ERDC/CERL TR-15-9

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DoD Corrosion Prevention and Control Program

Demonstration and Validation of a High-Performance Floor-Sealant System to Reduce Concrete Degradation

Final Report on Project F10-AR02

Clint A. Wilson and Susan A. Drozdz

May 2015

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Final report

Prepared for Office of the Secretary of Defense (OUSD(AT&L))
Washington, DC 20301-3090

Under Project F10-AR02, "Application of an Innovative, High Performance Concrete Floor Sealant at Hunter Army Airfield, Georgia"

Abstract

Military installations and bases maintain virtually countless facilities with concrete floors, such as warehouses, vehicle garages, and aircraft maintenance facilities. Because concrete is a porous material, it can prematurely deteriorate due to the intrusion of moisture, lubricants, and other contaminants in combination with mechanical stresses imposed by heavy equipment traffic. This project demonstrated and validated the performance characteristics of a high-performance sealant system designed to toughen concrete floor surfaces in order to reduce material degradation due to heavy use. This report describes a study undertaken to assess the capabilities and advantages of a high performance floor-sealant system to protect and improve the service life of concrete floors. The project demonstrated that military installations can reduce maintenance costs for concrete floors by providing a durable, penetrating surface sealant that toughens the concrete to resist material degradation.

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Preface

This demonstration was performed for the Office of the Secretary of Defense (OSD) under Department of Defense (DoD) Corrosion Control and Prevention Project F10-AR02, "Application of an Innovative, High Performance Concrete Floor Sealant at Hunter Army Airfield, Georgia." The proponent was the U.S. Army Office of the Assistant Chief of Staff for Installation Management (ACSIM), and the stakeholder was the US Army Installation Management Command (IMCOM). The technical monitors were Daniel J. Dunmire (OUSD(AT&L)), Bernie Rodriguez (IMPW-FM), and Valerie D. Hines (DAIM-ODF).

The work was performed by the Materials and Structures Branch of the Facilities Division (CEERD-CFM), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). A portion of this work was performed by Christopher Olaes and Larry Clark of Mandaree Enterprise Corp. (MEC), Warner Robins, GA. At the time this report was prepared, Vicki L. Van Blaricum was Chief, CEERD-CFM; Michelle J. Hanson was Acting Chief, CEERD-CF; and Kurt Kinnevan, CEERD-CZT, was the Technical Director for Adaptive and Resilient Installations. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Ilker Adiguzel.

The following Hunter Army Airfield personnel are gratefully acknowledged for their support and assistance in this project:

- CW4 Drew Gaboriaul, HHC 3/160th
- Mr. Mike Phillips, Hunter AAF Department of Public Works

The Acting Commander of ERDC was LTC John T. Tucker III, and the Director was Dr. Jeffery P. Holland.

Executive Summary

Military installations and bases maintain virtually countless facilities with concrete floors, such as warehouses, vehicle garages, and aircraft maintenance facilities. Because concrete is a porous material, it can prematurely deteriorate due to the intrusion of moisture, lubricants, and other contaminants in combination with mechanical stresses imposed by heavy equipment traffic. The Department of Defense Corrosion Prevention and Control Program (CPC) sponsored a project to demonstrate and validate the performance characteristics and economics of a high-performance penetrating sealant system designed to toughen concrete floor surfaces. The project objectives were to (1) demonstrate and validate the ability of the subject sealant system to reduce the degradation of concrete floors in military maintenance facilities and (2) perform an economic analysis of technology application to determine the return on investment (ROI) ratio as compared with conventional concrete floor surface treatments.

The demonstration was performed at Hunter Army Airfield, GA, in a vehicle and equipment maintenance facility where epoxy-based floor coatings were deteriorated and debonding. Application required no specialized techniques, only following industry-standard practices and manufacturer's specifications for surface preparation, application, and cure time.

Based on the results of quarterly onsite inspections, coupon stain and degradation tests, and interviews with building maintenance personnel, the demonstrated sealant system provided superior performance compared with the conventional epoxy-based floor coating previously used at the test site. The surface finish did not peel or chip, and was resistant (but not impervious) to staining by lubricants and chemicals. Treated floors were easier to clean than the standard finish when stains were removed promptly, and the sealant system did not reduce traction on floors despite the glossy finish appearance. The only problems reported by maintenance personnel were related to crack repairs and rubber joint seals that were incidental to the project and not caused by the sealant application.

The ROI for the CPC project was calculated to be 0.46 for two applications over 30 years. In a real-world application research-project costs would not apply, so the ROI could increase to 2.62 over 30 years.

Unit Conversion Factors

Multiply	By	To Obtain
feet	0.3048	meters
mils	0.0254	millimeters

1 Introduction

1.1 Problem statement

This project addresses a military facility corrosion problem ranked among the top 25 most costly to the Department of Defense (DoD): vehicle maintenance shops and hangars categorized under Facility Analysis Codes 2111, 2112, and 2141 (Herzberg et al. 2007). These facilities and others typically have concrete floors that are subject to loads, impacts, abrasion, and exposure to water, lubricants, and other chemical contaminants. Epoxy-based floor-coating materials are typically selected for treating concrete floors in these types of buildings. Clear sealers provide a protective, cleanable surface with a finished appearance. Pigmented epoxy-based paints are used to improve floor appearance and to reflect light from indoor fixtures and improve workspace illumination. One problem with epoxy-based floor sealers is that they become hazardously slippery when wet. Another problem is that the material is brittle, and easily chipped or cracked under the stress of dropped objects such as hand tools. Chips and cracks create incursion paths for liquids and other contaminants, which can result in large-scale peeling of the coating from the concrete substrate. As the coating becomes compromised, liquids, lubricants, and chemical contaminants such as road salts can permeate the porous concrete, permanently damaging and degrading the floor. Therefore, once epoxy-based coatings begin to chip and peel, their initial protective and cosmetic advantages are lost.

The proposed improvement to standard epoxy floor sealants is a commercially available two-part sealant system that densifies the concrete surface to improve wear resistance and impermeability to liquids and contaminants. The product selected for demonstration and validation in this DoD Corrosion Prevention and Control (CPC) project is called the Pentra Protective Coating System, which the manufacturer describes as a "hybrid inorganic/organic Nano-Lithium"* topcoat finish and surface hardener." The manufacturer claims a number of advantages offered by this sealant system in relation to typical epoxy floor sealants and paints (see section 2.1).

* Pentra and Nano-Lithium are trademarks of Convergent Concrete Technologies, West Orem, UT.

1.2 Objectives

The objectives of this project were to (1) demonstrate and validate the ability of the subject sealant system to reduce the degradation of concrete floors in military maintenance facilities and (2) perform an economic analysis of technology application to determine the return on investment ratio as compared with conventional concrete floor surface treatments.

1.3 Approach

The selected demonstration facility was Building 8005 at Hunter Army Airfield, GA. The building is a vehicle and ground-support equipment maintenance facility in which the epoxy-based floor coatings were deteriorated and debonding in many locations. Mission activities impose high wear requirements and exposure to numerous contaminants that can degrade the condition of concrete. Some floors had been coated several times with an epoxy paint system that was in a deteriorated condition. Other floors in Building 8005 had been covered with epoxy sealer, sheet vinyl, or vinyl tile, and these finishes had to be removed before application of the demonstrated sealant system.

Industry-standard practices were followed to prepare the floors and treat them with the demonstrated sealant system, with careful attention to the product manufacturer's instructions for surface preparation, coating application, and cure time.

2 Technical Investigation

2.1 Technology overview

The Pentra Protective Coating System, consisting of the products Pentra-Sil® 244+ and Pentra Guard® (HP), is a water-based lithium silicate formulation specified by the manufacturer for interior or exterior industrial applications. According to the manufacturer, the reactive chemistry of the coating system forms an insoluble permanent bond with concrete surfaces and rapidly cures, drying to touch in 30 – 60 minutes into a 2 – 3 mil film. The sealing mechanism is described as a series of chemical reactions resulting in total cross-linking, reinforcing, and sealing of the surface through a durable chemical bond with the substrate. The Material Safety Data Sheets (MSDS) for both system components are reproduced in Appendix A.

The purpose of demonstrating this sealant system is to assess its ability to reduce DoD costs of maintaining, repairing, and replacing concrete floors and their finishes. According to the manufacturer, the two materials comprising the sealant system react to harden, seal and densify concrete floor surfaces, providing a treatment that outperforms epoxy-based coatings. Furthermore, the manufacturer claims that this sealant system simplifies and shortens floor cleaning requirements by reducing the occurrence of rubber scuffs and stains, and also provides a surface that can be simply cleaned with water. It is claimed that the sealant system also is resistant to bacteria penetration, which has positive implications for indoor environmental quality.

2.2 Field work

The previous paint on the maintenance bay floors was an epoxy-based coating that was deteriorating. The appearance of the floor was poor due to peeling, chipping, and staining. Because of the light color of the floor, frequent cleaning was necessary. In addition to the maintenance bays (Figure 1 and Figure 2), a tool room (Figure 3), office (Figure 4), training room (Figure 5), and hallways (Figure 6) were also included in this demonstration. The training room and hallways were covered with two layers of vinyl tile that had to be removed.

Figure 1. Maintenance bays in Building 8005.

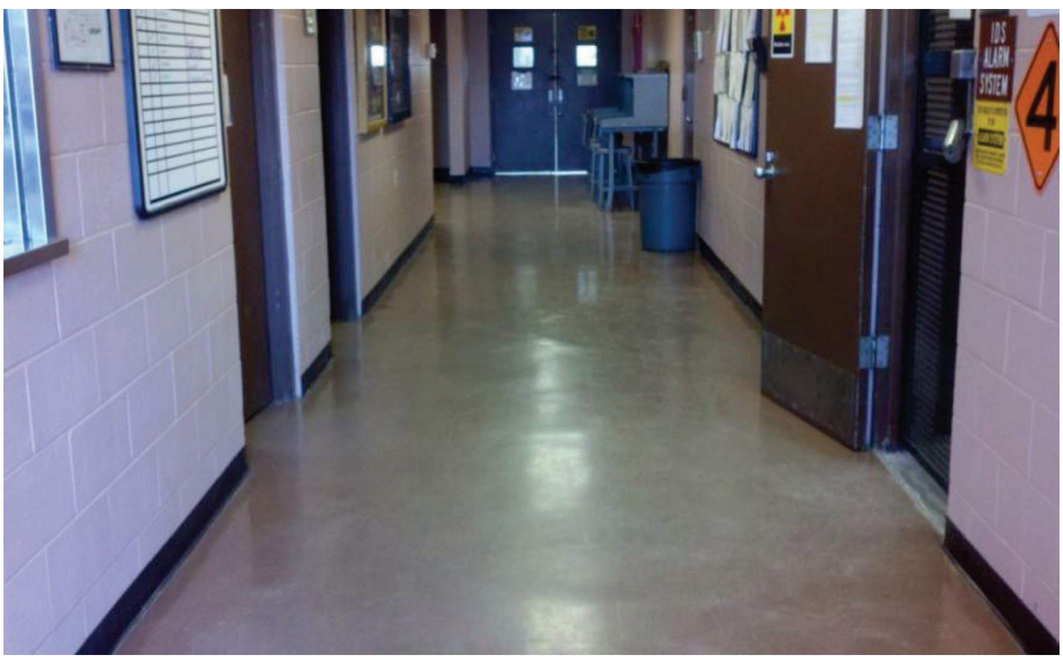
Figure 2. Condition of epoxy-coated maintenance bay floors before project.

Figure 3. Tool room floor.

Figure 4. Office floor.

Figure 5. Training room floor.

Figure 6. Hall floor.



The vehicle maintenance bays and two support offices had floors coated with an epoxy paint system. The paint first had to be removed mechanically using a planetary grinder with 30 grit abrasives. Figure 7 and Figure 8 show the paint removal equipment being used in the vehicle maintenance bays. The asphalt tile in the hallways and office spaces was removed with a reciprocating chisel and scraper (Figure 9).

Upon completing the coating installation as described in sections 2.2 and 2.3, all waste products were determined to be non- hazardous and disposal was accomplished by a licensed contractor in an approved landfill. All excess materials were removed from Hunter AAF.

Figure 7. Planetary grinder removing paint.

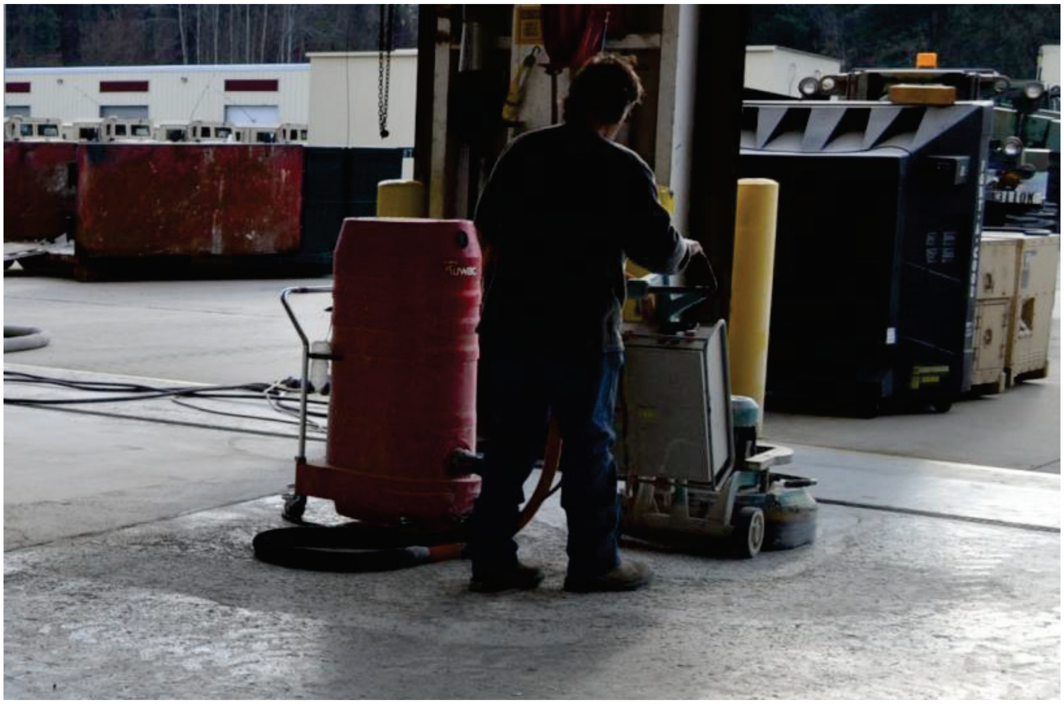


Figure 8. Vehicle maintenance bays.

Figure 9. Chisel removal of floor tile

Once the floor coverings were removed and before final grinding and sealing were started, the area was inspected, documented and photographed for the general state of the substrate as well as for any imperfections such as spalls, divots and cracks. Several imperfections needed to be repaired before surface preparation for the sealant application. A self-leveling patching cement called Rapid Set TRU* was used to fill minor spalls, divots, and hairline cracks. The concrete throughout the facility was in good condition, so only a few minor repairs were required. Where walls required protection during surface preparation and sealant application, plastic sheeting was used to cover the walls at least 36 in. high. This protection was mainly needed in the hallway and offices.

The floor was prepared by grinding the concrete floor surface with planetary grinders, utilizing incrementally finer abrasives at each stage. The surface sheen of the floor depends on the grade of the abrasive and the level of workmanship. Grinding began with a coarse 50 grit abrasive followed by 100 and 200 grit. After treatment with the 50 grit abrasive, other flaws in the concrete were repaired with the patching cement described above.

* Rapid Set and TRU are registered trademarks of CTS Cement, Cypress, CA.

After the floors were successively ground with 100 and 200 grit abrasives (Figure 10), Pentra-Sil® 244+ was applied manually using a standard floor mop (Figure 11). Excess liquid was removed with a wet vacuum (Figure 11) to prevent it from drying and compromising the quality of the final finish.

Figure 10. Floor after grinding with 200 grit abrasive.

Figure 11. Application of Pentra-Sil® 244+.

While the bulk of the floor was prepared as described for application of the Pentra-Sil® 244+, many areas of the floor were not accessible for use of the planetary grinders. Where the floor was uneven, close to walls, or where access was restricted by permanent fixtures, hand grinders had to be used for surface preparation (Figure 12 and Figure 13). The process is the same as with the planetary grinders and the grades of abrasive used are the same.

Figure 12. Hand grinding in close quarters.

Figure 13. Uneven floor area ground by hand.

Once the Pentra-Sil® 244+ was applied and allowed to dry for an hour, the final grinding and polishing steps were accomplished. The floors were polished successively with 400 and 800 grit abrasives to achieve a highly polished finish (Figure 14). Then the floor was thoroughly cleaned before application of the second material, Pentra Guard® (HP). This sealant is applied using a mop with a flat head and microfiber pad to facilitate even application (Figure 15). After drying, the sealant was burnished with a 1,500 grit diamond abrasive buffing pad (Figure 16).

Figure 14. Finish grind with 800 grit abrasive.

Figure 15. Application of Pentra Guard® (HP).

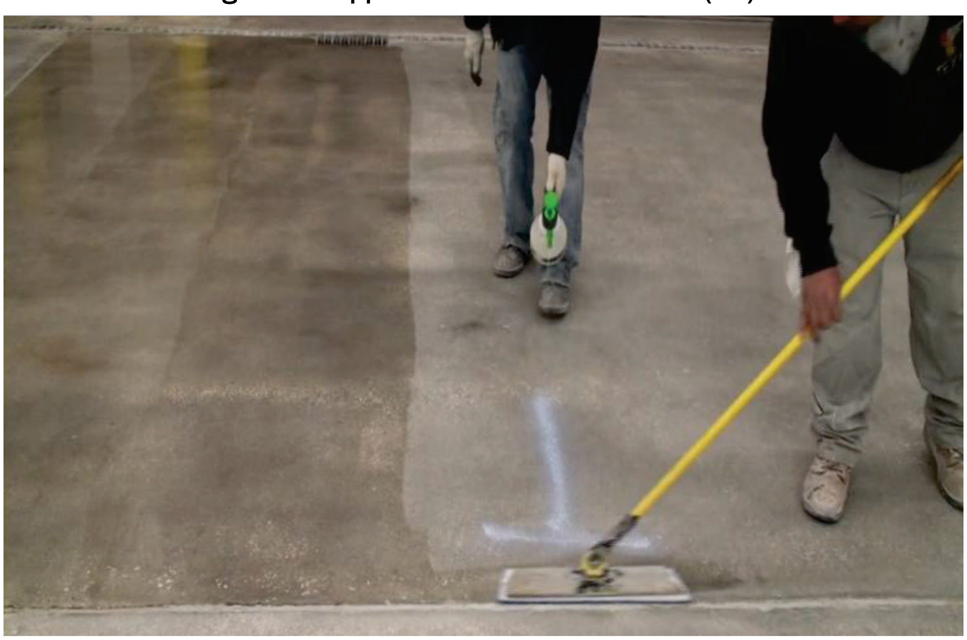


Figure 16. Final burnishing of sealant topcoat with 1,500 grit abrasive pad.

The final step in the maintenance bay application was to remove the existing seals from the construction joints in the floor and reseal them using a product called Ardex Ardiseal Rapid Joint Seal* (Figure 17). The old seals were difficult to remove, and the contractor had trouble removing the old material to the depth specified for new joint material.

The floors of the hallway, interior offices, and training room were finished in the same manner, but in addition a staining dye was applied to the floor surface for decorative effect. This stain was applied with a hand pump sprayer after the floors had been ground with the 200 grit abrasive and before application of the first sealant component (Pentra-Sil® 244+). That material was applied after the stain had dried.

* Ardex Americas, Aliquippa, PA.

Figure 17. Application of joint sealer.

The completed floors had an appearance and quality that facility personnel judged to be attractive (Figure 18–Figure 20).

Figure 18. Far-end completed vehicle maintenance bay.

Figure 19. Completed hallway showing concrete with applied stain.

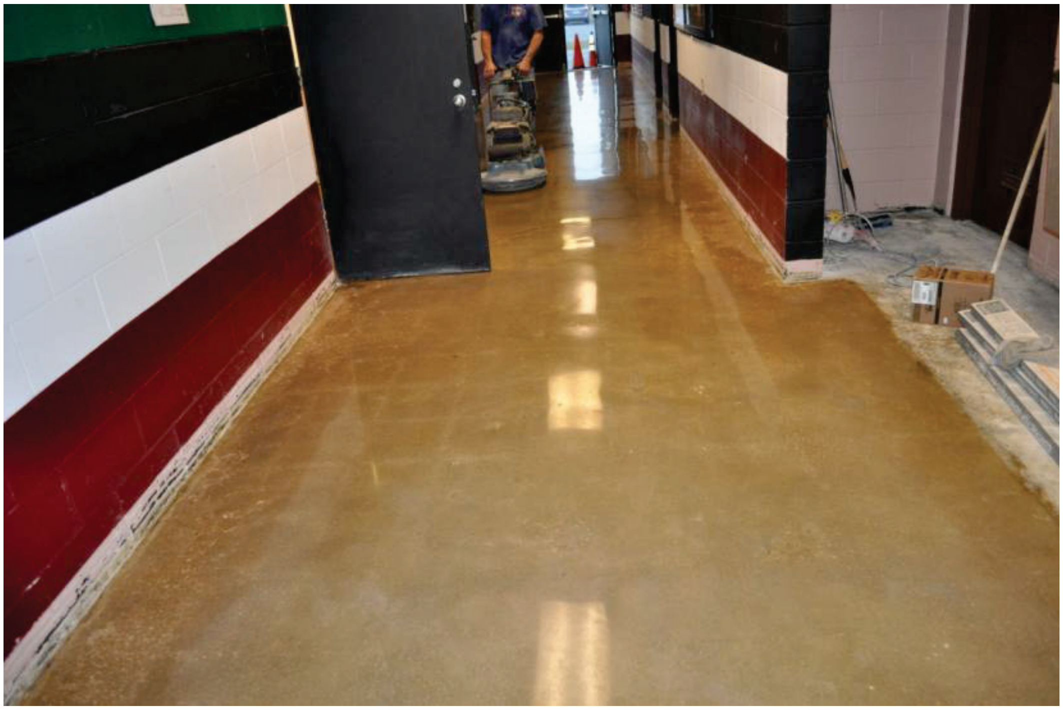


Figure 20. Completed training room showing concrete with applied stain.

2.3 Monitoring and testing

To evaluate the performance of the floor sealant system it was monitored for one year. The site was visited at 3, 6, 9, and 12 months after installation. Evaluators looked at each floor's finish and physical condition, and asked building users for their impressions of the sealant system's performance, especially with regard to ease of cleaning and maintenance.

In addition, a material test specimen was created to evaluate the floor sealant system against extended exposure to materials used in the vehicle maintenance facility. The test specimen was a 3 x 3 ft slab of newly poured concrete that was allowed to cure for 7 days. The slab was ground according to the same process used on the floors and treated with the Pentra-Sil® 244+and Pentra Guard® (HP) in the same way as the floor of Building 8005. The slab was later cut into for four parts to allow for handling and transport to the testing location at Mandaree Enterprise Corp. (MEC), Warner Robins, GA. In testing, the panel was exposed to a variety of contaminants, as described in section 3.2.5.

Gloss measurements on floors and test coupons were made as described in Chapter 3 under "Metrics."

3 Discussion

3.1 Metrics

Evaluators compared floor conditions at 0, 3, 6, 9, and 12 months to the pre-demonstration condition of the floors. They interviewed building users to document their impressions of the rehabilitated floor surfaces.

Gloss readings were measured using a Rhopoint Novo-Gloss 60* meter. Gloss units are as defined by the following standard:

- ISO 2813, *Paints and Varnishes — Determination of Gloss Value at 20°, 60° and 85°*
- TAPPI T480, *Specular Gloss of Paper and Paperboard at 75 Degrees*

Measurements were made according to the gloss meter manual at an incident angle of 60 degrees.

Slip-resistance data from friction tests provided by the manufacturer (Appendix C) were reviewed and verified against field observations.

Resistance to staining and contamination was evaluated by exposing concrete test coupons to a list of potential contaminants developed in coordination with the building occupants. As noted in section 2.3, this testing was performed at the MEC facility. A 10 ml sample of each identified contaminant (Table 1) was applied to the surface within a specified quadrant, covered by a watch glass, and left in place for 1 week (Figure 21). The surfaces of all four coupons were then cleaned with two different off-the-shelf cleaning products typically used to clean concrete floors. Each quadrant was visually examined and photographed to identify any deterioration caused by the exposure.

The number of gloss readings at the 6 and 12 month inspection times were more than at other times, due to limitations from ongoing operations in the facility. To determine penetration and wear, gloss and color readings were measured in accordance with the following standards:

* Rhopoint Instruments, St. Leonards-on-Sea, East Sussex, TN38 9AG, UK.

- ASTM E308, *Standard Practice for Computing the Colors of Objects by Using the CIE System*
- ASTM E1164, *Standard Practice for Obtaining Spectrometric Data for Object-Color Evaluation*

Figure 21. Initial application of test materials.

Table 1. Test chemicals.

National Item Identification Number	Part Number / MIL-SPEC	Description
01-438-6079	MIL-PRF-2104H	Engine Oil 15/40
01-035-5393	MIL-PRF-2105	80W90 Gear Oil
01-496-1948	MIL-PRF-2104G	10W Oil
01-464-9137	A-A-52624 Type 1 Recycled	Antifreeze
01-197-7692	MIL-PRF-10924H	GAA Grease
01-102-9455	MIL-PRF-46176B	Brake Fluid
00-252-6383	MIL-PRF-5606H	Hydraulic Fluid H515
01-439-0681	110054	WD-40 CPC
01-353-4799	Hydraulic Fluid	ATF Dextron 6

3.2 Results

For this demonstration a schedule of inspections and observations was established to assess sealant-system performance under conditions of normal use. The application-process log (zero months) is shown in Appendix B. The sections that follow summarize results noted at 3, 6, 9, and 12 months of use.

3.2.1 Three-month inspection

This inspection was performed in conjunction with a site visit scheduled by project team personnel to apply safety striping tape to vehicle bay floors. Stripes are needed around electrical junction boxes, which are installed in raised sections of the vehicle bay floor (Figure 22). Safety striping is normally painted on concrete floors, but tape was used because striping paint would not adhere to the sealed surfaces. At this same time, the treated floor surfaces were assessed, and no sealant deficiencies were noted.

Figure 22. Safety striping tape marking junction boxes on floor.

There was, however, an issue with concrete-repair materials that had been applied to some large cracks before sealant application. The concrete repair material showed signs of minor deterioration along some edges, but it was not related to the sealant application. The floors in the vehicle-maintenance bays were in excellent condition and only showed tire marks. Facility personnel reported that spills of vehicle-maintenance fluids on the floor were easy to clean and did not leave any penetrating stains.

3.2.2 Six-month inspection

Overall, the floors appeared to be in excellent condition. Project personnel spoke with several of facility maintenance workers, and each one expressed satisfaction with the floor. The building users reported that the floor was easier and quicker to clean than it was previously. However, they did note that tire tread marks were difficult to remove from the surface. A few floor areas were stained with maintenance fluids, but building users stated that the fluids had not been cleaned from the floor promptly. There also were places in high-traffic areas where the joint-sealer material between floor slabs was beginning to curl at the edges. Bays 3 and 4 were used most often for vehicle maintenance, and the floors showed a duller finish than other demonstration floors. By comparison, gloss measurements were significantly higher in lower-traffic areas such as in Bay 2 (see Table 2). The buffer pads provided by the installer for maintenance did not restore the gloss in Bays 3 and 4 to the same level as immediately after sealant application.

3.2.3 Nine-month inspection

The floors continued to look good overall without much degradation since the previous assessment. Personnel continued to express satisfaction with the ease of cleaning the floors. However, some problems related to the concrete repairs and floor-joint seals in the maintenance bays were still evident. Also, repairs made to floor crack in the hallway continued to deteriorate. A patch applied to repair some spalled concrete on the maintenance bay floor had come off. There was an area of deteriorated floor finish that appears to have been caused by a spill, and minor stains were noted in a few places. The overall floor appearance remained good (Figure 23).

Figure 23. General floor condition at 9 months.

3.2.4 Twelve-month inspection

The floors continued to look good overall, with little degradation since the last assessment. Personnel were still satisfied with the ease with which the treated surfaces could be cleaned. At the time of this inspection, the facility was being used heavily and the floors in the maintenance bays were considerably more soiled than in previous evaluations. There were still deficiencies, as previously noted, mostly related to repairs made to the floor and the seals applied to the construction joints between floor slabs in the maintenance bays. In heavy-use areas, the floor was stained from spills of petroleum products. The floor crack repairs in the hallway continued to deteriorate (Figure 24), and this is considered by the building users to be the biggest issue with the demonstration project results. Although the floor in the vehicle maintenance bays were in use and had not been cleaned recently, the Hunter personnel stated that they cleaned up fairly well with pressure washing and buffing. At 1 year after installation, the floor appearance continued to remain good, overall. The sealant system has not chipped or scratched as the standard paint treatment does. It remains easy to clean, and it is reported to be less slippery than a painted floor (Figure 25).

Figure 24. Repaired cracks, showing lighter areas of repair-material deterioration.

Figure 25. Bay 4 floor surface area after 1 year of service.

3.2.5 Coupon test results

The documentation of the coupon test results is located in Appendix D.

After the first week of concentrated exposure of the coupons to the test chemicals, nearly all of the chemicals had penetrated into the concrete with the exception of A-A-5264 antifreeze, which had no effect on the treated concrete. The caustic Nu-Brite product had etched the concrete surface.

The results after the second week of concentrated exposure were the same as the first, with increased absorption of the petroleum-based materials into the concrete and increased etching of the concrete by the Nu-Brite.

3.2.6 Other system characteristics

Hunter AAF personnel expressed concern that the sealed, unpainted floors would reduce available indoor light compared to when the floor surfaces were painted. particularly beneath vehicles. To evaluate this concern, comparative gloss measurements of the original and new floor surfaces were made. Table 2 shows the gloss meter readings of the initial painted floor and the Pentra-Sil® 244+and Pentra Guard® (HP) coated floor at 6 and 12 months. The floor's capacity for reflecting light was slightly higher when sealed with Pentra-Sil® 244+and Pentra Guard® (HP) than when painted. A gloss level of 10 to 25 units is considered an eggshell finish.

Table 2. Gloss measurements (60 degree incident angle).

	Bay	Initial	After 6 months	After12 months
East Side	1	13.1	11.4	19.6
	2		23.1	17.6
	3	15.1	13.8	16.8
	4		15.0	11.7
West Side	1	9.9	9.2	12.4
	2		21.7	13.6
	3	6.4	14.3	15.3
	4		9.0	19.2
Locker Area	2	20.6	20.0	18.4
	3	10.7		12.1

Another question about this floor sealant was whether it would make the floor slippery when wet. This question was not included for direct testing in the demonstration Scope of Work. However, the manufacturer provided the results of friction tests conducted on concrete treated with the demonstrated system in accordance with ASTM C-1028-96 (Appendix C). Those results indicated that the slip coefficient of concrete is not significantly changed by the application of the sealant system. Subjective qualitative observations by site personnel supported this claim; users observed that the treated floor, despite its shiny appearance, provided better traction than concrete coated with the standard epoxy paint.

The other question about the floor-sealant system was whether the shine of the floor would be distracting. Building users reported that the glossy appearance was acceptable.

3.3 Lessons learned

Because paints will not adhere to the demonstrated floor-sealant materials, yellow/black safety striping tape must be applied instead of painting the stripes on the floor to keep vehicles away from floor-mounted electrical junctions and similar obstacles.

Joint-sealer materials must be replaced or applied with care. In this project, it was difficult to dig old sealer material out of the joints consistently deep enough to ensure good performance of replacement materials. It is important to provide clear requirements as part of any contracts involving joint-sealer replacement.

As with joint sealers, crack repairs must be made with attention to detail. The edges of crack repairs did not hold up under use. The sealant system did not prevent these materials from chipping at the edges, but it should be noted that no floor sealant would be expected to prevent that sort of damage in a similar situation. The deterioration of the floor-crack repairs in the hallway were considered by the building users to be the main negative aspect of the project.

An additional test of the typical exposure that results from spills and then cleaned up within an eight-hour period would have provided data on the real-world stain-resistance capabilities of the sealant system. Spilled petroleum products are typically cleaned before a week passes, so the exposure tests conducted for this project represented a worst-case scenario for staining and chemical degradation versus a typical, everyday scenario. After 12 months of service and constant spills of materials used in the vehicle maintenance bays, no stains were as severe as those seen in the test coupons shown in Appendix D. Also, the bay floors were pressure washed while the test samples were hand washed, so a more rigorous exposure-testing procedure might have been designed and executed.

4 Economic Summary

4.1 Costs and assumptions

The Pentra-Sil® 244+ and Pentra Guard® (HP) sealant system is more expensive to use than a conventional polymer-based epoxy system because of the additional cost of floor preparation. However, there is a lower maintenance cost for the Pentra-Sil® 244+ and Pentra Guard® (HP), giving this system a significant life-cycle cost benefit.

Alternative 1 (Baseline Scenario). Recoating the floor area in Building 8005 with a standard epoxy system would cost $39,382 (materials $8,832, labor $30,550). The expected service life would be 5 years, based on the assumption that most coating-systems are have manufacturer warranties of 5 – 10 years. Annual cleaning costs for the epoxy floor system are estimated at $12,000, based on 4 man-hours per week, 50 weeks per year, at a cost of $60 per man-hour. In Table 3, there is a recurring baseline cost of $51,382 every fifth year, which covers both the reapplication of a new epoxy finish and the annual cleaning cost of $12,000.

Alternative 2 (Demonstrated System). The costs for the Pentra-Sil® 244+ and Pentra Guard® (HP) floor sealant system applied in Building 8005 was $62,840 (materials $7,600, other costs $21,589, labor $33,651), and this cost included removal of the existing polymer-based epoxy coating. The full cost of this demonstration/validation project was $360,000. The cleaning cost is cut in half, requiring only 2 man-hours per week, so it amounts to $6,000. The service life of the sealed floor is assumed to be 15 years.

4.2 Projected return on investment (ROI)

The net present value of the floor sealant system demonstrated in Building 8005, including one reapplication and maintenance, is estimated to be $95,736 over 30 years. Using methods specified in Office of Management and Budget Circular No. A-94, the ROI ratio is 0.46 over 30 years (see Table 3). However, in real-world applications in military facilities there will be no research-project costs to diminish the ROI, so the actual contract cost of $62,840 can be substituted into the calculation (Table 4), increasing the ROI to 2.62 over the 30 year service life.

Table 3. ROI for Pentra-Sil® 244+ and Pentra Guard® CPC demonstration project.

Return on Investment Calculation

Investment Required			360,000
Return on Investment Ratio	0.46	Percent	46%
Net Present Value of Costs and Benefits/Savings	95,736	260,292	164,556

A Future Year	B Baseline Costs	C Baseline Benefits / Savings	D New System Costs	E New System Benefits / Savings	F Present Value of Costs	G Present Value of Savings	H Total Present Value
1	51,382		6,000		5,608	48,022	42,414
2	12,000		6,000		5,240	10,481	5,240
3	12,000		6,000		4,898	9,796	4,898
4	12,000		6,000		4,577	9,155	4,577
5	12,000		6,000		4,278	8,556	4,278
6	51,382		6,000		3,998	34,236	30,238
7	12,000		6,000		3,736	7,472	3,736
8	12,000		6,000		3,492	6,984	3,492
9	12,000		6,000		3,263	6,527	3,263
10	12,000		6,000		3,050	6,100	3,050
11	51,382		6,000		2,851	24,412	21,561
12	12,000		6,000		2,664	5,328	2,664
13	12,000		6,000		2,490	4,980	2,490
14	12,000		6,000		2,327	4,654	2,327
15	12,000		6,000		2,174	4,349	2,174
16	51,382		68,840		23,316	17,403	-5,913
17	12,000		6,000		1,900	3,799	1,900
18	12,000		6,000		1,775	3,551	1,775
19	12,000		6,000		1,659	3,318	1,659
20	12,000		6,000		1,550	3,101	1,550
21	51,382		6,000		1,449	12,409	10,960
22	12,000		6,000		1,354	2,708	1,354
23	12,000		6,000		1,265	2,531	1,265
24	12,000		6,000		1,183	2,365	1,183
25	12,000		6,000		1,105	2,210	1,105
26	51,382		6,000		1,033	8,848	7,815
27	12,000		6,000		965	1,931	965
28	12,000		6,000		902	1,805	902
29	12,000		6,000		844	1,687	844
30	12,000		6,000		788	1,577	788

Table 4. ROI for Pentra-Sil® 244+ and Pentra Guard® excluding CPC project costs.

Return on Investment Calculation

Investment Required		62,840
Return on Investment Ratio	2.62	Percent 262%

Net Present Value of Costs and Benefits/Savings					95,736	260,292	164,556
A	B	C	D	E	F	G	H
Future Year	Baseline Costs	Baseline Benefits / Savings	New System Costs	New System Benefits / Savings	Present Value of Costs	Present Value of Savings	Total Present Value
1	51,382		6,000		5,608	48,022	42,414
2	12,000		6,000		5,240	10,481	5,240
3	12,000		6,000		4,898	9,796	4,898
4	12,000		6,000		4,577	9,155	4,577
5	12,000		6,000		4,278	8,556	4,278
6	51,382		6,000		3,998	34,236	30,238
7	12,000		6,000		3,736	7,472	3,736
8	12,000		6,000		3,492	6,984	3,492
9	12,000		6,000		3,263	6,527	3,263
10	12,000		6,000		3,050	6,100	3,050
11	51,382		6,000		2,851	24,412	21,561
12	12,000		6,000		2,664	5,328	2,664
13	12,000		6,000		2,490	4,980	2,490
14	12,000		6,000		2,327	4,654	2,327
15	12,000		6,000		2,174	4,349	2,174
16	51,382		68,840		23,316	17,403	-5,913
17	12,000		6,000		1,900	3,799	1,900
18	12,000		6,000		1,775	3,551	1,775
19	12,000		6,000		1,659	3,318	1,659
20	12,000		6,000		1,550	3,101	1,550
21	51,382		6,000		1,449	12,409	10,960
22	12,000		6,000		1,354	2,708	1,354
23	12,000		6,000		1,265	2,531	1,265
24	12,000		6,000		1,183	2,365	1,183
25	12,000		6,000		1,105	2,210	1,105
26	51,382		6,000		1,033	8,848	7,815
27	12,000		6,000		965	1,931	965
28	12,000		6,000		902	1,805	902
29	12,000		6,000		844	1,687	844
30	12,000		6,000		788	1,577	788

5 Conclusions and Recommendations

5.1 Conclusions

The results of this demonstration/validation project indicate that the Pentra-Sil® 244+ and Pentra Guard® (HP) concrete-sealant system provided superior performance compared with typical epoxy-based coatings like those previously used in Building 8005 at Hunter Army Airfield. Because the sealant system penetrates properly prepared concrete, the materials do not peel or chip away from undamaged concrete. The sealant materials densify the concrete in the penetration zone, providing resistance to typical types of abrasion in service. The demonstration validated that the coating system will reduce floor-maintenance requirements in utility and industrial facilities and provide performance and safety benefits.

Continued deterioration of floor crack repairs was noted through the twelve-month inspection (section 3.2.4), and this is considered by the building users to be the biggest issue with the demonstration project results.

5.2 Recommendations

5.2.1 Applicability

The demonstrated technology may be used on concrete floors in high-traffic vehicle garages, warehouses, workshops, and similar applications in military facilities. Caveats in section 3.3 pertaining to floor safety striping, joint sealers, crack repairs, and cleaning spills should be observed in order to obtain the best results.

5.2.2 Implementation

It is recommended that concrete sealant/densifier products such as the Pentra-Sil® 244+ and Pentra Guard® (HP) sealant system be considered for implementation as a treatment option for concrete floors in DoD utility-type buildings such as those listed in the previous paragraph.

Only one portion of Unified Facilities Guide Specification (UFGS) Section 09 67 23.13, "Standard Resinous Flooring," seems potentially applicable to promoting DoD-wide implementation. However, no language in the specification would apply to this sealant system. UFGS Section 03 35 00.00 10, "Concrete Finishing," is a suitable specification document for incorporating guidance for the use of this type of system on new concrete floors. Unified Facilities Criteria (UFC) 3, Section 270-04, "Concrete Repair," and UFC 3-320-06A, "Concrete Floor Slabs on Grade Subjected to Heavy Loads," offer possible locations for incorporating criteria for using this type of product in DoD facility applications.

A mechanism needs to be established to provide knowledge of these evaluations and their benefit to those organizations that will be finishing or refinishing floors. Facility operators typically work within budget constraints that would prohibit the increased cost of installing this type of sealant system in place of a conventional floor finish system. However, when long-term maintenance-cost savings are accounted for, the subject floor sealant system offers modest cost benefits. Improved aesthetics are an additional benefit.

References

ASTM C1028. 1996. *Floor Slip Resistance Testing*. West Conshohocken, PA: ASTM International.

ASTM E308. 2013. *Standard Practice for Computing the Colors of Objects by Using the CIE System*. West Conshohocken, PA: ASTM International.

ASTM E1164. 2012. *Standard Practice for Obtaining Spectrometric Data for Object-Color Evaluation*. West Conshohocken, PA: ASTM International.

Herzberg, E.F., K.L. Bissell, K.W. Crissman, J. Dovich, J. Hesson, F. Kaleba, E.M. Mallare, N.T. O'Meara, B. Stevens, E.D. Turner. 2007. *The Annual Cost Of Corrosion For the Department of Defense Facilities And Infrastructure*. Report SKT50T2, Rev. 1. McLean, VA: LMI Government Consulting.

ISO 2813. 1996. *Paints and Varnishes — Determination of Gloss Value at 20°, 60° and 85°*. Geneva, Switzerland: International Organization for Standardization, ISO Central Secretariat.

TAPPI T480. 2009. *Specular Gloss of Paper and Paperboard at 75 Degrees*. Peachtree Corners, GA: Technological Association of the Pulp and Paper Industry.

Appendix A: MSDS and Technical Data Sheet

Material Safety Data Sheet PENTRA-GUARD® (HP)

Section 1. Product and Company Identification


Irritant

Product Name: Pentra-Guard® (HP)
Product use: Concrete chemical hardener, sealer and densifier.
Effective Date: March 3, 2010

Manufacturer Information: Advanced Concrete Technologies, LLC
115 North 1380 West
Orem, UT 84057
Telephone number: 801-375-2280

USA Emergency Phone Number:
INFOTRAC (24-hr/7 days): 1-800-535-5053
Outside the United States call collect 1-352-323-3500
For Medical Emergency - Call 1-800-535-5053

Section 2. Ingredients and Hazards Information

Hazardous Components					
Component	CAS #	EINECS No	OSHA PEL	ACGIH TLV	Percent
Water	7732-18-5	231-791-2	NA	NA	45-55
Proprietary A	NA	NA	NA	NA	25-35
Proprietary B	NA	NA	NA	NA	15-25
Proprietary C	NA	NA	NA	NA	1 - 8
Proprietary D	NA	NA	NA	NA	1 - 8
None of the compounds contain carcinogens, Prop. 65, SARA 313 listings and are non-hazardous and non-flammable.					

Potential Acute Health Effects:
Eyes: Causes eye irritation
Skin: Expected to cause irritation to the skin
Inhalation: Vapors may cause respiratory irritation
Ingestion: May be harmful.

Section 3. Hazard Identification

The primary routes of entry are eyes, skin and respiratory.
Immediate Health Effects:
Eye Contact: Causes irritation.
Skin: Contact with the skin is expected to cause irritation
Ingestion: May cause headache, dizziness, nausea and vomiting.
Inhalation: The vapor or fumes from this product may cause respiratory irritation.
Delayed or other Health Effects: None determined.
Target Organs: None determined.

Section 4. First Aid Measures

Eye Contact: Flush eyes with water immediately while holding eyelids open. Remove contacts, if worn, after initial flushing and continue flushing for at least 15 minutes. Seek medical attention if irritation persists.
Skin Contact: Use soap and water to remove from the skin, remove contaminated clothing, clean thoroughly before reuse.
Inhalation: Move to fresh air. If not breathing, give rescue breathing. If breathing is difficult administer oxygen. Seek medical attention if breathing is still difficult.
Ingestion: If swallowed, get medical attention immediately. DO NOT INDUCE VOMITING. Never give anything by mouth to an unconscious person.

Section 5. Fire Fighting Measures

Flash Point: Not flammable
Flammability Limits: NE
Fire Fighting Media: Dry chemical, carbon dioxide, and water spray.
Special Fire Fighting Procedures: First responders need to wear full-bunker gear with SCBA, never enter a confined space unless fully protected with proper personal protective equipment (PPE).

Section 6. Accidental Release Measures

Clean-up Procedures: Wear proper PPE. Stop the source of the release if you are not put at risk. Use absorbent material to absorb the spill, use plastic shovel to pick up absorbent for disposal.
Spills and Leaks: Dispose in accordance to local, state or federal regulations.

Section 7. Handling and Storage

Handling: Do not get into eyes. Do not taste or swallow. Wash thoroughly after handling.
Storage: Store in original labeled container. Keep in cool and dry areas.

Section 8. Exposure Control/Personal Protection

Introductory Remarks: Consider the potential hazards of this product outlined in section 3. Use process exposures such as local exhaust ventilation, to control over exposure to airborne levels above recommended exposure limits.
Personal Protection:
Eyes: Wear safety goggles or safety glasses to prevent eye contact.
Body: Long sleeve shirts, long pants, socks, rubber boots and chemical resistant gloves.
Hands: Chemical resistant gloves
Respiratory: Wear an approved respirator that provides protection from this product if the airborne concentrations exceed the recommended exposure limits.
Other: None

Section 9. Physical and Chemical Properties

Odor/Color	Odorless & white liquid	**Vapor Pressure**	> 2.2 torr @ 68 ℉ (20 ℃)
pH	11.0	**Vapor Density(air=1)**	> 1.0
VOC	< 50 g/L	**Solubility**	95 % in water
Evaporation rate(water=1)	> 1.0	**Boiling Point**	212 ℉ (100 ℃)

Section 10. Stability and Reactivity

Chemical Stability: Considered stable under normal ambient temperatures.
Hazardous Decomposition: If complete combustion oxides of carbon and silicate are formed.
Hazardous Polymerization: Will not occur
Incompatibility~ Materials to Avoid: May react with strong oxidizers and strong acids. Extreme temperatures and freezing must be avoided.

Section 11. Toxicological Information

Acute Eye Irritation: Irritating
Acute Skin Irritation: Chronic exposure may be irritating
Acute Dermal Toxicity: Not expected to be toxic through the skin.
Acute Inhalation Toxicity: Not determined, expected to be an irritant to the respiratory system.
Carcinogenic Effects: None
Existing Medical Conditions Aggravated by Exposure: Exposure to eyes and skin may cause irritation to pre-existing conditions.

Section 12. Ecological Information

Ecotoxicity: The toxicity of this product has not been determined.
Environmental Fate: This product should be expected to be readily bio-degradable.

Section 13. Disposal Considerations

Waste Disposal Method: Whatever cannot be saved for recovery or recycling should be managed by the local, state or Federal Regulations.
Container Handling and Disposal: All containers should be triple rinsed and disposed of according to local, state and Federal regulations.

Section 14. Transport Information

Ground Classification: Not regulated by US DOT
Shipping Name: Pentra-Guard® (HP)
Technical Shipping Name: None
UNFIC: None
ID Number: None
Packaging Group: None
Labels: No US DOT Labels
Not regulated by IATA or IMO

Section 15. Regulatory Information

EPCRA 311/312 Categories:	Immediate (Acute) Health Effects:	Yes
	Delayed (Chronic) Health Effects:	Yes
	Fire Hazard:	No
	Sudden Release of Pressure	No
	Reactivity:	No

Right to know classification: None listed in CA, PA, MN, MA, MI, FL and NJ.
TSCA: All of the components either listed or exempt from listing on TSCA inventory.
Reportable Quantity (RQ): None
Prop. 65: Not listed
WHMIS: XI (Irritant to the eyes and skin)
None listed on chemical inventories of ACIS, ECL, EEC, ENCS, EU, Israel, MAC, MAK, MITI, PICCS, SWISS, Taiwan, USA and UK

Abbreviations:

AICS	Australian Inventory of Chemical Substances
CAS #	Chemical Abstract Service Number
°C	Celsius temperature scale
°F	Fahrenheit temperature scale
ECL	Korean Existing Chemicals List
EEC	European Economic Commission
ENCS	Japanese Existing and New Chemical List
EINECS #	European Inventory of Existing Chemical Substances Number
EU	European Union
(Israel)	2001 proposed list of chemical substances to be regulated under Israel Hazardous Substances Law and Regulations List
MAC	Netherlands
MAK	Germany
MITI	Ministry of International trade and Industry
NA	Not applicable
PEL	Permissible Exposure Limit
PICCS	Philippines Inventory of Chemicals and Chemical Substances
PPE	Personal Protective Equipment
Prop.	Proprietary
NA	Not applicable
ND	Not determined
STEL	Short Term Exposure Limit
SWISS	Giftliste 1
SWISS	Inventory of Notified New Substances
TLV	Threshold Limit Value
TSCA	Toxic Substance Control Act
TWA	Time Weighted Average
(Taiwan)	List of Toxic Chemical Substances regulated under Taiwan Toxic Chemical Substances Control Act of 1086
USA	United States of America
UK	United Kingdom

Section 16. Other Information

Hazardous Material Information (HMIS) **National Fire Protection Association (NFPA)**

Health	1	1	Health
Fire	0	0	Fire
Reactivity	0	0	Instability
Personal Protection	C		NA

Health 4 Deadly 3 Extreme Danger 2 Dangerous 1 Slight hazard 0 No hazard
Fire 4 < 73 ºC 3 < 100 ºC 2 < 200 ºC 1 >200 ºC 0 Will not burn
Reactivity/Instability 4 – May detonate 3 Explosive 2 Unstable 1 Normally stable 0 Stable

Risk phrases: R36, Irritating to eyes; R37, Irritating to respiratory system; and R38, Irritating to skin.
Safety phrases: S2, Keep out of reach of children; S24, Avoid contact with skin; S25, Avoid contact with eyes;S37, Wear suitable gloves; and S39, Wear eye/face protection.

Prepared by: Dennis E. Belau
DBelau@comcast.net
Reviewed by: Kent Barrus

Material Safety Data Sheet PENTRA-SIL™ 244+

Section 1. Product and Company Identification


Irritant

Product Name: Pentra-Sil™ 244+
Product use: Concrete chemical hardener, sealer and densifier.
Effective Date: April 19, 2010

Manufacturer Information: Advanced Concrete Technologies, LLC
115 North 1380 West
Orem, UT 84057
Telephone number: 801-375-2280

USA Emergency Phone Number:
INFOTRAC (24-hr/7 days): 1-800-535-5053
Outside the United States call collect 1-352-323-3500
For Medical Emergency - Call 1-800-535-5053

Section 2. Ingredients and Hazards Identification

Hazardous Components					
Component	CAS #	EINECS No	OSHA PEL	ACGIH TLV	Percent
Water	7732-18-5	231-791-2	NA	NA	45-55
Proprietary A	NA	NA	NA	NA	35-45
Proprietary B	NA	NA	NA	NA	15-25
Proprietary C	NA	NA	NA	NA	1 - 8
Proprietary D	NA	NA	NA	NA	5 - 7
None of the compounds contain carcinogens, Prop. 65, SARA 313 listings and are non-hazardous and non-flammable.					

Potential Acute Health Effects:
Eyes: Causes eye irritation
Skin: Expected to cause irritation to the skin
Inhalation: Vapors may cause respiratory irritation
Ingestion: May be harmful.

Section 3. Hazard Identification

The primary routes of entry are eyes, skin and respiratory. Immediate Health Effects:
Eye Contact: Causes irritation.
Skin: Contact with the skin is expected to cause irritation
Ingestion: May cause headache, dizziness, nausea and vomiting.
Inhalation: The vapor or fumes from this product may cause respiratory irritation.
Delayed or other Health Effects: None determined.
Target Organs: None determined.

Section 4. First Aid Measures

Eye Contact: Flush eyes with water immediately while holding eyelids open. Remove contacts, if worn, after initial flushing and continue flushing for at least 15 minutes. Seek medical attention if irritation persists.
Skin Contact: Use soap and water to remove from the skin, remove contaminated clothing, clean thoroughly before reuse.
Inhalation: Move to fresh air. If not breathing, give rescue breathing. If breathing is difficult administer oxygen. Seek medical attention if breathing is still difficult.
Ingestion: If swallowed, get medical attention immediately. DO NOT INDUCE VOMITING. Never give anything by mouth to an unconscious person.

Section 5. Fire Fighting Measures

Flash Point: Not flammable
Flammability Limits: NE
Fire Fighting Media: Dry chemical, carbon dioxide, and water spray.
Special Fire Fighting Procedures: First responders need to wear full-bunker gear with SCBA, never enter a confined space unless fully protected with proper personal protective equipment (PPE).

Section 6. Accidental Release Measures

Clean-up Procedures: Wear proper PPE. Stop the source of the release if you are not put at risk. Use absorbent material to absorb the spill, use plastic shovel to pick up absorbent for disposal.
Spills and Leaks: Dispose in accordance to local, state or federal regulations.

Section 7. Handling and Storage

Handling: Do not get into eyes. Do not taste or swallow. Wash thoroughly after handling.
Storage: Store in original labeled container. Keep in cool and dry areas.

Section 8. Exposure Control/Personal Protection

Introductory Remarks: Consider the potential hazards of this product outlined in section 3. Use process exposures such as local exhaust ventilation, to control over exposure to airborne levels above recommended exposure limits.
Personal Protection:
Eyes: Wear safety goggles or safety glasses to prevent eye contact.
Body: Long sleeve shirts, long pants, socks, rubber boots and chemical resistant gloves. Hands: Chemical resistant gloves
Respiratory: Wear an approved respirator that provides protection from this product if the airborne concentrations exceed the recommended exposure limits.
Other: None

Section 9. Physical and Chemical Properties

Odor/Color	Odorless & clear (reddish tint) liquid	**Vapor Pressure**	> 2.2 torr @ 68 °F (20 °C)
pH	11.0	**Vapor Density(air=1)**	> 1.0
VOC	< 50 g/L	**Solubility**	95 % in water
Evaporation rate(water=1)	> 1.0	**Boiling Point**	212 °F (100 °C)

Section 10. Stability and Reactivity

Chemical Stability: Considered stable under normal ambient temperatures.
Hazardous Decomposition: If complete combustion oxides of carbon and silicate are formed.
Hazardous Polymerization: Will not occur
Incompatibility~ Materials to Avoid: May react with strong oxidizers and strong acids. Extreme temperatures and freezing must be avoided.

Section 11. Toxicological Information

Acute Eye Irritation: Irritating
Acute Skin Irritation: Chronic exposure may be irritating
Acute Dermal Toxicity: Not expected to be toxic through the skin.
Acute Inhalation Toxicity: Not determined, expected to be an irritant to the respiratory system.
Carcinogenic Effects: None
Existing Medical Conditions Aggravated by Exposure: Exposure to eyes and skin may cause irritation to pre- existing conditions.

Section 12. Ecological Information

Ecotoxicity: The toxicity of this product has not been determined.
Environmental Fate: This product should be expected to be readily bio-degradable.

Section 13. Disposal Considerations

Waste Disposal Method: Whatever cannot be saved for recovery or recycling should be managed by the local, state or Federal Regulations.
Container Handling and Disposal: All containers should be triple rinsed and disposed of according to local, state and Federal regulations.

Section 14. Transport Information

Ground Classification: Not regulated by US DOT
Shipping Name: Pentra-Sil 244+
Technical Shipping Name: None
UNFIC: None
ID Number: None
Packaging Group: None
Labels: No US DOT Labels
Not regulated by IATA or IMO

Section 15. Regulatory Information

EPCRA 311/312 Categories:		
	Immediate (Acute) Health Effects:	Yes
	Delayed (Chronic) Health Effects:	Yes
	Fire Hazard:	No
	Sudden Release of Pressure	No
	Reactivity:	No

Right to know classification: None listed in CA, PA, MN, MA, MI, FL and NJ.
TSCA: All of the components either listed or exempt from listing on TSCA inventory.
Reportable Quantity (RQ): None
Prop. 65: Not listed
WHMIS: XI (Irritant to the eyes and skin)
None listed on chemical inventories of ACIS, ECL, EEC, ENCS, EU, Israel, MAC, MAK, MITI, PICCS, SWISS, Taiwan, USA and UK

Abbreviations:

AICS	Australian Inventory of Chemical Substances
CAS #	Chemical Abstract Service Number
ºC	Celsius temperature scale
ºF	Fahrenheit temperature scale
ECL	Korean Existing Chemicals List
EEC	European Economic Commission
ENCS	Japanese Existing and New Chemical List
EINECS #	European Inventory of Existing Chemical Substances Number
EU	European Union
(Israel)	2001 proposed list of chemical substances to be regulated under Israel Hazardous Substances Law and Regulations List
MAC	Netherlands
MAK	Germany
MITI	Ministry of International trade and Industry
NA	Not applicable
PEL	Permissible Exposure Limit
PICCS	Philippines Inventory of Chemicals and Chemical Substances
PPE	Personal Protective Equipment
Prop.	Proprietary
NA	Not applicable
ND	Not determined
STEL	Short Term Exposure Limit
SWISS	Giftliste 1
SWISS	Inventory of Notified New Substances
TLV	Threshold Limit Value
TSCA	Toxic Substance Control Act
TWA	Time Weighted Average
(Taiwan)	List of Toxic Chemical Substances regulated under Taiwan Toxic Chemical Substances Control Act of 1086
USA	United States of America
UK	United Kingdom

Section 16. Other Information

Hazardous Material Information (HMIS) **National Fire Protection Association (NFPA)**

Health	1	1	Health
Fire	0	0	Fire
Reactivity	0	0	Instability
Personal Protection	C		NA

Health 4 Deadly 3 Extreme Danger 2 Dangerous 1 Slight hazard 0 No hazard
Fire 4 < 73 °C 3 < 100 °C 2 < 200 °C 1 >200 °C 0 Will not burn
Reactivity/Instability 4 – May detonate 3 Explosive 2 Unstable 1 Normally stable 0 Stable

Risk phrases: R36, Irritating to eyes; R37, Irritating to respiratory system; and R38, Irritating to skin.
Safety phrases: S2, Keep out of reach of children; S24, Avoid contact with skin; S25, Avoid contact with eyes;S37, Wear suitable gloves; and S39, Wear eye/face protection.

Prepared by: Dennis E. Belau
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Reviewed by: Kent Barrus

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The information is furnished without warranty, representation, inducement, or license of any kind, except that it is accurate to the best of Advanced Concrete Technologies, LLC knowledge. Because use conditions and applicable laws may differ from one location to another and may change with time, Recipient is responsible for determining whether the information is appropriate for recipient's use. Since Advanced Concrete Technologies, LLC has no control over how this information may be ultimately used, all liability is expressly disclaimed and Advanced Concrete Technologies, LLC assumes no liability.

Appendix B: Application-Process Log

Date	Inspection Notes
1/15/2013	Contractor arrived and unloaded equipment.
1/16/2013	Contractor began grinding for paint removal in maintenance bay and hand grinding areas not accessible by planetary grinder. All required PPE in use and all safety practices being followed. No repairs required to maintenance bay floors.
1/17/2013	Contractor continued grinding for paint removal and began grinding concrete for surface preparation. All safety practices employed.
1/18/2013	Dumpster arrived for waste disposal. Continued floor surface preparation in first two maintenance bays. No discrepancies noted.
1/19/2013	Continued floor surface preparation in first two maintenance bays. No discrepancies noted.
1/20/2013	Continued floor surface preparation in first two maintenance bays. Applied Pentra-Sil 244 to center maintenance bay. No discrepancies noted.
1/21/2013	Continued floor surface preparation in second maintenance bay. Accomplished polish grind of center maintenance bay. No discrepancies noted.
1/22/2013	Continued floor surface preparation in second maintenance bay and applied Pentra-Sil 244. Applied Pentra-Guard and buffed center maintenance bay. Began floor preparation in storage room and tool room. No discrepancies noted.
1/23/2013	Continued floor surface preparation in storage room and tool room. Accomplished finish grind and applied Pentra-Guard and buffed second maintenance bay. Began floor tile removal in equipment room and hallway. Applied Pentra-Sil 244 to floors in storage room and tool room. Removed sealant from maintenance bay expansion joints. No discrepancies noted.
1/24/2013	Applied sealant to maintenance bay expansion joints. Accomplished finish grind of floors in storage room and tool room. Continued floor tile removal in hallway and equipment room. No discrepancies noted.
1/25/2013	Began initial grind of floor preparation in equipment room and followed by application colored concrete stain and then application of Pentra-Sil 244 to floor. Applied Pentra-Guard and buffed floors in, storage room, tool room, and equipment room. Repaired cracks in hall floor after all floor tile removed. No discrepancies noted.

Date	Inspection Notes
1/26/2013	Began initial grind of hall floor preparation followed by application of colored concrete stain. Applied Pentra-Guard and buffed floors in equipment room. Began grinding for coating removal of final maintenance bay. No discrepancies noted.
1/28/2013	Applied Pentra-Sil 244 to hall floor and then did the polish grind. Applied Pentra-Guard and buffed hall floor. Began grinding for paint removal of final maintenance bay. No discrepancies noted.
1/29/2013	Continued grinding for paint removal of final maintenance bay, difficulties in removing paint due to uneven floor. Began grinding for surface preparation in some areas of final maintenance bay. No discrepancies noted.
1/30/2013	Continued grinding and preparation for final maintenance bay. Due to configuration, significant areas of this maintenance bay must be ground with hand grinders. No discrepancies noted.
1/31/2013	Completed preparation grinding of final maintenance bay and applied Pentra-Sil 244. Began final polishing grind and applied Pentra-Guard then buffed. No discrepancies noted.
2/1/2013	Applied sealant to final maintenance bay expansion joints and painted grounding points. Contractor began loading equipment for demobilizing and area clean up. Construction dumpster removed from site. Closed out meeting held with the government and no discrepancies requiring correction noted.

Appendix C: Coating Friction Test Results

This series of tests was conducted by Convergent Concrete Technologies according to ASTM C-1028-96 guidelines. All samples had a machine trowel finish. The Pentra-Guard sample was also polished with diamond discs up to 1000 grit. Note that the testing personnel may not be independent of the manufacturer.

Results

Dry untreated specimen = 0.710
Wet untreated specimen = 0.480

Pentra-sil treated specimen

Dry =0 .770
Wet =0 .470

Pentra-sil 244+ treated specimen

Dry =0 .731
Wet =0.470

Pentra-Guard treated specimen

Dry = 0.690
Wet = 0.360

Interpretation

The dynamics of friction on concrete are very complex. This testing can only be interpreted to mean that Pentra-sil products do not significantly alter the friction qualities of the surface they are applied to. All standard methods for accident prevention must be used in situations where slip and fall or traction concerns exist.

Lee Barrus, Test Engineer
Convergent Concrete Technologies

Appendix D: Exposure Test Results

Table D1 lists the test chemicals used and which specimen sample each was exposed to each. Figure D1 through Figure D24 comprise a photographic record of the exposure test procedure.

Table D1. Test chemicals.

Sample No.	National Item Identification Number	Part Number / MIL-SPEC	Description
1	01-438-6079	MIL-PRF-2104H	Engine Oil 15/40
2	01-035-5393	MIL-PRF-2105	80W90 Gear Oil
3	01-496-1948	MIL-PRF-2104G	10W Oil
4	01-464-9137	A-A-52624 Type 1 Recycled	Antifreeze
5	01-197-7692	MIL-PRF-10924H	GAA Grease
6	01-102-9455	MIL-PRF-46176B	Brake Fluid
7	00-252-6383	MIL-PRF-5606H	Hydraulic Fluid H515
8	01-439-0681	110054	WD-40 CPC
9	01-353-4799	Hydraulic Fluid	ATF Dextron 6
10	N/A	LOCAL PURCHASE	Nu-Brite

Figure D1. Test specimen showing sample numbers.

Figure D2. Initial application of test chemicals.

Figure D3. After one week exposure.

Figure D4. Watch glasses removed.

Figure D5. Selected commercial cleaning products.

Figure D6. After initial cleaning with Simple Green.

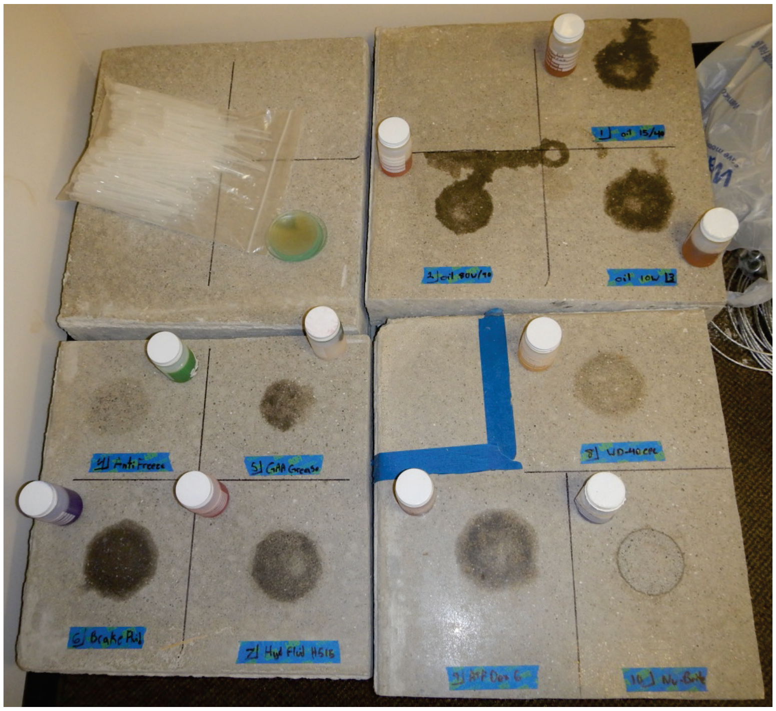

Figure D7. After initial cleaning with Citrus Cleaner.

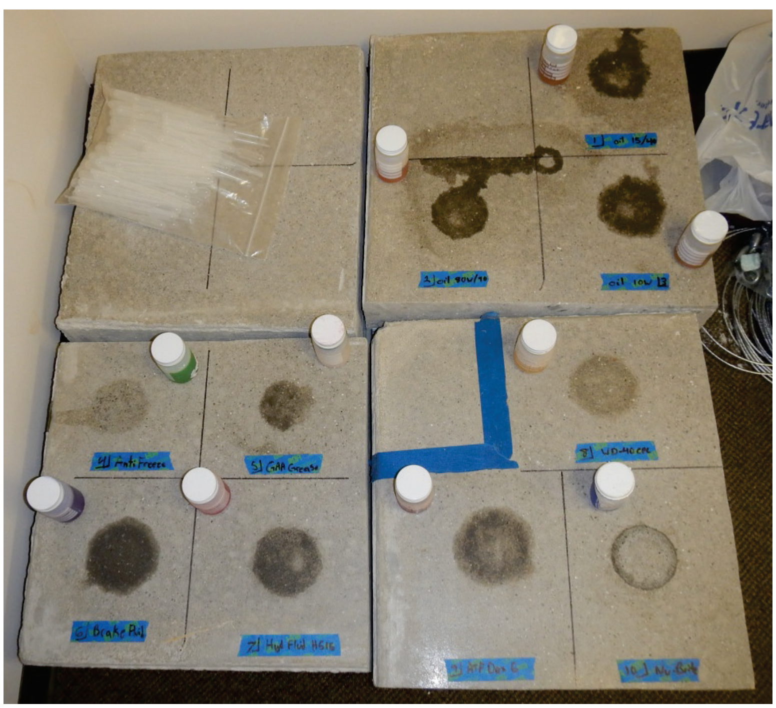

Figure D8. Twenty-four hours after cleaning.

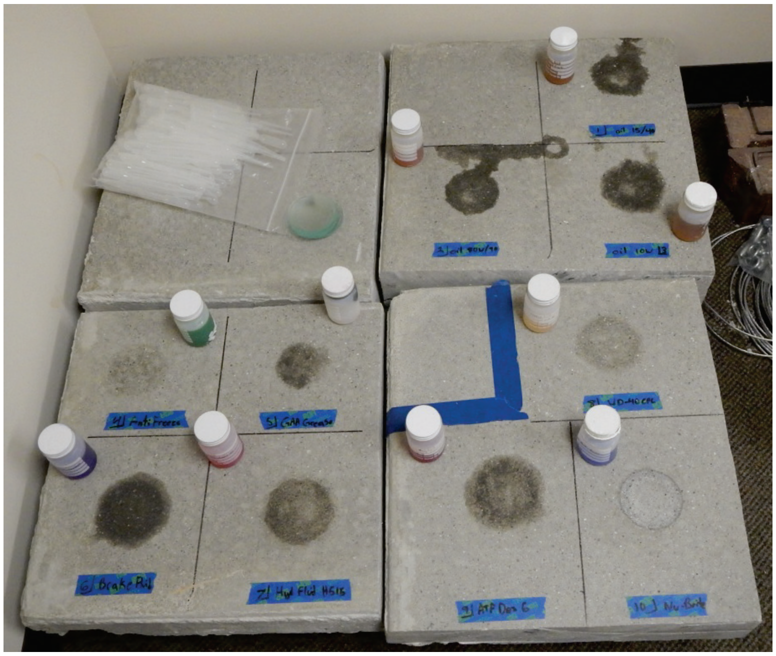

Figure D9. Second application of test chemicals.

Figure D10. Second exposure, after one week.

Figure D11. After watch glasses removed.

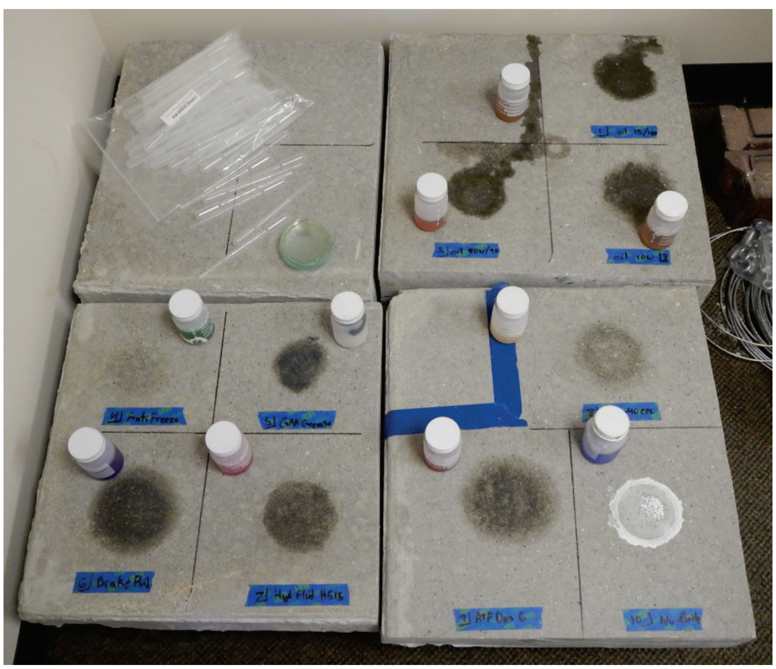

Figure D12. After second cleaning with Simple Green.

Figure D13. After second cleaning with Citrus Cleaner

Figure D14. Twenty-four hours after second cleaning.

Figure D15. Test 1–MIL-PRF-2104H engine oil 15W40.

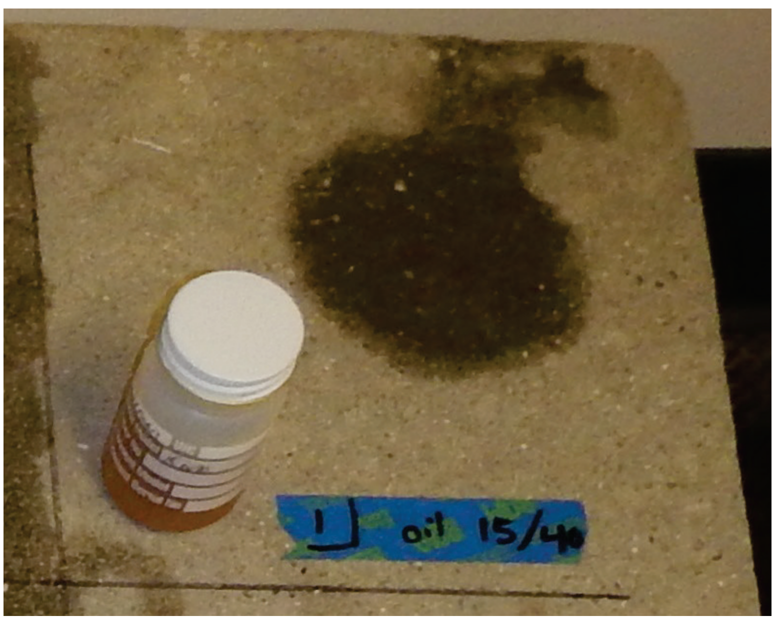

Figure D16. Test 2–MIL-PRF-2105 80W90 gear oil.

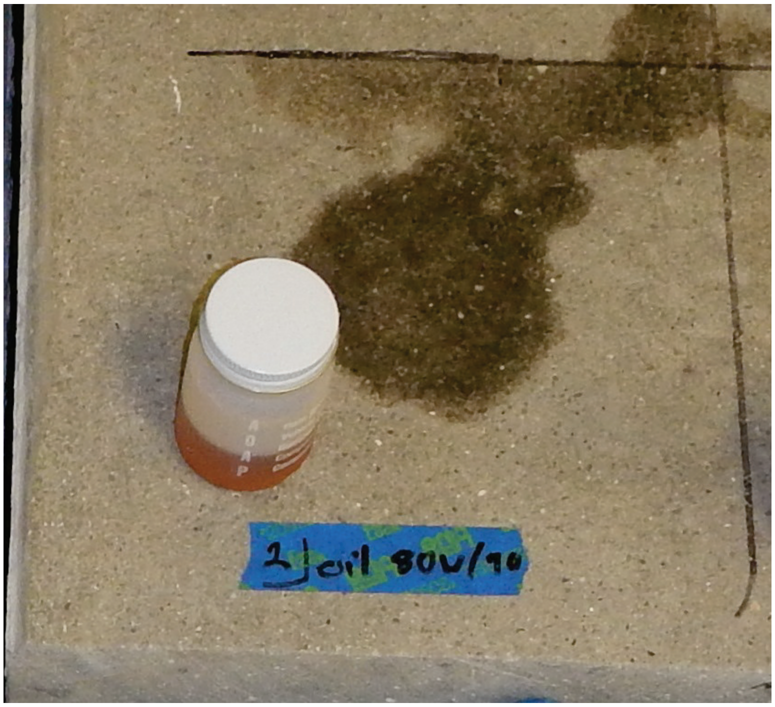

Figure D17. Test 3–MIL-PRF2104G 10W oil.

Figure D18. Test 4–A-A-52624 Type 1 recycled antifreeze.

Figure D19. Test 5–MIL-PRF-10924H GAA grease.

Figure D20. Test 6–MIL-PRF-46176B brake fluid.

Figure D21. Test 7–MIL-PRF-5606H hydraulic fluid.

Figure D22. Test 8–110054 WD-40 light lubricant.

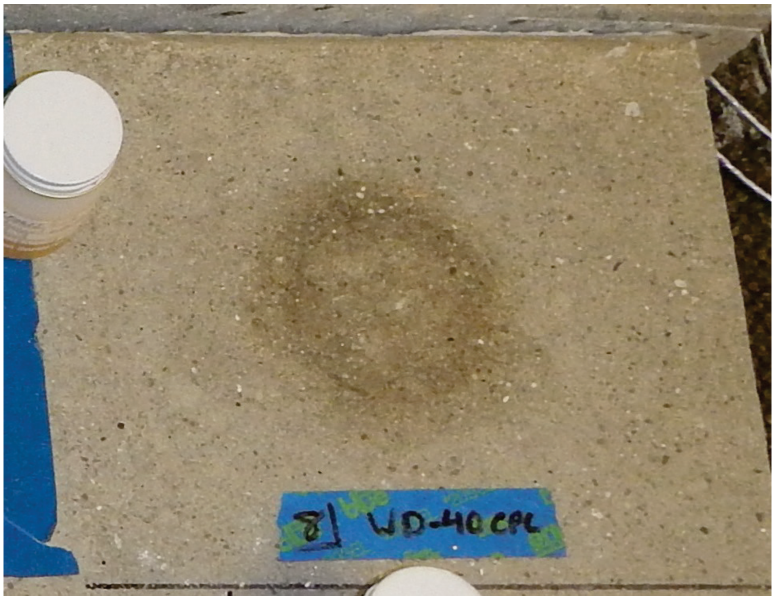

Figure D23. Test 9–Hydraulic Fluid ATF Dextron 6.

Figure D24. Test 10–Nu-Brite alkaline coil cleaner.

Only one material—Nu-Brite Alkaline Coil Cleaner—had any damaging effect on the Pentra-Sil® 244+ and Pentra Guard® (HP) surface sealant system. This caustic chemical defeated the sealant system and physically etched the polished concrete surface.

The A-A-52624 Type 1 Recycled Antifreeze had no effect on the concrete or sealant system. All the other test chemicals penetrated the sealant system and were absorbed by the concrete coupons to differing degrees, leaving permanent stains.

The scope of this testing was limited to assessing the sealant system's stain-protection and cleanability characteristics, and did not evaluate the physical impact of chemical absorption on the concrete. However, with the exception of the caustic coil cleaning product, the test chemicals had no discernible effect on the concrete coupons other than the residual stain.

Color and gloss measurements after chemical exposure

The test specimens were evaluated for gloss and color change upon completion of exposure testing. Table D2 documents the color and gloss data. A control sample was simulated by averaging gloss and color readings taken from three areas of the specimen that were not tested. The averaging provided an appropriate benchmark against which data from the treated samples could be compared.

Table D2. CIELAB color and gloss readings on test specimens.

Sample Material	Date and Time	Color scale L*	Gloss	Date and Time	Color scale L*	Gloss
1: Engine Oil 15/40	11/22/13 07:08:31pm	60.60	7.0	01/17/14 08:43:57pm	33.14	11.0
2: 80W90 Gear Oil	11/22/13 07:10:03pm	58.78	13.6	01/17/14 08:44:28pm	35.48	10.3
3: 10W Oil	11/22/13 07:10:15pm	60.85	9.3	01/17/14 08:44:40pm	32.52	10.5
4: Antifreeze	11/22/13 07:10:28pm	63.42	6.1	01/17/14 08:44:52pm	59.45	8.6
5: GAA Grease	11/22/13 07:10:37pm	59.79	9.9	01/17/14 08:45:03pm	36.47	6.8
6: Brake Fluid	11/22/13 07:10:48pm	60.85	12.7	01/17/14 08:45:13pm	39.46	6.5
7: Hydraulic Fluid H515	11/22/13 07:10:58pm	60.89	13.3	01/17/14 08:45:23pm	38.55	16.4
8: WD-40 CPC	11/22/13 07:11:10pm	59.48	18.0	01/17/14 08:45:31pm	57.88	8.2
9: ATF Dextron 6	11/22/13 07:11:19pm	62.04	8.4	01/17/14 08:45:39pm	38.83	9.0
10: Nu-Brite	11/22/13 07:11:27pm	60.81	14.7	01/17/14 08:45:47pm	61.02	3.8
Control_1		62.00	5.8			
Control_2		63.13	2.9			
Control_3		61.75	2.6			
Average		**62.29**	**3.78**			

The results of the gloss test show that the absorption of test chemicals into the concrete increased the gloss readings as compared with the control value.

Color test results reveal the darkening of the test areas due to chemical staining. This test used the International Commission on Illumination LAB color space, called the *1976 CIE L*a*b* Space* (Adobe Systems, http://dba.med.sc.edu/price/irf/Adobe_tg/models/cielab.html) as the benchmark for determining color changes. In particular, it applied the *luminance* axis of darkness-lightness values (respectively 0 – 100), ignoring the *a* and *b* axes of the LAB color space.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)* May 2015

2. REPORT TYPE Final

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Demonstration and Validation of a High-Performance Floor-Sealant System to Reduce Concrete Degradation: Final Report on Project F10-AR02

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
Corrosion Prevention and Control

6. AUTHOR(S)
Clint A. Wilson and Susan A. Drozdz

5d. PROJECT NUMBER
F10-AR02

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

US Army Engineer Research and Development Center
Construction Engineering Research Laboratory
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CERL TR-15-9

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of the Secretary of Defense (OUSD(AT&L))
3090 Defense Pentagon
Washington, DC 20301-3090

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

Military installations and bases maintain virtually countless facilities with concrete floors, such as warehouses, vehicle garages, and aircraft maintenance facilities. Because concrete is a porous material, it can prematurely deteriorate due to the intrusion of moisture, lubricants, and other contaminants in combination with mechanical stresses imposed by heavy equipment traffic. This project demonstrated and validated the performance characteristics of a high-performance sealant system designed to toughen concrete floor surfaces in order to reduce material degradation due to heavy use. This report describes a study undertaken to assess the capabilities and advantages of a high performance floor-sealant system to protect and improve the service life of concrete floors. The project demonstrated that military installations can reduce maintenance costs for concrete floors by providing a durable, penetrating surface sealant that toughens the concrete to resist material degradation.

15. SUBJECT TERMS

sealant systems, concrete, military installations, performance, maintenance costs

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
Unclassified	Unclassified	Unclassified		66	