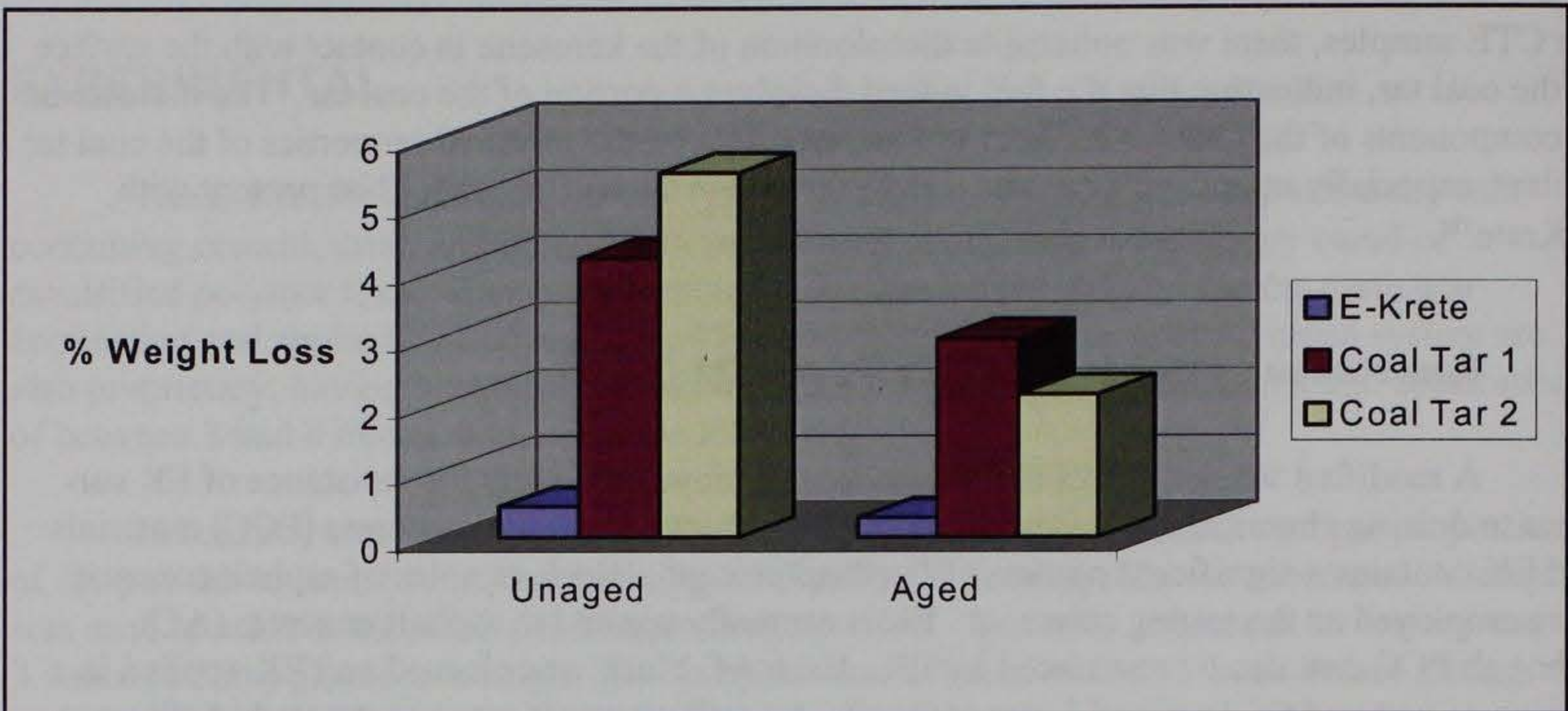


Figure 1. Abrasion resistance of E-Krete™ compared to coal tar emulsion using a modified form of the wet track abrasion test

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

Miscellaneous Testing

The E-Krete™ was placed on unglazed ceramic tiles as used in ASTM 2939 and placed in a forced air oven for 200 °C (392 °F). A second set of tiles was also placed in the oven and soaked with hydraulic fluid (MIL-H-5606F AM1 from Huls America) on business days. After 2 weeks it was noted that the hydraulic fluid was volatilizing rapidly and not remaining on the surface. The temperature of the oven was lowered to 150 °C (302 °F) and left for 45 days. At the end of 45 days (60 total) the E-Krete™ tiles were visually inspected and had no visual signs of distress from either the heat or the hydraulic fluid.

FIELD DEMONSTRATIONS

In 1998, demonstrations of Polycon, Inc., products were placed at eight sites under the guidance of the USACE. The demonstrations were intended to place the Polycon products under a wide range of environmental conditions with heavy 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 2000, all eight demonstration sites were visited to conduct condition surveys, 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.)

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 ¹ kPa, (psi)	Average Adhesion ² kPa (psi)	Average BPN ³
ERDC	24 (75)	620 (90) ⁴	---	72
MacDill AFB	30 (85)	793 (115) ⁴	2344 (340) ⁵	70
Tyndall AFB	30 (85)	---	1724 (250) ⁶	72
Norfolk Naval Station	16 (60)	862 (125) ⁴	---	68
Forbes Field	13 (55)	1379 (200) ⁴	1896 (275) ⁶	66
McConnell AFB	---	---	---	---
North Island NAS	22 (72)	689 (100) ⁴ 172 (25) ⁵	---	72
Edwards AFB	16 (60)	620 (90) ⁴	---	

¹ ASTM D4541 using 1.5-in. diam dolly on asphalt.

² ASTM D4541 using 1.5-in. diam dolly on concrete.

³ ASTM E303, asphalt BPN generally ranges from 60 to 80.

⁴ Cohesive failure within the asphalt or coal tar substrate, average of 3 readings.

⁵ Adhesive failure (pulled E-Krete™ from the underlying substrate).

⁶ Cohesive failure within the E-Krete™.

U.S. Army Engineer Research and Development Center, Vicksburg, MS

The E-Krete™ was placed in the morning of August 25, 1998, under clear skies in temperatures ranging from 27 to 35 °C (80-95 °F) and 50 to 60 percent relative humidity. Pavement temperatures were above 50 °C (122 °F) at the start of the demonstration. The materials were mixed on-site in a mortar mixer and placed in approximately 2 hr. The area covered was approximately 140 sq m (1,500 sq ft). The E-Krete™ material (pigmented black) reached a non-tacky condition within 15 to 25 min. No particular problems were encountered during the placement (Figure 2). The test area is in a remote location at ERDC and receives very little traffic.



Figure 2. Application of E-Krete at ERDC, August 1998

On Friday, August 28, 1998, an M-60 tank (approximately 106,000 lb gross weight or approximately 53 tons) was employed as a test vehicle (Figure 3). This vehicle was chosen for several reasons. It was readily available and tracked vehicles (with rubber pads) have a history of causing significant raveling of aggregate particles from the surface of asphalt pavements. In particular, conducting “pivot steers” in which the vehicle spins while remaining in one location, placing substantial shear forces on the pavement surface. This would certainly be a “worst case scenario” for virtually any type of normal road or airfield traffic.

Approximately 10 total pivot steers were conducted on the E-Krete™ surfaces with no delamination from the underlying asphalt. The damage to the E-Krete™ surface was some slight 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. The areas that had no surface



Figure 3. 106,000-lb M-60 tank conducting pivot steers on E-Krete surface at ERDC

sand did not display any scuffing. In an effort to cause delamination or peeling from the asphalt, the tank was moved to an area outside of the E-Krete™ sections and allowed to swing into the sections over the edge of E-Krete™. However, no delamination could be detected in these areas either, although some scuffing was apparent. The tank testing ended prematurely with the rupture of a fuel line on the tank spilling 2 to 3 gal of diesel onto the E-Krete™ surface. After 2 days, no residue of the fuel or staining of the E-Krete™ was apparent.

In addition, a section of latex-modified coal tar emulsion was subjected to similar traffic conditions. After two complete pivot steers, the coal tar surface appeared polished and smooth in trafficked areas that may have been a result of the frictional heat generated under the tank treads. Some aggregate particles from the underlying asphalt were visible in the trafficked area. These observations indicated that the coal tar surface was severely abraded. The edges of the coal tar emulsion sections were also abraded when the tank track was allowed to swing onto the coal tar sections. A strong odor of coal tar was also apparent after the surface was trafficked.

In October 2000, the E-Krete™ section at Vicksburg displayed two cracks, both reflecting from cracks in the underlying asphalt. Both of the 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 4). Some staining was apparent from water pooling in one area. 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 E-Krete™ pulling away from the asphalt surface (adhesive failure). This indicates strong adhesion to the asphalt.



Figure 4. E-Krete surface in October 2000. Some scuffing of the surface from the tank testing in August 1998 is apparent

MacDill AFB, Tampa, FL

Two E-Krete™ sections, each approximately 23 by 23 m (75 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 in the 55 to 70 percent range. Winds were light. E-Krete™ was mixed in a mortar mixer and placed by hand using a combination squeegee/broom to coat the pavement surface. The E-Krete™ 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™ reached a non-tacky condition in 30 min for the first section (placed about 10:00 am) and 25 min for the second section (placed at 2:00 pm). The primary aircraft operating on the E-Krete™ and PermaStripe™ surfaces is the KC-135 tanker.

A PermaStripe™ line, approximately 30 ft long, was placed on Taxiway L. The PermaStripe™ was placed on top of the existing paint and reached a nontacky condition within 30 min. The PermaStripe™ was sprayed using a proprietary device designed specifically for application of PermaStripe™. A mask was used to prevent overspray. Reflective beads were placed on the surface by hand.



Figure 5. E-Krete surface in October 2000 at MacDill AFB. The adjacent pavement is coal tar that is approximately 14 years old and is severely deteriorated



Figure 6. E-Krete section at MacDill AFB showing reflective cracking. Note that the crack has not widened or displayed any raveling from the crack face

In October 2000, the E-Krete™ and PermaStripe™ sections were in excellent condition. In the E-Krete™ area, reflective cracks had propagated up from a severely map-cracked underlying coal tar surface (Figures 5 and 6) and a small area (approximately 2 sq m or 3 sq yd) was stained with some type of aircraft fluid (Figure 7). The fluid had caused a noticeable softening of the E-Krete™ and is most likely a synthetic jet turbine lubricant. Recent laboratory studies have noted that certain types of synthetic jet turbine fluids may cause softening of the E-Krete™. This softening could be prevented by a topcoat sealer in areas where aircraft park. It was noted that many of the reflective cracks in the coal tar layer did not propagate up through the E-Krete™ layer. In several locations along the edge of the E-Krete™ sections, cracks in the coal tar were visible running up to the edge but did not proceed into the overlying E-Krete™ layer. Adhesion tests pulled up the underlying coal-tar and the frictional resistance was similar to asphalt. The PermaStripe™ line was in excellent condition when compared to the distressed conventional paint striping (Figure 8).



Figure 7. E-Krete section at MacDill AFB exhibiting staining from synthetic jet turbine lubricant

Tyndall AFB, Panama City, FL

An E-Krete™ section was placed at the fuel depot on the west end of the runways at Tyndall AFB in October 1998. Black E-Krete™ 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™ was placed over concrete in a fuel station servicing light-duty government vehicles, however, heavy trucks carrying aviation fuel must pass over the E-Krete™ section as

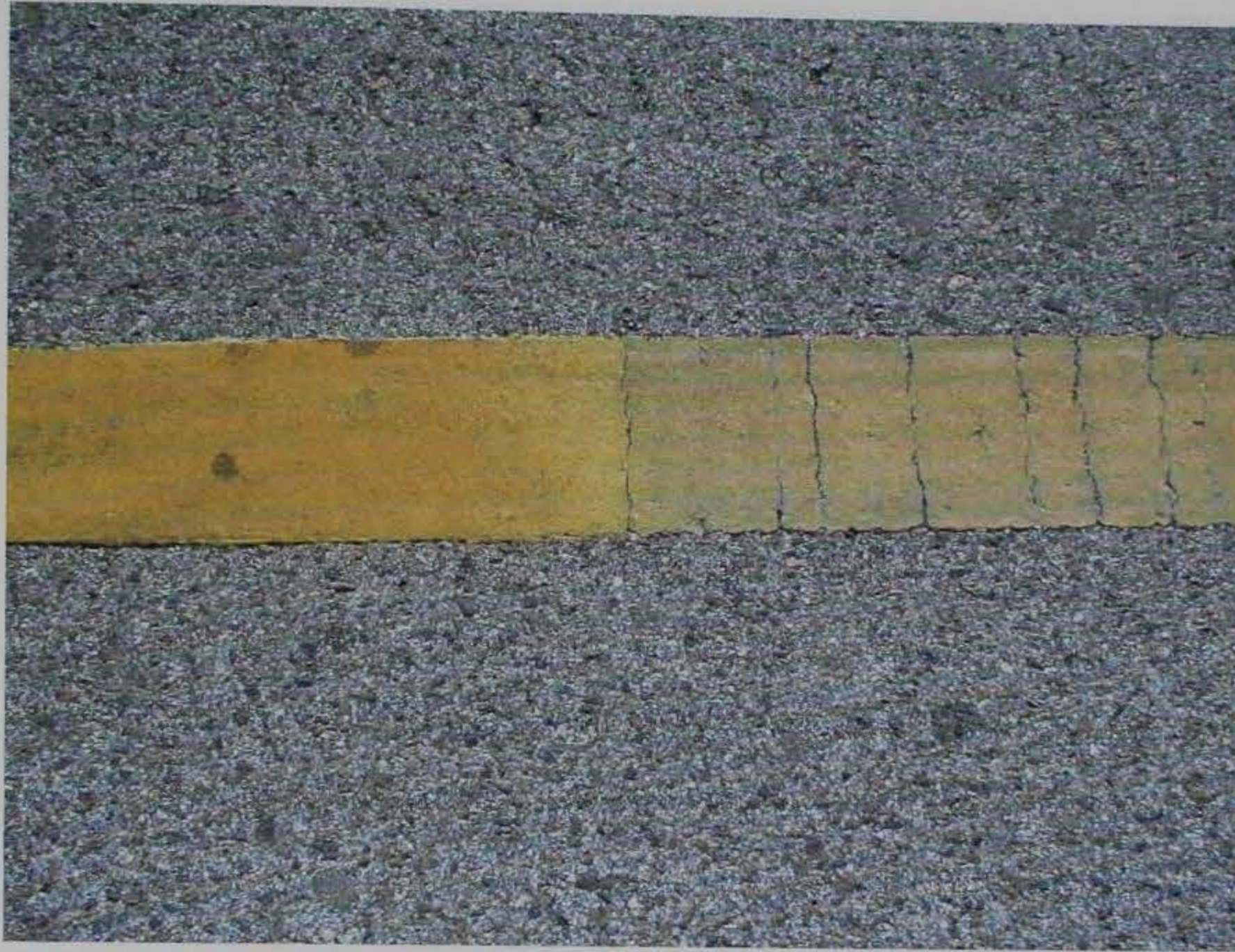


Figure 8. PermaStripe line at MacDill AFB in October 2000 after a full 2 years in service. Note the transverse cracking in the conventional airfield pavement marking paint. The marking paint is approximately 3 years old in this picture

well. To prevent the E-Krete™ 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™ had reached a nontacky condition (approximately 45 min), the tape was removed, leaving the joint intact.

A PermaStripe™ stopbar was placed in the entrance to the parking lot of the Air Force Civil Engineering Service Center (AFCEA) 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-ft intervals along the stopbar for an average of 340 millicandelas/sq m/lux.

The condition of the E-Krete™ test site in October 2000 was excellent (Figures 9 through 11) with some oil-stains and scuffing from recent construction activity. However, a marking crew placed standard road marking paint over the top of the PermaStripe™ in September 2000 so no assessment of that feature is given. Base personnel commented on the ease of cleaning the E-Krete™ 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 E-Krete™ exhibiting a cohesive failure (the E-Krete™ pulled apart rather than losing adhesion and pulling off the concrete surface). Frictional resistance was similar to asphalt.



Figure 9. E-Krete section in fuel depot at Tyndall AFB, October 2000



Figure 10. Oil staining of the E-Krete section at Tyndall AFB, October 2000



Figure 11. Scuff marks from backhoe stabilizers on the E-Krete section at Tyndall AFB, October 2000. The marks do not penetrate to the underlying cement

Norfolk Naval Station, Norfolk, VA

An E-Krete™ area approximately 30 by 30 m (100 by 100 ft) with PermaStripe™ around the aircraft tie-downs was placed in October 1998. The materials were placed under clear skies with temperatures between 25 and 30 °C (77 and 85 °F). Winds were light. Pavement temperatures were approximately 40 to 49 °C (104 to 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 edge of the pavement adjacent to a field. The demonstration section contained a small concrete island in the middle (Figure 12). The asphalt surface of the section exhibited severe joint reflection cracking from old concrete underlying the asphalt. The E-6 aircraft provided most of the traffic to this section. 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 PermaStripe™ displayed slight delamination in some areas where oil/hydraulic fluid was evident. This was likely because of the wicking of pooled hydraulic fluid under the tie-downs (Figure 13). No softening of the E-Krete™ was noted in these areas. Adhesion tests in areas not soaked with fluids pulled up the underlying asphalt. Frictional resistance was similar to asphalt.



Figure 12. E-Krete and PermaStripe at Norfolk Naval Station. Note the severe hydraulic fluid staining around the concrete island. This area has been used repeatedly for servicing aircraft



Figure 13. Closeup view of the E-Krete and PermaStripe at Norfolk Naval Station. The hydraulic fluid is literally pooled around the PermaStripe tie-down. Some delamination of the PermaStripe has occurred because of the ingress of hydraulic fluid under the surface of the PermaStripe where the asphalt and concrete meet

Edwards AFB, Barstow, CA

In November 1998, an E-Krete™ area approximately 6 by 6 m (20 by 20 ft, Figure 14) was placed in the parking lot of the Civil Engineering (CE) office and PermaStripe™ markings were placed on some roadways. The materials were placed under clear skies with temperatures between 27 and 30 °C (80 and 85 °F). Winds were light. Pavement temperatures were approximately 43 to 49 °C (110 to 120 °F) during placement.



Figure 14. E-Krete and PermaStripe at Edwards AFB. Note the severely cracked asphalt surface upon which the E-Krete was placed. Although many of the cracks have reflected back up through the E-Krete, it is in much better condition than the asphalt with virtually no raveling, unlike the surrounding pavement

The condition of the E-Krete™ was excellent aside from the reflective cracks from the underlying asphalt. The reflective cracking is excessive but no distresses related to the E-Krete™ were noted. 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 in. wide. Some cracks have also reflected through the white arrow. The color of the E-Krete™ is darker than the surrounding pavement and is holding the color well. There is a white arrow of PermaStripe™ in the middle of this section that was placed directly on top of the E-Krete™. 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 E-Krete™ section pulled up the underlying asphalt.

A yellow center-line PermaStripe™ stripe was placed on Rosemond Avenue (a four-lane highway), across from the northern CE exit. It is a double yellow line with one side being their conventional yellow paint (Figure 15). The section is about 200 ft long and at two locations the lines are covered with black paint, where traffic crosses. Both the PermaStripe™ and the paint appear to be in good condition. The paint is approximately 1 year old. PermaStripe™ 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; and of course it is thinner. Generally, a paint stripe is 38 to 76 microns (15 to 30 mils) thick and PermaStripe™ is from 76 to 152 microns (30 to 60 mils) in thickness. The PermaStripe™ 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 one 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.



Figure 15. PermaStripe (on the left) roadway lines at Edwards AFB. The PermaStripe has not faded but is close to the original color as placed

North Island NAS, San Diego, CA

E-Krete™ and PermaStripe™ were placed in November 1998 in an area approximately 15 by 15 m (50 by 50 ft). The materials were placed under clear skies with temperatures between 24 and 27 °C (75 and 80 °F). Winds were light. Pavement temperatures were approximately 38 to 43 °C (100 to 110 °F). A photograph of the section from November 2000 is shown in

Figure 16. A 203-cm-wide (8-in.) PermaStripe™ white line surrounds the perimeter and a 152-cm (6-in.) yellow PermaStripe™ line splits the middle of the section (Figure 17). The section was placed on severely aged and cracked asphalt and receives traffic from light-duty aircraft (C-12s) only. The condition in November 2000 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 (Table 1). However, measurements made at the opposite side of the section demonstrated low adhesion to the underlying asphalt. This is the only location tested where the E-Krete™ placed on the asphalt failed because of adhesion loss. The reason is not known, however, it is possible that the pavement in that area was dirty or perhaps oily (from a spill) and prevented the E-Krete™ from bonding well.

The overall condition of the pad is better than the surrounding pavement. A white discoloration is noticeable on the E-Krete™, in areas adjacent to hairline cracking. A similar condition was noted on one of the E-Krete™ 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 3 mm (1/8 in.). The largest cracks are up to 6 mm (1/4 in.) wide. These types of cracks, while widespread, did not cover the entire pad. The yellow center strip did not appear to have cracks and is holding color well with little apparent fading. All of the cracks were reflecting up from the underlying asphalt.



Figure 16. E-Krete and PermaStripe at North Island NAS. Note the severely cracked asphalt surface upon which the E-Krete was placed. Although many of the cracks have reflected back up through the E-Krete, it is in much better condition than the asphalt with virtually no raveling, unlike the surrounding pavement



Figure 17. E-Krete and PermaStripe at North Island NAS. The PermaStripe has not faded and is holding its color well

Forbes Field, Topeka, KS

In November 1998, two E-Krete™ and one PermaStripe™ areas were placed. The materials were placed in poor conditions under clear skies and temperatures between 4 and 10 °C (40 to 50 °). Winds were high and gusting. Pavement temperatures ranged from 10 to 24 °C (50 to 75 °F). These conditions were not ideal, but this was unavoidable because of scheduling. The PermaStripe™ area was placed on concrete in a “Red Carpet” area for dignitaries as they exit aircraft. In Figure 18, the section is shown immediately after construction. The “Red Carpet” area was placed in late morning. Figure 19 shows the area from November 2000. One E-Krete™ area (Section 1, Figure 20) is approximately 23 by 15 m (75 by 50 ft) and was placed on severely cracked but not delaminated coal tar. Section 1 was placed in the morning when pavement temperatures were well below 16 °C (60 °F). The second E-Krete™ section was placed on severely delaminating coal tar (Figure 21). This section was placed later in the afternoon when pavement temperatures were above 16 °C (60 °F) (Figure 22). This section is approximately 6 by 6 m (20 by 20 ft). The condition of all the sections was excellent, although reflective cracking had occurred.

Whitening of the E-Krete™ surface adjacent to the cracks has occurred in Section 1 (Figure 20). This may be related to unreacted Portland cement in the E-Krete™ that slowly leached out over time as water seeped from the cracks after precipitation. This does not seem to have affected the performance. Many of the cracks from the coal tar substrate have reflected up



Figure 18. "Red Carpet" area at Forbes Field in November 1998. This E-Krete section was placed to provide a walkway for dignitaries exiting aircraft



Figure 19. "Red Carpet" area in November 2000. Some fading of the red has occurred and reflective cracks are present, but overall, this section is in excellent condition



Figure 20. Large E-Krete section at Forbes Field. This section was placed on severely cracked coal tar and a portion of a small concrete island. The white staining about the reflective cracks is most likely effervescence from the cement powder within the E-Krete resulting from poor application conditions (see text for more detail).



Figure 21. Severe delamination of existing coal tar surface (prior to E-Krete application)

through the E-Krete™. However, this only occurred with the larger cracks. The adhesion tests conducted over the concrete failed cohesively with the E-Krete™ pulling apart rather than delaminating from the concrete. Adhesion tests pulled up the underlying coal tar. Frictional resistance was similar to asphalt.

Section 2 was a small area placed over severely delaminating coal tar (Figure 21). The purpose was to determine if the E-Krete™ 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 22).

McConnell AFB, Wichita, KS

In November 1998, three E-Krete™ “pads” approximately 15 by 15 ft in diameter were constructed at parking areas B10, B11, and B12. The materials were placed in poor conditions under clear skies and temperatures between 7 and 16 °C (45 and 60 °F). Winds were between high and gusting. Pavement temperatures ranged from 10 to 27 °C (50 to 80 °F). B10 was overlaid with three coats of E-Krete™ to a total thickness of approximately 3 to 5 mm (1/8 to 3/16 in.). Two layers of E-Krete™ with a fuel-resistant clear topcoat sealer were placed on B11. Two layers of E-Krete™ only were placed on B12. All three layers were placed on relatively new concrete about 2 months old but with substantial hydraulic fluid staining and were pressure washed only before E-Krete™ placement. No detergent or solvents were used to clean the surface. The concrete joints were covered with masking tape during application.



Figure 22. Area from Figure 20, about 2 years after E-Krete application. The large areas of missing coal tar have been completely encapsulated with no further delamination

The conditions under which the E-Krete™ must perform in service at McConnell AFB are extreme. The B-1B is a high-performance aircraft that loses considerable amounts of hydraulic and lubricating fluid. The B-1B aircraft has an auxiliary power unit (APU) exhaust port approximately 1m (3 to 4 ft) 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 177 °C (350 °F). The combination of heat and fluid chemistry destroys the cement paste resulting in severe spalling and cracking (McVay et al. 1995). Eventually this requires reconstruction of the concrete pads, generally every 2 to 3 years. Several approaches have been attempted to solve the problem and have mainly focused on an improved concrete mixture design that would be resistant to the thermochemical pavement degradation (Anderson et al. 2000). Replacement of the concrete with specialized concrete mixtures is costly and time-consuming to repair. A more economical approach is to prevent the ingress of fluids into the porous concrete surface using surface coating that are resistant to heat and hydraulic fluids. The testing regimen conducted on the E-Krete™ product revealed that the material could withstand temperatures up to at least 200 °C (392 °F) for 2 weeks, followed by 150 °C (302 °F) for an additional 45 days without serious damage.

Approximately 2 months after placement of the E-Krete™, 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 E-Krete™ placement crew, it was discovered that the masking tape covering the joints was not removed until well after the E-Krete™ had begun 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 E-Krete™. Thus, it was surmised that the hydraulic fluid on the concrete had prevented a proper bond of the E-Krete™ 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 2000, a detailed inspection of the B-1B pads was conducted. The overall condition of the E-Krete™ was described as good. Approximately 10 percent of the E-Krete™ surface has delaminated, with severe staining from hydraulic fluid. In pads B10 and B12 the E-Krete™ had turned rubbery. This rubbery condition is resulting from swelling of the polymer within E-Krete™ by synthetic jet turbine fluid. The condition of the E-Krete™ on pad B11 (Figure 23) was better than B10 (Figure 24) and B12, but some rubbery areas were noted. Despite this condition, the E-Krete™ 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 2 years, the performance of the E-Krete™ coating was considered highly successful. Delamination of the E-Krete™ occurred from poor adhesion resulting from existing aircraft fluids already present on the concrete and proceeded from the joints towards the center of the concrete slab (Figure 25). It is apparent that using E-Krete™ with a fuel-resistant top coating to prevent aircraft fluid ingress into the concrete is a viable and economical solution to prevent concrete damage under B-1B aircraft. Further use of the E-Krete™ product is planned at McConnell AFB in the fall of 2001.



Figure 23. Overall view of B1B aircraft pad B11 in November 2000. The E-Krete is completely soaked with hydraulic and turbine fluid and is in good condition



Figure 24. Overall view of B1B aircraft pad B10 in November 2000. As with B11, the E-Krete is completely soaked with aircraft hydraulic and turbine fluid and is in good condition.



Figure 25. Closeup view of B-1B pad B11. On the left side of the joint, the E-Krete is intact but rubbery and has prevented ingress of aircraft fluid into the underlying concrete. On the right side of the joint, some delamination and blistering is evident. The delamination and blistering was likely the result of preexisting oil on the surface before application of the E-Krete

Estimated Life of Coal Tar and E-Krete™

Studies conducted by both the Federal Aviation Administration (FAA) (Saraf, Majidzadeh, and Kumar 1992) and ERDC (Shoenberger 1993) have shown that average functional life of a coal tar based fuel resistant sealer (FRS) is 2 to 5 years. In most cases, the severity of cracking is such that the sealer has lost its effectiveness in 2 to 3 years. Thus, the expected functional life of a coal tar based FRS is approximately 3 years. In practice, resealing typically occurs every 5 to 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 E-Krete™ is not simple. ERDC has nearly 3 years of field experience with this product. Pavements that have been sealed with E-Krete™ for more than 5 years have been found to be in excellent condition. No cracking that can be attributed to the E-Krete™ has been observed. Based on the experiences with coal tar FRS, severe abrasion from aircraft traffic is not a significant form of distress. The majority of the E-Krete™ demonstration sites have not had significant traffic and given that E-Krete™ 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 E-Krete™ products will be presented for two scenarios. The first is the higher cost material (\$6.67/sq m or 5.58/sq yd) which represents a high-quality application consisting of added aggregate chip that is placed at approximately 3- to 6-mm (1/8- to 1/4-in.) thickness. The second is an economical application (\$4.41/sq m or \$3.69/sq yd) that is approximately 2- to 3-mm (3/16- to 1/8-in.) thickness that contains primarily quartz sand. These figure represent the bounds of costs for most airfield applications requiring a fuel-resistant surface.

Using a net present value life cycle cost analysis (NPV), where r is the annual discount rate and n is the year of expenditure, one can determine in today's dollars the comparative costs of E-Krete™ and coal tar fuel-resistant sealers. Net present value provides an estimate of what a capital outlay today will purchase in the future. Based on the aforementioned discussion, an estimated *functional* life of 3 years for a coal tar FRS is appropriate and that for E-Krete™ is estimated at 10 years.

$$\text{Net Present Value} = \sum_0^n \frac{\text{Initial Cost}}{(1+r)^n}$$

Assume that a 83,612 sq m (100,000 sq yd) parking area is sealed with a coal tar emulsion that costs \$2.15/sq m (\$1.80/sq yd or \$.20/sq ft) the resulting total initial project cost is \$180,000. The cost of \$1.80/sq yd is the actual charge for a coal tar resealing job (as placed, not material costs) conducted at MacDill AFB in 1999. The annual discount rate based on inflation is 3 percent. In 6 years, the parking area would need retreating two times for a cost based on present dollar value of approximately \$495,500. In 10 years, the costs for resealing would be nearly \$633,500.

For the premium application of E-Krete™, assume that the same size parking area (83,612 sq m (100,000 sq yd)) is sealed with E-Krete™ that costs \$6.67/sq m (\$5.58/sq yd or 0.62/sq ft) for a total initial project cost of \$558,000. The E-Krete™ is assumed to have a life span of 10 years. Thus, the cost difference compared to coal tar over a 10-year period would be \$75,000 in net present dollar value. This represents a difference of approximately 14percent. The longer life of the E-Krete™ eliminates the need to interrupt aircraft operations every three years. In addition, coal tar sealers fail by cracking which may cause distress in the underlying asphalt, and many of the cracks will eventually reflect up and crack the new sealer surface.

For the economy application, assume that the same size parking area (83,612 sq m (100,000 sq yd)) is sealed with E-Krete™ that costs \$4.41/sq m or \$3.69/sq yd for a total initial project cost of \$369,000. Thus, the cost difference compared to coal tar over a 10-year period would be over \$125,000 in net present dollar value.

SUMMARY

The results indicate that the fuel and abrasion resistance of the E-Krete™ product exceeds that of a typical unmodified coal tar emulsion. E-Krete™ is resistant to hydraulic fluid but softens in contact with synthetic jet turbine fluids. The abrasion resistance is approximately 8 to 10 times greater for unsealed E-Krete™ and two times greater for sealed E-Krete™ as compared to a typical unmodified coal tar emulsion sealer. No freeze-thaw damage occurred to E-Krete™ with deicing fluid after seven freeze-thaw cycles. The laboratory data and field data both suggest that the material is durable and resistant to weathering.

The field demonstrations have been successful with performance at or above expectations at all sites. However, although the performance has been rated as excellent, this is based on only 2 to 3 years of experience with these products. Field conditions are reported from observations conducted in November 2000. Several of the demonstrations were placed on severely cracked asphalt and many of those cracks have reflected through the E-Krete™ surface. No significant forms of distress that are directly related to the E-Krete™ product have been observed as of November, 2000. Based on the observations at McConnell and MacDill Air Force Bases, it appears that the E-Krete™ will soften if exposed to synthetic jet turbine lubricant spills.

Overall, the E-Krete™ product would appear 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 service life of E-Krete™ will be approximately 10 years in areas with light traffic. Life cycle cost analysis indicates that the costs of E-Krete™ based on an estimated 10 year E-Krete™ life and using resealing of a coal-tar surface every 3 years.

Although the initial cost is higher than coal tar, the estimated life cycle costs are substantially lower using present net worth value assuming an average functional life of coal tar sealer to be 3 years and that of the E-Krete™ to be 10. For an 83,612 sq m (100,000 sq yd) parking area sealed with E-Krete™ that costs \$6.67/sq m (\$5.58/sq yd or 0.62/sq ft) compared to coal tar at \$2.15/sq m (\$1.80/sq yd or \$0.20/sq ft), the cost savings realized over a 10 year period are over \$75,000 (in today's dollars) assuming an inflation rate of 3 percent.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE (DD-MM-YYYY) November 2003		2. REPORT TYPE Final report		3. DATES COVERED (From - To)					
4. TITLE AND SUBTITLE E-Krete™ Polymer Composite Micro-Overlay for Airfields: Laboratory Results and Field Demonstrations				5a. CONTRACT NUMBER CRDA-9804-E-C242					
				5b. GRANT NUMBER					
				5c. PROGRAM ELEMENT NUMBER					
6. AUTHOR(S) J. Kent Newman, James E. Shoenberger				5d. PROJECT NUMBER					
				5e. TASK NUMBER					
				5f. WORK UNIT NUMBER					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Engineer Research and Development Center Geotechnical and Structures Laboratory 3909 Halls Ferry Road Vicksburg, MS 39180-6199				8. PERFORMING ORGANIZATION REPORT NUMBER ERDC/GSL TR-03-24					
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Polycon, Inc. 300 Industrial Drive South Madison, MS 39211				10. SPONSOR/MONITOR'S ACRONYM(S)					
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)					
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.									
13. SUPPLEMENTARY NOTES									
14. ABSTRACT <p>The results indicate that the fuel and abrasion resistance of the E-Krete™ product exceeds that of a typical unmodified coal tar emulsion. E-Krete™ is resistant to hydraulic fluid but has been shown to soften in contact with synthetic jet turbine fluids. Use of an appropriate surface sealer will delay E-Krete™ from softening in areas where jet turbine fluids may be spilled. The abrasion resistance is approximately 8 to 10 times greater for unsealed E-Krete™ and 2 times greater for sealed E-Krete™ compared to a typical unmodified coal tar emulsion sealer. No freeze-thaw damage occurred to E-Krete™ with deicing fluid after seven freeze-thaw cycles. The laboratory data and field data both suggest that the material is durable and resistant to weathering.</p> <p>The field demonstrations have been successful with performance at or above expectations at all sites. However, although the performance has been rated as excellent, this is based on only 2 to 3 years of experience with these products. Field conditions are reported from observations conducted in November 2000. Several of the demonstrations were placed on severely cracked asphalt and many of those cracks have reflected through the E-Krete™ surface. No significant forms of distress that are directly related to the E-Krete™ product have been observed as of November 2000. Based on the observations at McConnell Air Force Base and MacDill Air Force Base, it appears that the E-Krete™ will soften if exposed to synthetic jet turbine lubricant spills. (Continued)</p>									
15. SUBJECT TERMS <table border="0" style="width: 100%;"> <tr> <td style="width: 50%;">Fuel-resistant sealers</td> <td>Polymer concrete</td> </tr> <tr> <td>Pavement sealing</td> <td>Slurry seal</td> </tr> </table>						Fuel-resistant sealers	Polymer concrete	Pavement sealing	Slurry seal
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Pavement sealing	Slurry seal								
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON				
a. REPORT UNCLASSIFIED	b. ABSTRACT UNCLASSIFIED	c. THIS PAGE UNCLASSIFIED			19b. TELEPHONE NUMBER (include area code)				

14. ABSTRACT (Concluded)

Overall, the E-Krete™ product would appear to be an excellent alternative to conventional coal tar fuel resistant sealer (FRS). Based on the performance of demonstration sites and inspection of other sites over 5 years old, it is estimated that the service life of E-Krete™ will be approximately 10 years in areas with light traffic. Life cycle cost analysis indicates that the costs of E-Krete™ based on an estimated 10 year E-Krete™ life and using resealing of a coal-tar surface every 3 years.