Although there are annual reports, various testing reports and publications related to SURTREAT® technologies, case studies within the U.S. Military, and regardless of the positive outlook that such reflect, the assembled materials that follow are not presented or to be interpreted as an "Endorsement" by the U.S. Armed Forces or any of the engineering divisions or departments within.

The materials related to the collaboration between SURTREAT® and NASA inherit NASA's mandate to share and develop new technologies partnered with the private sector resulting in their progressive publicizing of the successes, such as the decade-long joint venture with SURTREAT®.

Technical Reports and Publications

US Army Corps of Engineers
Engineer Research and Development Center

Abstract: The corrosion of steel rebar in reinforced concrete structures is a pervasive and expensive problem for the Department of Defense.

The maintenance and repair costs for affected structures and equipment amounts to hundreds of millions of dollars each year, and the degradation negatively impacts military readiness and infrastructure safety.

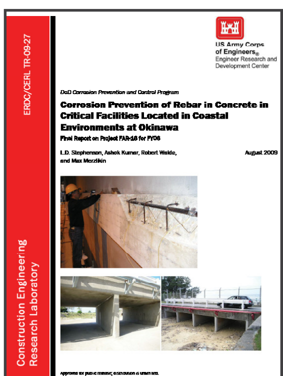
This report documents a demonstration of a concrete rebar corrosion inhibitor system and a liquid galvanic coating that provides cathodic protection for steel-reinforced concrete.

These treatments were applied to critical infrastructure in a highly corrosive environment located at U.S. military facilities in Okinawa, specifically, two portions of a wall ring girder in a warehouse at Naha Military Port and two culvert bridges at the Kadena Air Force Base fuel storage depot.

The data obtained in this demonstration show quantitatively that the corrosion inhibitor application significantly reduced the corrosion rate of the rebar on the tested structures. The galvanic coating appears to be providing protection to the rebar, but quantifying the extent of protection or positive impact on service life would require further monitoring and evaluation.

Executive Summary

This OSD Corrosion Control and Prevention (CPC) project evaluated and demonstrated the use of two types of emerging technologies to mitigate corrosion in existing concrete structures.


ERDC/CERL TR-09-27

US Army Corps of Engineers® Engineer Research and Development Center

DoD Corrosion Prevention and Control Program

Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa

Final Report on Project FAR-18 for FY06

L.D. Stephenson, Ashok Kumar, Robert Weide, and Max Merzlikin — August 2009

Construction Engineering Research Laboratory

Approved for public release; distribution is unlimited.

The first type consists of surface applied corrosion inhibitors for steel reinforced concrete structures. The second type is a sacrificial cathodic corrosion protection coating developed by the National Aeronautics and Space Administration (NASA).

The Surtreat corrosion protection system used in this project consists of (1) an ionic-anodic type of inorganic migratory corrosion inhibitor (TPSII), (2) an organic vapor phase migratory corrosion inhibitor (TPS XII), and (3) a reactive silicone surface protection agent (TPS XVII).

The combined application of these three corrosion-inhibiting formulations provides a durable and multifunctional corrosion-inhibiting environment along with a reduction in water penetration rate.

The cathodic coating system consists of an inorganic silicate vehicle containing zinc, aluminum, magnesium, and indium metal powders. The coating is applied to a reinforced concrete surface along with titanium mesh strips that are connected to the rebar to conduct cathodic current produced by the coating.

Two culvert bridges located at the Kadena Air Force Base fuel tank farm and two wall ring girders in the northeast end of Warehouse Building 306 at the Naha Military Port were selected as the technology demonstration sites.

The two bridges exhibited early signs of rebar corrosion as seen by concrete spalling in several areas, exposing rusted rebar. The two sections of wall ring girders exhibited significant signs of rebar corrosion in the form of concrete spalling and exposed rusty rebar.

The project results show that properly selected and applied migratory corrosion inhibitors or sacrificial cathodic coating systems can be successfully used to extend the life of reinforced concrete structures. These technologies demonstrated the capability of reducing measured corrosion rates.

Before and after measurements indicated rates were reduced by a factor of 3.5 on culvert 2, by 2.7 on ring girder 1, and by 1.9 on ring girder 2. Water permeation rates were also significantly reduced. A return on investment of 10.29 is projected, resulting from a service life increase for the treated structures.

SURTREAT

Final Report for N62470-14-D-3006 at U.S. Military Installations Okinawa, Japan

Prepared for: Naval Facilities Engineering Command 6/8/2016
Prepared by: Corrpro, an AEGION Company (Project No. – 340531156)

Note: This is a synopsis of the full report provided by Corrpro which is available upon request. This is the third and final report on this project since it was implemented in 2006.

Corrpro, a company specialized in corrosion protection, has been contracted by the National Institute of Building Sciences to conduct testing as part of an evaluation to determine the effectiveness of corrosion inhibitor technology for steel rebar in reinforced concrete.


Prepared For:
NAVFAC
Prepared By:
corrpro
an AEGION company

This testing is a follow up to the testing performed after installation in January 2007 as documented in the CERL report dated August 2009, and subsequent testing performed as documented in the Corrpro 2010 report.

Because corrosion of steel reinforcement is an ongoing expensive maintenance issue effective treatments are studied to reduce the impact of corrosion on military infrastructure. The structures selected for this test are in particularly corrosive coastal environments.

Two project sites in Okinawa were selected due to the harsh environment and visible deterioration of concrete. Two culvert bridges located at Kuwae Tank Farm (referred to in the CERL project report ERDC/CERL TR-09-27 as bridges 2 and 3) were chosen for application of the SURTREAT system. Bridge 2 received the entire 3-part SURTREAT system.

Bridge 3 only received the inorganic inhibitor and silicone sealant. The second project site was inside a warehouse at Naha Military Port. Two sections of ring girder were selected, one treated with the SURTREAT system, and the other coated with the NASA coating which was not part of this evaluation but was found to be greatly deteriorated.

ANALYSIS

Concrete pH and depth of carbonation were measured using a rainbow indicator solution. The pH measured immediately under the treated surface was in the range of 9-10 at a depth of 1/8".

A series of compressive strength measurements were made using a Schmidt hammer on an area of concrete previously tested. The average measured value was 5200 psi, which is an increase from the previous measurements in 2010 and 2007.

We compared the most recent corrosion rate values with the previously measured values before treatment, 6 months after treatment, and approximately 3 years after treatment. The 3-part SURTREAT system, based upon measurements of corrosion rate and moisture penetration, is effectively protecting the rebar from corrosion. To date, an average reduction in the corrosion rate by 79 to 80% has been realized.

Results: Over 10 years later the concrete is stronger than when first poured and corrosion has been reduced approximately 80% which will significantly extend the life of these assets.

"SURTREAT" is performance tested and verified by independent laboratories and agencies" Frank Wilson, President, AECOM

National Aeronautics and Space Administration (NASA)

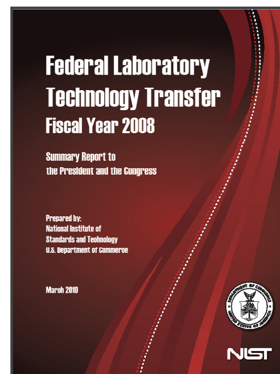
Since its creation in 1958, NASA has been charged with disseminating the results of its research broadly for public benefit.   The organization responsible for technology transfer within NASA is the Innovative Partnerships Program (IPP).

With offices at HQ and all ten of NASA's field centers, IPP seeks to develop technology to meet NASA's needs through partnerships with industry, academia, government agencies, and national 38 laboratories, and facilitates intellectual property protection and transfer out of NASA developed technology for commercial application and broad public benefit.

IPP also works through its center offices to foster collaboration with state and local governments involved in public benefit and local economic growth through technology development and technology transfer.

Each year, NASA documents some notable successes from technology transfer efforts in the annual Spinoff publication. It is available online at http://www.sti.nasa.gov/spinoff and hard copies are available upon request More than 1,600 spinoff successes have been documented in the publication and are all searchable by keyword on the website.

In addition, NASA has established a website called NASA@Home, NASA City, located at http://www.nasa.gov/city which helps the public understand how NASA technologies are present in and contributing to the quality and safety of their everyday life. NASA is also participating, along with several other federal agencies, in using RSS feeds to highlight technologies available for licensing to the commercial and research communities; details are made available on the IPP web site.



More information about the NASA Innovative Partnership Program can be found at: http://www.ipp.nasa.gov; http://www.sti.nasa.gov/spinoff; http://www.nasa.gov/city

Treatment Prevents Corrosion in Steel and Concrete Structures

To protect concrete launch structures at Kennedy Space Center from corrosion, NASA developed an electromigration technique that sends corrosion-inhibiting ions into rebar to prevent rust, corrosion, and separation from the surrounding concrete.

Kennedy worked with Surtreat Holding LLC, of Pittsburgh, Pennsylvania, a company that had developed a chemical option to fight structural corrosion, combining Surtreat's TPS-II anti-corrosive solution and electromigration. Kennedy's materials scientists reviewed the applicability of the chemical treatment to the electromigration process and determined that it was an effective and environmentally friendly match.

NASA has also developed a new technology that will further advance these efforts-a liquid galvanic coating applied to the outer surface of reinforced concrete to protect the embedded rebar from corrosion. Surtreat licensed this new coating technology and put it to use at the U.S. Army Naha Port, in Okinawa, Japan.

The new coating prevents corrosion of steel in concrete in several applications, including highway and bridge infrastructures, piers and docks, concrete balconies and ceilings, parking garages, cooling towers, and pipelines.

A natural complement to the new coating, Surtreat's Total Performance System provides diagnostic testing and site analysis to identify the scope of problems for each project, manufactures and prescribes site-specific solutions, controls material application, and verifies performance through follow-up testing and analysis

SPACE ACT AGREEMENT Defined

The National Aeronautics and Space Act of 1958 (herein, the Space Act), as amended (42 U.S.C. sec 2451 et seq.), authorizes NASA "to enter into and perform such contracts, leases, cooperative agreements, or other transactions as may be necessary in the conduct of its work..." with domestic and foreign entities.

Under this unique authority, NASA has entered into a large number of agreements with diverse organizations, both in the private and public sectors, in order to meet wide-ranging NASA mission and program requirements. The agreement partner can be a U.S. or foreign person or entity, and academic institution, a Federal, state, or local governmental unit, a foreign government, or an international organization, for profit, or not for profit.

A Space Act Agreement between Kennedy Space Center and SURTREAT® resulted in a new treatment that keeps buildings from corroding away over time. The agreement merged Kennedy Space Center's research into electrical treatments of structural corrosion with chemical processes developed by SURTREAT. Combining NASA and SURTREAT technologies has resulted in a unique process with broad corrosion-control applications.

NASA TECHNOLOGY TRANSFER PROGRAM

Forty years ago in July of 1958 a congressional mandate directed the National Aeronautics and Space Administration to ensure the widest possible dissemination of information resulting from its R&D efforts.

This gave birth in, 1962, to NASA's Technology Utilization Program. It included three Industrial Assistance Centers, released the first Tech Brief in loose-leaf format, expanded the industrial outreach each by increasing the Assistance Centers to ten over a period of years, and started COSMIC, the Computer Software and Management Information Center.

In recent years, the Program has changed its structure, goal, and mission, and has broadened its scope. It is currently known as the NASA Commercial Technology Program, with a wide network of organizations ready to do business in a different, improved, and more appropriate way.

Today, the NASA Commercial Technology Network provides a great number of different publications and services geared to enhance and further the global competitiveness of U.S. industry. The Commercial Technology Division at NASA Headquarters and the Commercial Technology Program offices at the ten field centers serve as gateways to accessing the cutting-edge research and technology available for transfer and commercial use.

1988 - Concrete Solution

NASA Center: Kennedy Space Center - Public Release Year: 1998 - Reference Number: KSC-SO-31
Category: Environment and Resource Management - Origin: Corrosion Resistance on Launch Pads at Cape Canaveral

Abstract:

A Space Act Agreement between Kennedy Space Center and Surtreat Southeast, Inc., resulted in a new treatment that keeps buildings from corroding away over time. Structural corrosion is a multi-billion dollar problem in the United States. The agreement merged Kennedy Space Center's research into electrical treatments of structural corrosion with chemical processes developed by Surtreat. Combining NASA and Surtreat technologies has resulted in a unique process with broad corrosion-control applications.

2007 - Treatment Prevents Corrosion in Steel and Concrete Structures

NASA Center: Kennedy Space Center - Public Release Year: 2007 - Reference Number: KSC-SO-107
Category: Environment and Resource Management - Origin: TPS-II anti-corrosive solution and electromigration

Abstract:

In the mid-1990s, to protect rebar from corrosion, NASA developed an electromigration technique that sends corrosion-inhibiting ions into rebar to prevent rust, corrosion, and separation from the surrounding concrete. Kennedy Space Center worked with Surtreat Holding LLC, of Pittsburgh, Pennsylvania, a company that had developed a chemical option to fight structural corrosion, combining Surtreat's TPS-II anti-corrosive solution and electromigration.

Kennedy's materials scientists reviewed the applicability of the chemical treatment to the electromigration process and determined that it was an effective and environmentally friendly match. Ten years later, NASA is still using this approach to fight concrete corrosion, and it has also developed a new technology that will further advance these efforts-a liquid galvanic coating applied to the outer surface of reinforced concrete to protect the embedded rebar from corrosion.

Surtreat licensed this new coating technology and put it to use at the U.S. Army Naha Port, in Okinawa, Japan. The new coating prevents corrosion of steel in concrete in several applications, including highway and bridge infrastructures, piers and docks, concrete balconies and ceilings, parking garages, cooling towers, and pipelines. A natural compliment to the new coating, Surtreat's Total Performance System provides diagnostic testing and site analysis to identify the scope of problems for each project, manufactures and prescribes site-specific solutions, controls material application, and verifies performance through follow-up testing and analysis

2016 - Primer Stops Corrosion without Requiring Rust Removal

NASA Center: Kennedy Space Center - Public Release Year: 2016 - Reference Number: KSC-SO-140
Category: Public Safety - Origin: Concrete corrosion inhibition at Kennedy

Abstract:

In the mid-1990s, Pittsburgh-based Surtreat Inc. developed two corrosion inhibitors that, applied to the surface of concrete, migrated to the rebar inside. The company entered into a Space Act Agreement with Kennedy Space Center, conducting tests that validated the inhibitors as among the most effective on the market. Recently, Surtreat used a compound similar to one tested at Kennedy to develop a new pigmented primer that can be applied directly to rusty steel to inhibit corrosion.

Primer Stops Corrosion without Requiring Rust Removal

NASA Technology

"The world is made out of bad concrete and rusty steel, and corrosion is the primary cause of deterioration of our infrastructure," says Bob Walde, vice president of technology for Surtreat Holding LLC. The problem, he says, is that engineers tend to try to stop corrosion by physical means that address the symptoms but not the underlying causes. "Corrosion is an electrochemical process, and it can be inhibited by changing the chemical environment around the steel."

To that end, in the mid-1990s Surtreat, based in Pittsburgh, developed two corrosion inhibitors that worked by chemical means and were designed to be applied to the surface of concrete, where they would migrate to the steel rebar inside. By 1996, though, the formulas still had not been formally tested and validated.

Meanwhile, of all the concrete in all of NASA's field centers, probably none has it harder than that in the structuresat Kennedy Space Center. Not only is the seaside campus, located near Orlando, constantly bathed in damp, salty air, but some of its concrete is in and around the Cape Canaveral launch pad, where rocket boosters blast it with white heat, hydrochloric acid, and other hazards, while it's simultaneously sprayed with water for cooling. For these reasons, in February 1996, Kennedy entered into a Space Act Agreement with Surtreat to test its products (Spinoff 1998). Joe Curran, a NASA-contracted corrosion engineer at Kennedy, set up the testing.

A worker applies Surtreat's volatile corrosion inhibitor, which was validated through testing at NASA's Kennedy Space Center, to bare, rusty steel rebar on a bridge over the New Jersey Turnpike. The company has now created an epoxy primer that also can be applied directly to rusted steel to inhibit further corrosion.

One of the products validated during those tests has now led to a new epoxy primer that can be applied directly to clean or rusty steel to stop corrosion.

Kennedy spends considerable money on corrosion prevention, says Curran, who now does similar work for the Air Force at Cape Canaveral Air Force Station. "If there's a less expensive way to do it, you should think about doing that."

Rusting occurs as iron, the main ingredient in steel, loses electrons, he explains, noting that saltwater, which is highly conductive, accelerates this process. As rebar rusts, it expands, breaking up the concrete surrounding it. l

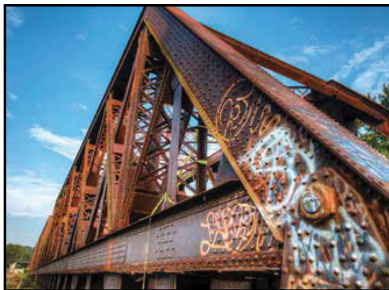
One of Surtreat's early solutions was an inorganic compound whose ions would readily migrate through the concrete to the steel to form a corrosion-resistant surface. The other was an organic compound whose vapor would pass rough the pores and cracks in the concrete and form a protective film on the steel surface.

During testing, Curran applied a number of different manufacturers' inhibitor products to several reinforced concrete "coupons" and assessed them by three different methods. Salt-fog chamber testing subjected them to a measured chloride concentration at a set frequency of salty fog for a set duration. Another test used a technique called electrochemical impedance spectroscopy to measure the rebar's resistance to corrosive current flow.

He also employed the American Society for Testing and Materials' widely used method for determining the effects of chemical admixtures on the corrosion of rebar in concrete. Curran waited until corrosion was taking place in the salt-laden test blocks, then treated them with corrosion inhibitors. After a period of time, he measured the macro-corrosion currents between the rods of rebar and determined that corrosion rates were reduced.

Of the several corrosion inhibitors he tested, Curran says, Surtreat's vapor-migrating inhibitor was a top performer and was subsequently used on Kennedy's Launch Pad 39A and other reinforced concrete structures at the space center. Other private contractors used the Surtreat product to treat beachside condominium balconies and other structures in the Central Florida area.

82 Public Safety *Spinoff 2016*



Far right, Surtreat's latest product, an epoxy primer with a volatile corrosion inhibitor, has been applied to a rusted abutment bearing under a bridge in Houston as part of a pilot project.

The U.S. Navy is interested in the primer for ship maintenance, and the Federal Department of Transportation is considering using it, especially on bridges.

Technology Transfer

"The NASA results showed that the inhibitors did migrate from the surface to the rebar and did inhibit the corrosion," Walde says. "That allowed us to go out and market these two corrosion inhibitors with greater confidence." The products went on to be used on bridges, parking garages, military installations, power plants, condominiums, and other structures across the country and abroad.

In a 2007 partnership with the U.S. Army Corps of Engineers, Surtreat experimented with applying its products directly to the surface of corroded steel at two military installations in Okinawa.

The work was successful, and in 2010 the Corps of Engineers commissioned the company to develop a pigmented epoxy primer that could be applied to rusty steel to inhibit corrosion. Surtreat ended up using an organic compound similar to the one that had been tested at Kennedy, known as a volatile corrosion inhibitor (VCI), whose vapor would migrate through the rust to the steel surface and form a protective film.

"We had to find a paint system that the VCI would be compatible with, where it wouldn't change any of the characteristics of the paint, and the paint wouldn't hinder the corrosion inhibitor," Walde says. The company developed a two-part primer, which was evaluated by the U.S. Army Corps of Engineers in 2012 and was found to be effective on rusty surfaces to the point that it offered 5–10 times the corrosion-inhibiting properties of the standard primer. Surtreat filed for a patent that year and created VCI Coatings LLC to market the product.

Benefits

"We're still trying to get people to understand that if you have a problem of chemical deficiency, you might want to use a chemical solution," Walde says. But people are beginning to come around. The U.S. Department of Transportation has expressed interest in the new corrosion-inhibiting paint, mostly for use on bridges, and the Navy is interested in it for ship maintenance, Walde says, adding that by late 2014 a number of painting contractors had also used VCI Coatings' primer to protect everything from metal roofs to bridge cables, to the galvanized pans under a football stadium's walkway.

"We're quite optimistic about the commercial opportunity here," Walde says. Other corrosion inhibitors require all rust to be scraped off a steel surface before they're applied, at a cost that Surtreat estimates at as high as $5 per square foot. That adds up quickly on a large structure. The new product costs about twice what a basic primer costs, but that expense is more than offset by the savings in surface preparation and the increased lifespan of the steel.

The company calculates a cost of 57 cents per square foot per year over 10 years for a basic primer, as opposed to 10 cents a year over 20 years for its primer with the VCI agent. The primer can also be applied to new steel surfaces to increase their lifespan. Walde says the company still credits the Space Agency with proving the effectiveness of this family of compounds.

"It was the work done by Joe Curran at NASA Kennedy Space Center that first defined the functionality of these corrosion inhibitors for migrating to a steel surface, which has evolved into what's now been incorporated into the primer," he says.

Treatment Prevents Corrosion in Steel and Concrete Structures

Originating Technology/NASA Contribution

NASA's Kennedy Space Center is located on prime beachfront property along the Atlantic coast of Florida on Cape Canaveral. While beautiful, this region presents several challenges, like temperamental coastal weather, lightning storms, and salty, corrosive, sea breezes assaulting equipment and the Center's launch pads.

The constant barrage of salty water subjects facility structures to a type of weathering called spalling, a common form of corrosion seen in porous building materials such as brick, natural stone, tiles, and concrete.

In spalling, water carries dissolved salt through the building material, where it then crystallizes near the surface as the water evaporates. As the salt crystals expand, this creates stresses which break away chips, or spall, from the surface, causing unsightly and structural damage.

The potential for corrosion heightens as concrete structures age, because over time concrete loses its acidity, or pH. When it starts out, poured concrete has a high pH value, between 11 and 13, which helps to inhibit corrosion. Over time, though, this value drops, and when the pH value dips into the 8 to 9 range, there is potential for corrosion of the steel reinforcing bars, or rebar, causing further structural concerns.

In the mid-1990s, to protect the rebar, NASA developed an electromigration technique that sends corrosion-inhibiting ions into rebar to prevent rust, corrosion, and separation from the surrounding concrete.

An ounce of prevention is worth a pound of cure, and with the help of Florida's Technological Research and Development Authority, an independent state agency that partnered with Kennedy on technology transfer initiatives, the Center began working with Surtreat Holding LLC, of Pittsburgh, Pennsylvania, a company that had developed a chemical option to fight structural corrosion in 1997.


The Surtreat coating is environmentally friendly and lasts 10 years or more, reducing maintenance costs over the lifetime of the structure.

Surtreat's method was to apply its anti-corrosive solution product, TPS-II, to the surface of a corroding concrete slab, where it would then seep through to the rebar, coating it and preventing further corrosion.

Combining Surtreat's TPS-II with electromigration fit well in the Kennedy dual-use program, part of NASA's technology transfer and commercialization effort.

The cooperative effort involved Surtreat providing NASA with the corrosion-inhibiting chemical and concrete test slabs, along with technical support as needed.

Kennedy provided testing specifications and procedures, then prepared the concrete with the Surtreat chemical and carried out an environmental evaluation of the treatment. Kennedy's materials scientists reviewed the applicability of the chemical treatment to the electromigration process and determined that it was an effective and environmentally friendly match, suitable for use at the NASA facility.

Ten years later, NASA is still using this combined approach to fight concrete corrosion, and it has also developed a new technology that it believes will further advance these efforts. The technology is a liquid galvanic coating, applied to the outer surface of reinforced concrete, to protect the embedded rebar from corrosion.

The coating contains one of several types of metallic particles—magnesium, zinc, or indium. An electrical current established between metallic particles in the applied coating and the surface of the steel rebar produces cathodic protection of the rebar.

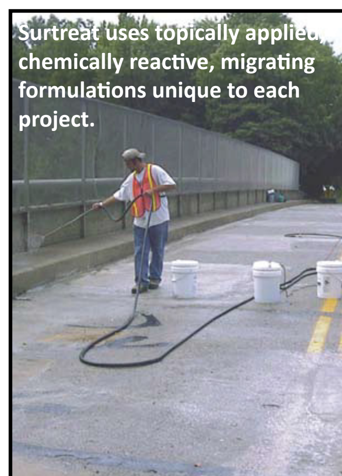
This parking structure was suffering from water and deicing salt infiltration, causing a number of corrosion-related problems throughout the structure. The Surtreat chemicals migrated over 2 inches below the surface, halting corrosion.

The current forces a flow of electrons from the coating (anode) to the rebar along a separate metallic connection. This surplus of electrons at the rebar (cathode) prevents the loss of metal ions that would normally occur as part of the natural corrosion process.

The technology, made of inexpensive, commercially available ingredients, can be applied to the outside surface of reinforced concrete (most rebar corrosion prevention must be applied directly to the rebar) and with a conventional brush or spray, eliminating the need for expensive, specialized labor.

Partnership - Ten years after its initial partnership, Surtreat has partnered with NASA again by licensing the new liquid galvanic coating technology and has already put it to use. Its first test, in early 2007, was completed at the U.S. Army Naha Port, in Okinawa, Japan, a coastal facility built during the Korean War and subject to much of the same environmental stressors as those found at Kennedy.

Product Outcome - The NASA-developed coating may be used to prevent corrosion of steel in concrete in several applications, including highway and bridge infrastructures, piers and docks, concrete balconies and ceilings, parking garages, cooling towers, and pipelines, to name just a few.



Surtreat uses topically applied chemically reactive, migrating formulations unique to each project.

Surtreat is the ideal partner to bring this technology to the public, as the company has a proven record of providing full-service, innovative, and technical solutions for the restoration and prevention of deterioration and corrosion in steel-reinforced concrete structures.

Their Total Performance System provides diagnostic testing and site analysis to identify the scope of problems for each project, manufactures and prescribes site-specific solutions, controls material application, and verifies performance through follow-up testing and analysis.

The coating lasts 10 years or more, reducing maintenance costs over the lifetime of the structure; and testing has proven that the treatment yields reductions in rebar corrosion potential, water penetration, chemical reactivity, and water-soluble chloride, while generating increases in hardness, flexural strength, and pH levels.

The treatment also provides resistance to chloride penetration and problems associated with freezing and thawing of the porous structures. Surtreat treatments are environmentally friendly, and the company focuses on preventing and minimizing adverse environmental impacts by identifying and controlling potential environmental risks in advance.

The solutions used are water-soluble and environmentally safe, and in testing have shown no effect on the turbidity, pH, or dissolved oxygen content levels in water. Surtreat's formulations bond inorganic compounds to structures, where they become part of the steel and concrete matrix indefinitely. It leaves no residues, coatings, or materials that could potentially harm humans, animals, fish, or the environment.

Spinoff 2007 *Environmental and Agricultural Resources 89*

Environment and Resource Management

CONCRETE SOLUTION

Billions of dollars worth of structures are literally eaten away by corrosion. To fight this destruction, a NASA Space Act agreement merged Kennedy Space Center (KSC) research, tied to electrical treatments of structural corrosion, with chemical processes developed by Surtreat Southeast, Inc., of Cape Canaveral, Florida.

KSC materials scientists became experts regarding an electrical treatment known as electromigration. This procedure sends corrosion-inhibiting ions to the rebar, or steel bars within a concrete slab, to prevent it from rusting, corroding and separating from the concrete.

The issue was coming up with a viable treatment that can be repeatedly applied to counter the Florida clime—a mix of salt, moisture, and baking sun.

While that trio adds up to an ideal situation for tourists, it's a tripleheader threat to launch pads, as well as miles of beachfront condos and other buildings.

Indeed, the aging oceanfront condominium market, as well as seaside commercial buildings, are in constant need of upkeep and restoration.

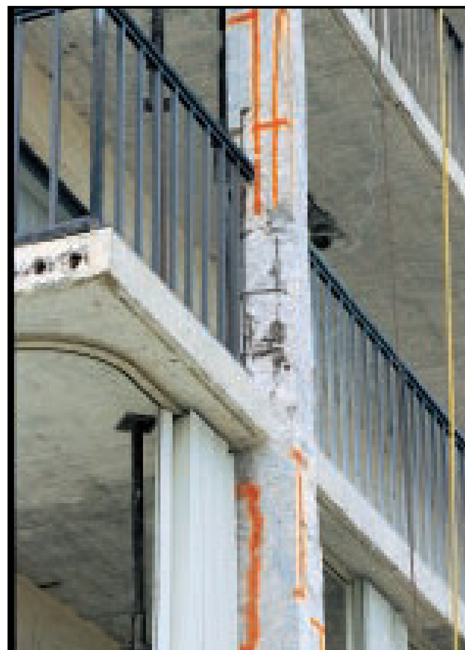
The steel reinforcement bars—called rebars—that are embedded in concrete patio floors of beachside condo units have been particularly hard hit. Cracks and splitting of the concrete are major headaches.

Cracks allow more water, more salt, and more acid to enter. Penetration accelerates, causing larger cracks and spalling. This troublesome material malady hits many concrete structures with decks that face the beach. Balconies in Florida have been deteriorating at a rapid pace.

With the help of Florida's Technology Research and Development Authority, an independent state agency that partners with KSC in technology transfer initiatives, Surtreat Southeast approached KSC with a chemical option to fight structural corrosion.

Surtreat's GPHP product is applied to the surface of a corroding concrete slab and then seeps through to the rebar, coating it and preventing further corrosion.

"It corrects the chemical imbalance that causes the rebar to corrode. Traditional structural repair methods only last a couple of years," explains Jim Emory, president of Surtreat Southeast.



Salty sea breezes create spalling on Florida's concrete balconies.

The salt migrates down to the steel reinforcing bars, rusting the bars and cracking the concrete.

The edges and surfaces get unsightly and structural damage occurs in support columns.

76-A Commercial Benefits—Spinoffs

Emory explains that concrete, due to aging and other factors, loses its pH, or acidity value. Poured concrete has a high pH value of 11, 12, or 13. That high value can inhibit corrosion.

The aging of the concrete is a natural process in which the pH starts to drop. When the pH value dips into the 8 to 9 range, there is potential for corrosion of the reinforcing bars, he points out.

Combining Surtreat's GPHP with electromigration fit well in the KSC dual use program, part of NASA's technology transfer and commercialization effort.

That combination is expected to result in a unique process with broad corrosion control applications. Saving money by NASA and others is anticipated by creating a structural repair method that lasts longer than just a couple of years.

The cooperative effort involved Surtreat providing to NASA the corrosion-inhibiting chemical and concrete test slabs, along with technical and staff support as needed.

From KSC, testing specifications and procedures were provided. The NASA center also prepared the test slabs with the Surtreat chemical and carried out an environmental evaluation of the treatment.

KSC materials scientists reviewed the applicability of the chemical treatment to the electromigration process and is preparing a report on its effectiveness following a 12-month test program.

The results could have national importance, says Rupert Lee, the NASA project engineer leading the joint effort. "Any breakthrough in corrosion mitigation technology will have a significant impact on the integrity of this nation's infrastructure," he explains.

The cracked (spalled) concrete must be chipped away and replaced.

The Surtreat chemical is sprayed on the concrete and exposed steel bars.

FINAL REPORT

FOR

N62470-14-D-3006

VALIDATE CORROSION INHIBITOR

AT

U.S. MILITARY INSTALLATIONS

OKINAWA, JAPAN

(Corrpro Project No. – 340531156)

0	6/8/16	Issued for Approval	A. Johnson	G. Graham
REV	**DATE MM/DD/YY**	**REMARKS**	**PREPARED BY**	**CHECKED BY**

TABLE OF CONTENTS

1.0 INTRODUCTION

Corrpro, a company specialized in corrosion protection, has been contracted by the National Institute of Building Sciences to conduct testing as part of an evaluation to determine the effectiveness of corrosion inhibitor technology for steel rebar in reinforced concrete. This testing is a follow up to the testing performed after installation in January 2007 as documented in the CERL report dated August 2009, and subsequent testing performed as documented in the Corrpro 2010 report. The original project scope included two different technologies, however only the corrosion inhibitor technology was evaluated for this contract.

The corrosion inhibitor system was applied at two United States military installations in Okinawa Japan:

1. Naha Military Port – Building 306
2. Kadena Air Force Base – Kuwae Tank Farm

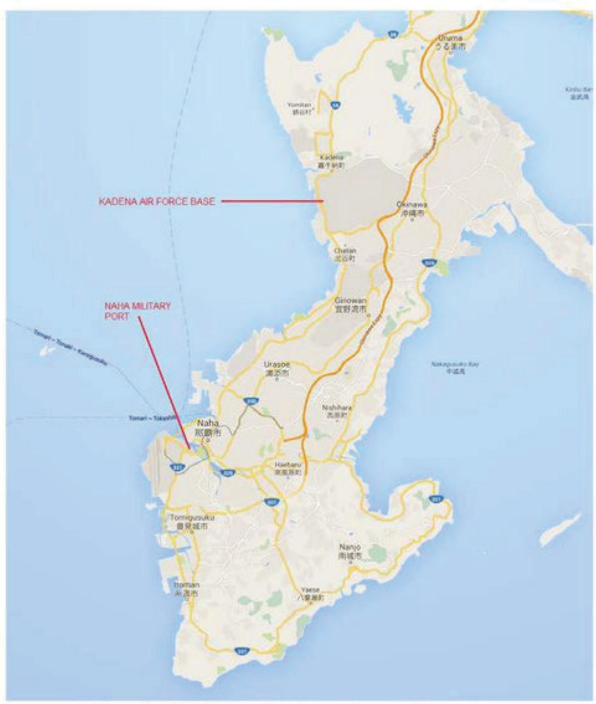


Figure 1 – Area View of Test Locations, Okinawa, Japan

Because corrosion of steel reinforcement is an ongoing expensive maintenance issue effective treatments are studied to reduce the impact of corrosion on military infrastructure. The structures selected for this test are in particularly corrosive coastal environments. The Surtreat surface applied corrosion inhibitor system which was applied to the structures under test and evaluated consists of three main components:

1) An ionic-anodic type inorganic migratory corrosion inhibitor (TPS II)

2) An organic vapor phase migratory corrosion inhibitor (TPS XII)

3) A reactive silicone surface protection agent (Repel WB)

Corrosion inhibitors are used to protect infrastructure in environments where typically other corrosion protection methods may be infeasible, impractical due to costs or implementation challenges, or where temporary corrosion protection is desired.

Concrete is generally considered as an excellent material for providing corrosion protection of steel due to its alkalinity. However, in costal environments, concrete is often saturated with water and chlorides which decrease its ability to provide effective corrosion protection. Surface sealers of silicone or siloxane formulation are often used, in addition to barrier coatings, to effectively seal the porous surface of the concrete and reduce the level of moisture and contaminates permeating into the concrete.

The evaluated Surtreat system uses a combination of migratory corrosion inhibitors to effectively reduce or stop active corrosion, with a silicone sealer to seal the concrete. This also has an added benefit of extending the useful life of the corrosion inhibitor which would otherwise be greatly reduced if the concrete remained cyclically saturated.

2.0 REFERENCES

1. ACI, American Concrete Institute, 38800 Country Club Drive, Farmington Hills, MI 48331
    a. ACI 222R, Protection of Metals in Concrete Against Corrosion
2. ASTM International, American Society for Testing & Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428
    a. ASTM, C876, Standard Test Method for Corrosion Potentials of Uncoated Reinforcing Steel in Concrete
    b. ASTM, C805, Standard Test Method for Rebound Number of Hardened Concrete
3. Rilem Commission 25, PEM, Test Method II.4
4. ERDC/CERL TR-09-27 Report "Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa", by Construction Engineering Research Laboratory (CERL), Dated August 2009
5. Final Report, Corrpro, Dated September 2010

3.0 SAFETY

All work on site shall be performed in accordance with Corrpro standard health & safety policy as well as site specific requirements. A daily job safety analysis (JSA) will be completed and the following personal protective equipment (PPE) will be utilized: hard hat, safety glasses, steel toe shoes, gloves, ear plugs, and high visibility vests. No hazardous materials or wastes will be used or generated.

4.0 EQUIPMENT

Corrpro is an ISO 9001 company and maintains all field equipment calibrated, traceable, and in good working order. Equipmented used for testing on site included:

- Calibrated Fluke Digital Multi-Meters
- Silver/Silver Chloride Reference Electrode
- Copper/Copper Sulfate Reference Electrode
- Wire Leads
- Rainbow pH Indicator Solution
- Galvapulse GP-5000
- Rebar Locator
- Drill & Masonry Core Bit
- Schmidt Rebound Hammer
- Rilem Tubes
- Digital Psychrometer
- Chipping Hammer & Misc. Tools

5.0 FIELD TESTING

Two project sites in Okinawa were selected due to the harsh environment and visible deterioration of concrete. Two culvert bridges located at Kuwae Tank Farm (referred to in the CERL project report ERDC/CERL TR-09-27 as bridges 2 and 3) were chosen for application of the Surtreat system. Bridge 2 received the entire 3-part Surtreat system. Bridge 3 only received the inorganic inhibitor and silicone sealant. The second project site was inside a warehouse at Naha Military Port. Two sections of ring girder were selected, one treated with the Surtreat system, and the other coated with the NASA coating which was not part of this evaluation but was found to be greatly deteriorated.

Corrpro tested Bridge 2 at the Kuwae Tank Farm, Kadena AFB (figure 2), and Section 1 of the ring girder at Building 306 in the Naha Military Port (figure 3). Corrpro performed the evaluation of the corrosion inhibitor system during the weeks of March 14th and 21st, 2016 in the same manner as was previous done by Corrpro in 2010.

Kuwae Tank Farm

Bridge 2 that received the full Surtreat system was evaluated for effectiveness of the system. The same three specific areas chosen for the 2007 inspection were previously tested in 2010 as shown in Figure 2 were evaluated. These areas were designated as areas A, B, and C. All three areas were on vertical surfaces. No cracking or spalling of the treated area was visually apparent. A few small square patches were observed that were not originally present at the time of treatment, and the circumstances of their installation are unknown. Figures 3, and 4 show the condition of Bridge 2 as found in 2016.

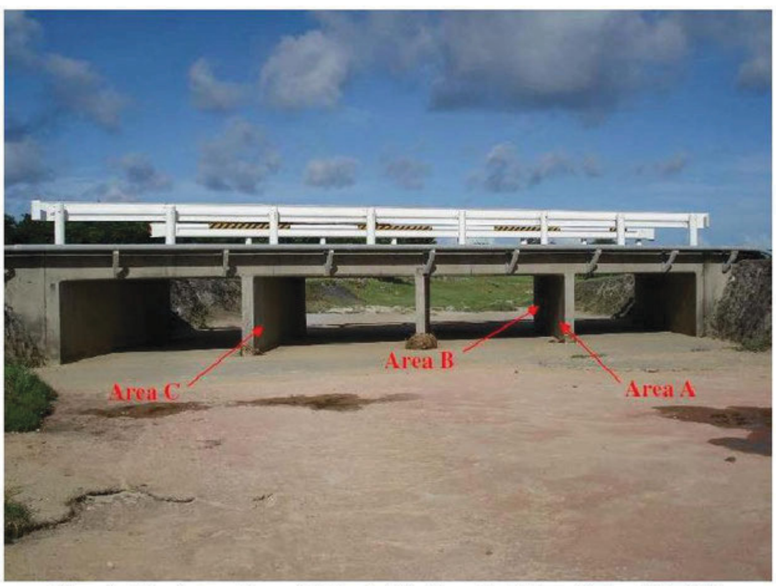


Figure 2 – View from upstream of Bridge 2 at the Kuwae Tank Farm, Kadena AFB, 2010

Figure 3 – View from upstream of Bridge 2 at the Kuwae Tank Farm, Kadena AFB, 2016

Figure 4 – View from downstream of Bridge 2 at the Kuwae Tank Farm, Kadena AFB, 2016

Table 1 compares the most recent corrosion rate values with the previously measured values before treatment, 6 months after treatment, and approximately 3 years after treatment. The data from sites A, B, and C are combined as resulting data was similar in nature. Galvapulse measurements, as shown in Figure 5, showed that corrosion rate remains significantly reduced from pre-treatment levels. Although the corrosion rates have increased since 2010 they are still below the first posttreatment evaluation in July 2007. Measurements ranged from 2.1 µm/yr to 22.4 µm/yr and were more consistent around lower sections of test areas which had lower resistance likely from the reduced effectiveness of the silicone treatment over time.

Table 1 – Corrosion Rate Measurements on Bridge 2, Kuwae Tank Farm

	Before Treatment	After Treatment			Overall Reduction
	January 2007	July 2007	July 2010	March 2016	
Median (50% Probability)	29.8 µm/yr (1.17 mpy)	7.8 µm/yr (0.31 mpy)	6.9 µm/yr (0.27 mpy)	7.7 µm/yr (0.30 mpy)	74%
Average	37.4 µm/yr (1.47 mpy)	13.1 µm/yr (0.52 mpy)	7.1 µm/yr (0.28 mpy)	11.5 µm/yr (0.46 mpy)	79%

Figure 5 – Measuring corrosion rate

Water absorption was negligible and the silicone sealer is still effectively sealing the concrete from moisture. Rilem tube tests, as shown in Figure 6, performed in the same location as earlier testing showed virtually no measurable water absorption. Wetting out concrete on the test areas required a series of repeated wettings over a period of several hours to lower concrete resistance sufficiently for measurements to be made. Figure 7 shows an area of concrete where sealer was still inhibiting the absorption of water after several applications of water. Areas of application of the Surtreat system was still readily evident by a white coloration, or lack of discoloration, on the concrete where it was applied.

Figure 6 – Collecting rilem test tube, white area where Surtreat system applied

Figure 7 – Sealer still evident after several wettings of the concrete

A series of compressive strength measurements were made using a Schmidt hammer on an area of concrete previously tested between sections A and B. The average measured value was 5200 psi, which is an increase from the previous measurements in 2010 and 2007. Concrete pH and depth of carbonation were measured using a rainbow indicator solution. The pH measured immediately under the treated surface was in the range of 9-10 at a depth of 1/8".

Naha Military Port

The Surtreat system was previously applied at the warehouse building no. 306 in Naha Military Port. Section 1 where the system was applied is a section of ring girder adjacent to the exit door in section A of the building. Visually, the ring girder identified as Section 1 with the Surtreat system had no apparent changes since the last testing performed in 2010 as shown in Figures 8 and 9. Section 1 appeared in good shape without signs of deterioration. However, the other ring girder identified as Section 2 with the NASA coating had a clear visual indication of the coating delaminating from the concrete surface. This deterioration can be seen in Figure 10 below.

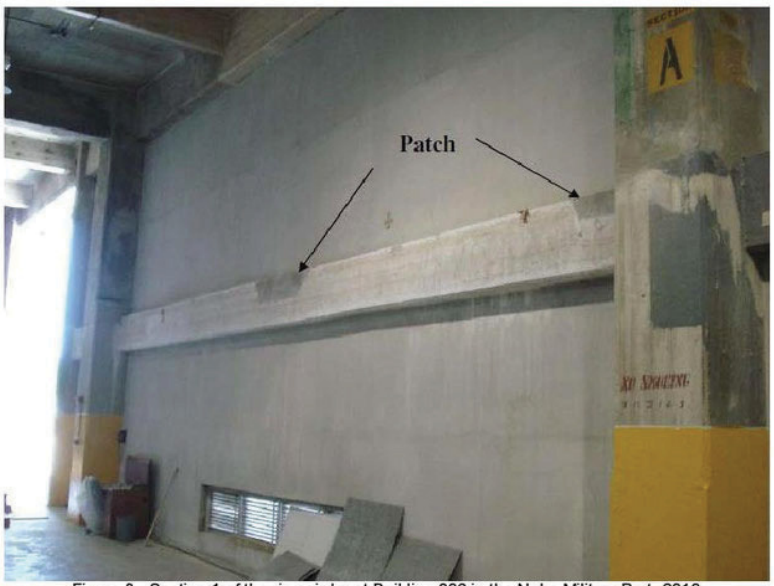


Figure 8 - Section 1 of the ring girder at Building 306 in the Naha Military Port, 2010

Figure 9 - Section 1 of the ring girder at Building 306 in the Naha Military Port, 2016

Figure 10 - Section 2 of the ring girder at Building 306 in the Naha Military Port, 2016

Table 2 below provides a comparison of the most recently obtained data to that previously collected. It should be noted that the concrete was difficult to wet because of the sealer and required numerous applications of clean water. Rebar in Section 1 showed low corrosion rate compared with prior to treatment, and was even a bit lower than the 6 month after treatment evaluation. There was wide variation in the data, though, and this is believed to occur from the high resistance in the concrete being effectively sealed from the silicone sealer. To ensure continuity Corrpro cored concrete to rebar to make a physical connection onto the horizontal reinforcement. Corrpro also removed the silicone sealer at some locations to take readings without the influence of a sealer. Average measurements with sealer removed provide a corrosion rate of 8.46 μm/yr with corrosion rate reduction of 80%.

Table 2 – Corrosion Rate Measurements on Section 1 Building 360, Naha Military Port

	Before Treatment	After Treatment			Overall Reduction
	January 2007	July 2007	July 2010	March 2016	
Median (50% Probability)	41.4 μm/yr (1.63 mpy)	5.7 μm/yr (0.22 mpy)	4.9 μm/yr (0.19 mpy)	6.2 μm/yr (0.24 mpy)	85%
Average	61.3 μm/yr (2.41 mpy)	24.3 μm/yr (0.96 mpy)	14.0 μm/yr (0.55 mpy)	25.7 μm/yr (1.01 mpy)	68%

Rilem tube water penetration, as seen in Figure 11, yielded no noticeable absorption after several hours. Schmidt Hammer compressive strength of Section 1 averaged 5700psi which were close to the values previously obtained in 2010. As seen in Figure 12, pH testing provided a pH of approximately 9 to a depth of 1.5 inches where the pH subsequently increased.

Figure 11 – Rilem test tubes placed on section 1 ring girder.

Figure 12 – Core removed over horizontal rebar, and pH indicator applied

Figure 13 – Visual comparison of section 1 ring girder in to ring girder adjacent to exit door.

6.0 ANALYSIS

The 3-part Surtreat system, based upon measurements of corrosion rate and moisture penetration, is effectively protecting the rebar from corrosion. To date, an average reduction in the corrosion rate by 79 to 80% has been realized. Visually the sealer is still well intact indoors and outdoors which is made apparent by the white to opaque coloration present and inability for moisture to readily penetrate the treated areas.