FIELD PERFORMANCE OF *SURTREAT TPS* A SURFACE APPLIED, PENETRATING CORROSION INHIBITOR

Construction Report
March, 2004

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16. ABSTRACT
Surtreat TPS penetrates into the PCC structure being treated, reacting with the cement phase of the concrete to increase hardness and compressive strength, decrease permeability, and render the concrete inert to attack and penetration by acids, bases and other aggressive chemical solutions.

17. KEY WORDS
Corrosion Inhibitor, Existing Structures, Reinforcing Steel

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The contents of this report reflect the views of the author(s) who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the views of the Oklahoma Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. While trade names may be used in this report, it in not intended as an endorsement of any machine, contractor, process, or products.

SI (METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units

Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	25.40	millimeters	mm
ft	feet	0.3048	meters	m
yd	yards	0.9144	meters	m
mi	miles	1.609	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.0929	square meters	m^2
yd^2	square yards	0.8361	square meters	m^2
ac	acres	0.4047	hectacres	ha
mi^2	square miles	2.590	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallon	3.785	liters	L
ft^3	cubic feet	0.0283	cubic meters	m^3
yd^3	cubic yards	0.7645	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.4536	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	degrees Fahrenheit	(°F-32)/1.8	degrees Celsius	°C
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.448	Newtons	N
lbf/in^2	poundforce per square inch	6.895	kilopascals	kPa

Approximate Conversions from SI Units

Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.0394	inches	in
m	meters	3.281	feet	ft
m	meters	1.094	yards	yds
km	kilometers	0.6214	miles	mi
		AREA		
mm^2	square millimeters	0.00155	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.196	square yards	yd^2
ha	hectacres	2.471	acres	ac
km^2	square kilometers	0.3861	square miles	mi^2
		VOLUME		
mL	milliliters	0.0338	fluid ounces	fl oz
L	liters	0.2642	gallon	gal
m^3	cubic meters	35.315	cubic feet	ft^3
m^3	cubic meters	1.308	cubic yards	yd^3
		MASS		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.1023	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	degrees Fahrenheit	9/5(°C)+32	degrees Celsius	°F
		FORCE and PRESSURE or STRESS		
N	Newtons	0.2248	poundforce	lbf
kPa	kilopascals	0.1450	poundforce per square inch	lbf/in^2

FIELD PERFORMANCE EVALUATION OF *SURTREAT TPS* A SURFACE APPLIED, PENETRATING CORROSION INHIBITOR

CONSTRUCTION REPORT

March 2004

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EXECUTIVE SUMMARY

Corrosion is a major problem for most concrete structures, occurring in the steel bars used to reinforce the concrete. The expense incurred in North America as a result of corrosion-induced repair numbers in the billions of dollars, with more than 50% of the 575,000 bridges in the United States affected by corrosion. Corrosion inhibitors are one of the most cost-effective solutions to this problem, but little independent information is available on their effectiveness in actual use.

Reinforced concrete structures are usually durable in average environments, but their integrity can be compromised when exposed to carbonation or other environments such as chloride salts. [1] These environments reduce the potential service life of reinforced concrete structures and increase maintenance costs. A number of options exist for prolonging the life of concrete structures exposed to aggressive environments, and corrosion inhibitors are among these options. While corrosion inhibitors are available and have been used for increasing the protectiveness of concrete in new construction, [2] the focus of this report is on the reduction of corrosion in existing structures. The costs resulting from damage due to corrosion of existing concrete structures is estimated to be approximately $8.3 billion per year for highway bridges alone, [3] and there are many other types of concrete structures that are also exposed to corrosion.[4]

Steel corrosion can be mitigated through several approaches. In concrete bridges, the damaged area can be periodically repaired. However, the cost of such repair over the life of a structure can often exceed the cost of total replacement. Another approach is cathodic protection. This can be very effective, but it requires long-term maintenance and a continual supply of electrical power or sacrificial anodes, depending on the selected mode.

BACKGROUND

The Oklahoma Department of Transportation (ODOT) experimentally treated the deck of an existing bridge with *Surtreat TPS*, a surface applied, penetrating corrosion inhibitor. *Surtreat TPS* reportedly can abate corrosion, by creating a passivating ionic film on the reinforcing steel. *Surtreat TPS* claims to permanently modify the cement matrix of existing PCC structures. These modifications result in increased strength and lower permeability. If successful, the use of *Surtreat TPS* could substantially reduce the cost of corrosion maintenance by arresting corrosion - caused spalls, thus reducing the necessity for patching and other repairs.

PURPOSE

The purpose of this study is to evaluate the effectiveness of *Surtreat TPS* corrosion inhibitor in a field performance situation. *Surtreat TPS* is a proprietary product produced by the *Surtreat* Corporation of Pittsburgh, Pennsylvania. According to the manufacturer's literature, *Surtreat TPS* penetrates into the PCC structure being treated, reacting with the cement phase of the concrete to increase hardness and compressive strength, decrease permeability, and render the concrete inert to attack and penetration by acids, bases and other aggressive chemical solutions. This project will focus on *Surtreat's* reported ability to decrease corrosion in an existing structure.

OBJECTIVES

- Conduct half-cell potential tests (ASTM 876-91) on the bridge (Bridge no. 4621 0140 X, NBI 17601, McIntosh County), before and after the application of *Surtreat TPS* to evaluate *Surtreat's* ability to reduce corrosion.
- Conduct Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration tests (AASHTO 277) to determine if the compound demonstrates the ability to reduce the amount of chloride present in the concrete.
- Conduct pH testing using Germann Instruments Rainbow Dye Test on the existing deck before and after treatment to determine any change in pH.
- Conduct the Standard Test for Abrasion resistance by sandblasting (ASTM 418) before and after *Surtreat TPS* application to document any change in this property.
- Monitor the application process. A. Document application rate, including time required for treatment. B. Document lane closure requirements.
- Conduct surveys of the general condition of the deck at regular intervals after treatment.
- Conduct half-cell potential tests on the bridge (Bridge No. 4621 0140 X, NBI 17601, McIntosh County), one and two years after the application of *Surtreat TPS* to evaluate Surtreat's ability to reduce corrosion on a long-term basis.

PROJECT INFORMATION

Surtreat TPS has the potential to reduce maintenance and life cycle costs and can be used for deck rehabilitation. ODOT will be using this product on S.H. 150 (bridge) over lake Eufaula in McIntosh County as shown in Figure 1. The bridge deck is 100 percent in PONTIS condition state 4 (repaired areas and spalls are more than 10 percent but less than or equal to 25 percent of the total deck area). The project consisted of preparation and treatment of the bridge deck, 2505 square yards, with *Surtreat TPS* 2, a surface applied inorganic migratory corrosion inhibitor. The goal of the project is to abate corrosion at the level of the reinforcing steel, minimizing the need for future deck patching. ODOT has no prior experience with this product, and considers it an experimental application at this point, the application and the treated bridge will be monitored by the Research Section, Engineering Services Branch of ODOT's Planning & Research Division as described below.

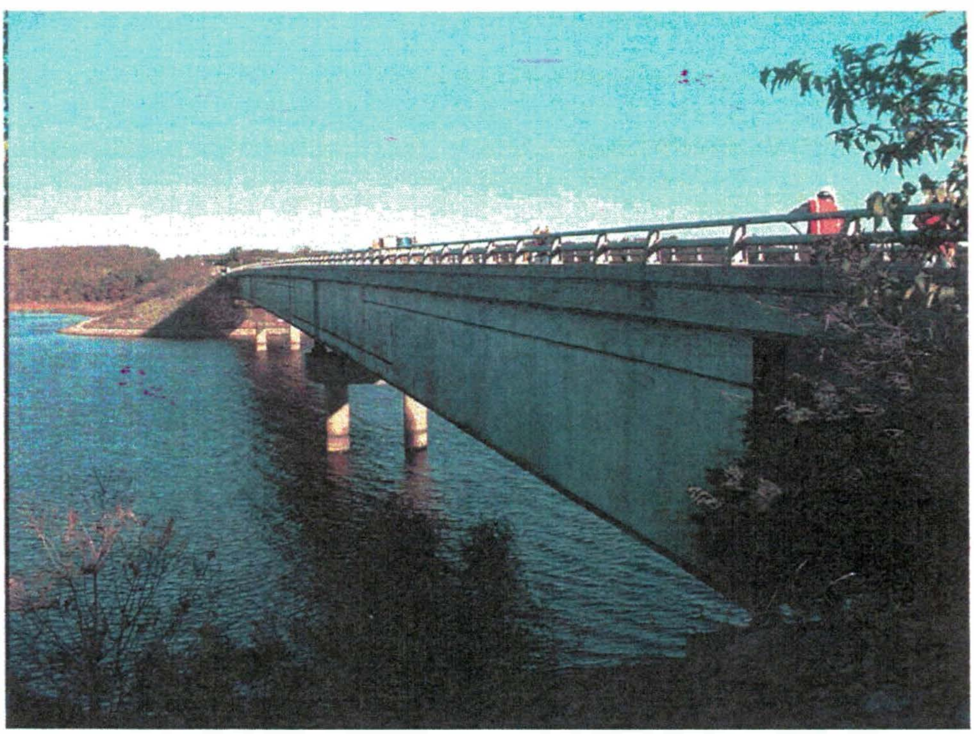

Figure 1. Bridge during application of Surtreat

CONSTRUCTION

Concrete Services Corporation of Tulsa was awarded the contract to prepare and treat the deck. Traffic control was provided by ODOT Division 1 maintenance personnel. ODOT specified treatment of the deck with *Surtreat TPS* 2 at a rate of one gallon per 100 square feet. Preparation of the bridge deck included careful water blasting to remove surface dirt and debris, without causing further delamination or removal of repair material. One lane of traffic was maintained in service at all times during the construction period. The cleaning and treatment of the entire bridge took 6 days. The first 2 days were used to clean the entire bridge deck and the remaining 4 days for application of *Surtreat TPS* 2. *Surtreat* was applied with low pressure sprayers in 3 applications, followed by a clean water misting. Low areas were broomed to minimize puddling of the *Surtreat*. Actual lane closing time was 8 hours or less for each work day. Traffic was resumed on both lanes every day after the work area was rinsed. Traffic was restricted to one lane for less than 48 hours for the entire construction period, minimizing inconvenience to highway users.

Figure 2. Water blasting the deck

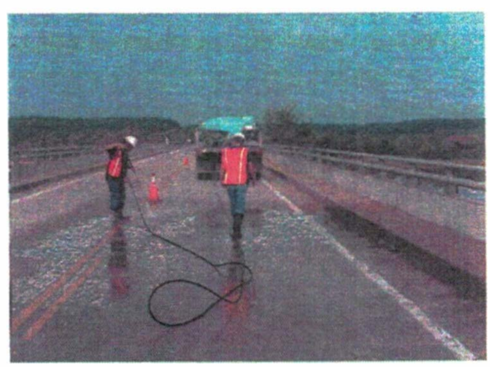

Figure 3. Water blasting the deck

Figure 4. Treating the deck

Figure 5. Treating the deck

DATA COLLECTION

Research activity was included in monitoring the application process, including any necessary preparation work such as cleaning, sandblasting, joint repair, etc. Information was gathered on application rate and time required to treat the bridge, with lane closure (time) requirements. A survey of the general condition of the deck was completed before *Surtreat TPS* application. Half-cell testing of the deck was done before and after *Surtreat* application to quantify any reduction in corrosion activity. In order to insure that the *Surtreat* has time to work, the time between application and half-cell testing was 4 months which was recommended by the *Surtreat* representative. Cores were taken before and after *Surtreat* application. These will be tested for abrasion resistance and permeability to determine the amount of improvement after treatment.

A second survey will be done one year after application. This will include half-cell testing, and a survey of the treated area's general condition. A final survey will be done two years after treatment. The same data will be collected for both the one-year and two-year surveys.

Figure 6. Taking test cores

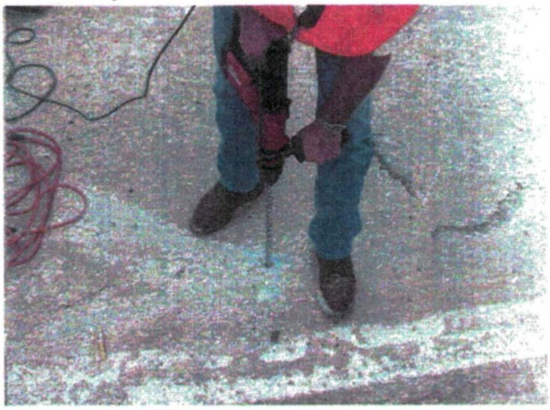

Figure 7. Gathering chloride samples

DISCUSSION

For the *Surtreat TPS* to extend the service life of structures undergoing active chloride induced corrosion they must:

- penetrate the cover concrete to depth of the reinforcing steel
- penetrate accumulated corrosion products in pitting cells to the depth where oxidation of the steel is occurring and or retard or stop the cathode reaction.
- inhibit active chloride induced corrosion cells in the presence of relatively high chloride concentrations

It is difficult to determine if the *Surtreat* actually penetrated the concrete cover. This could be helped by having the manufacturer put some type of dye in the product and conduct some type of color test to determine the presence of the product and to what depth was obtained. A small number of cores were taken for the project. Tests on the cores may show the depth obtained by the product.

A question that needs to be answered is how much of the chemical is getting to the steel surface? Also how much is being absorbed into the concrete and with that how much concentration on the surface is needed to reduce or stop corrosion?

There have been some questions regarding the delamination of the bridge deck and if that would cause the half-cell numbers to be unreliable. The half-cell potential numbers should have decreased if the Surtreat was working as intended. However, our results showed that the majority of the numbers either stayed the same or increased. This could show that the treatment was not as effective as we had expected, 4 months was not long enough to see these improvements in the half-cell numbers, or the delamination in the deck caused some of the numbers to be unreliable.

RESULTS

Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration (AASHTO 277):

	Charge Passed (Coulombs)	Relative Chloride Permeability
Prior to application	4712	High
4 months after application	4176	High

Abrasion Resistance of concrete by sandblasting (ASTM C418):

	SSD Weight, g			
	Before	After	Loss, g	% Loss
Prior to application	229.47	228.07	1.40	0.61
4 months after application	168.28	167.30	0.98	0.58

* The reason for the difference in weight before and after is due to size of the cores that were tested.

Half-cell results can be found in Appendix B:

pH testing using Germann Instruments Rainbow Dye Test:

	pH level
prior to application	11
4 months after application	11

REFERENCES

1. Bjegovic and B. Miksic (CORTEC). "Migrating Corrosion Inhibitor Protection of Concrete". Materials Performance Vol. 38, No. 11, pp. 52-56 (1999) November.

2. D. Bjegovic and B. Miksic, "MCI Protection of Concrete." Cortec Supplement to Materials Performance, January 2001, pages 10-13.

3. Cost of Corrosion Study, http://nace.org/nace/content/nacenews/news_win/html/costcorr.htm, July 2002.

4. Corrosion in Concrete, http://corrosion.ksc.nasa.gov/html/corrincon.htm, July 2002.

APPENDIX A

Technical Surtreat Data

SURTREAT

SURTREAT TPS 2
Material Safety Data Sheet

SECTION I SUPPLIER INFORMATION

Common Name:	SURTREAT-TPS 2
Chemical Name:	
Formula:	
Supplier:	SURTREAT 437 Grant Street, 1210 Frick Building Pittsburgh, PA 15219
Phone:	(412) 281 – 1202
Emergency Phone:	Chem-Tel 1-800-255-3924 (24 hours)
Date Prepared	Monday, June 09, 2003

SECTION II HAZARDOUS INGREDIENT INFORMATION

CFR 29 Part 1910.1000 Table Z-1 (July 1, 1996 issue)

Ingredient	CAS Number	PEL-OSHA (ppm)	TWA-OSHA (mg/m^3)	TLV-ACGIH (ppm)	STEL-ACGIH (ppm)
This product contains no hazardous materials.					

SECTION III PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point:	212	°F
Specific Gravity:	1.094	
Melting Point:	N/A	°F
pH:	12	
Vapor Pressure (mm Hg):	N/A	
Vapor Density (Air=1):	N/A	
Evaporation Rate (Butyl Acetate = 1):	N/A	
Solubility in Water:	100%	
Appearance and Odor:	A clear liquid with a sweet odor.	

SECTION IV FIRE AND EXPLOSION HAZARD DATA

Flash Point:	none	°F
Auto-Ignition Temperature:	N/A	°F
LEL:	N/A	%
UEL:	N/A	%
Extinguisher Media:	This material is not expected to burn.	
Special Fire Fighting Procedures:	None known.	
Unusual Fire and Explosion Hazards:	None known	

SECTION V REACTIVITY DATA

Stability	Stable
Conditions and Materials to Avoid	Flammable hydrogen gas may be produced on prolonged contact with metals such as aluminum, tin, lead, and zinc. Avoid contact with glass and reactive metals.
Hazardous Decomposition or By-Products	Hydrogen gas.
Polymerization	Will not occur.
Conditions to Avoid	None known

SECTION VI HEALTH HAZARD DATA

Inhalation

Acute	Causes irritation to the respiratory tract.
Chronic	No data available.

Turnkey Technical Solutions for Concrete Restoration, Rejuvenation and Protection

SURTREAT CORP.
INFORMATION

INTRODUCTION

Technological advances made by Surtreat Corp. are based on the fact that the deterioration of Portland cement concrete is largely a chemical process which can be chemically inhibited and reversed.

The internationally accepted **SURTREAT®** method is the most effective and inexpensive way to restore the original properties of deteriorating concrete and to offer long-term protection to all surfaces exposed to hostile environments.

BENEFITS

The unique **SURTREAT** system increases the ability of concrete to resist physical and chemical breakdown by:

- ***Increasing compression strength, hardness***
- ***Inhibiting reinforcing steel corrosion***
- ***Resisting attack and penetration by acids, salts and other aggressive chemical solutions***
- ***Extracting chlorides and pacifying chloride activity***
- ***Pacifying alkali-silica reaction***
- ***Elevating the pH***

APPLICATION

The benefits are achieved by continuous application of a combination of **SURTREAT** proprietary chemical formulations which penetrate into the concrete microstructure in liquid and vapor state to combine with the cement phase of the concrete and deposit on steel components. Application is made by Surtreat Corp. or a qualified contractor.

TESTING

Performance of **SURTREAT-GPHP** has been verified on numerous projects as well as through extensive laboratory testing performed by Professional Service Industries, Inc., Pittsburgh, PA. Results of the tests reflect the following:

Compression Strength Increase
ASTM C-42 increased by 300 to 2000 psi depending on original strength and number of applications.

Water Penetration Reduction
100% resistance after 14 days exposure to 6 inch column of water.
75% resistance after 28 days exposure to 6 inch column of water.
90% resistance after 24 hours @ 100 psi.

Freeze Thaw Resistance
ASTM C-672 – 50 cycles no surface loss.
AASHTO T-161 – 146 cycles no surface loss.

Chloride Penetration Resistance
AASHTO T-250 – 30% decrease at 1 inch depth.
ASTM C-672 – 42% decrease at 2 inch depth.

Water-soluble Chloride Reduction
Gel pour extraction method.
Reduced by 58% at 1-inch depth.
Reduced by 67% at 2-inch depth.

Increase in Hardness
ASTM C-418 – 14% increase in hardness of new concrete.
ASTM C-414 – 64% increase in hardness of deteriorated concrete.
ASTM C-501 – 1000 cycles – 38% increase in wear index.

Reduced Rebar Corrosion Potential
ASTM C-876 – Half-cell potential – reduced voltage by 50% in 14 days (400 to 200mV).

Increased Surface Adhesion
No failure of epoxy bonded to treated surface.

Reduced Chemical Reactivity
Resistant to attack and pentration by concentrated hydrochloric acid.

Flexural Strength
Increased from 423 to 543 psi.

The majority of projects that involve installation of **SURTREAT** products include comprehensive testing and analysis before and after the treatment. Tests performed on site often include: **Compression Strength (CAPO Pull Out), Water Permeability (Pressure Cell), pH (Indicator Dye), Corrosion Potential (Silver Chloride Half-Cell), Chloride Ion and Acid Reactivity**. Customer representatives or engineers are invited to observe testing procedures and verify the results. Comprehensive project reports are submitted on request.

Surtreat Corp., 437 Grant Street, 1210 Frick Building, Pittsburgh, PA 15219
phone 412-281-1202, fax 412-281-1282, e-mail srtrt@nauticom.net

SURTREAT® CORROSION INHIBITION PROCESS AND FORMULATIONS

The Process of Corrosion

Reinforcing steel corrosion is the most common cause of failure of concrete structures. Steel corrosion is an oxidation process requiring the presence of air (oxygen) and moisture. Corrosion is promoted by anions, like chloride, and an acid environment. Corrosion is inhibited by an alkaline environment, cations and barrier coatings.

Freshly poured low water-cement ratio concrete provides excellent protection for imbedded reinforcement. However, as time passes, under the influence of salts and atmospheric acids cement bonds in concrete begin to deteriorate, concrete becomes increasingly permeable and susceptible to intrusion of contaminants and moisture. As the pH of concrete falls, electrochemical activity increases. The process perpetuates itself as oxidized rebar expands forcing concrete to crack and delaminate, thus encouraging air and water penetration. Once started, rebar corrosion can not be stopped by simply waterproofing the surface of the concrete, in fact application of a waterproofing membrane or coating will make the situation worse by trapping the chlorides and moisture inside the concrete microstructure which in combination with a low pH is a perfect environment for corrosion.

SURTREAT® Process

The corrosion process is influenced and promoted by penetration of air, water, chloride, and an acid environment.

The **SURTREAT** process for corrosion inhibition includes application of **SURTREAT Volatile Corrosion Inhibitor (VCI)**, which permeates throughout the structure as a vapor and deposit on rebar forming a passive film on the surface of the white steel. Application of **SURTREAT VCI** is usually followed by an application of **SURTREAT General Purpose Restoration and Protection Formulation (GPHP).**

SURTREAT GPHP penetrates the concrete surface reacting with Portland cement and solidifies inside becoming a permanent part of the structure. **SURTREAT GPHP** inhibits corrosion by:

- ***Complexing water soluble chlorides***
- ***Purging and inhibiting penetration of chlorides***
- ***Raising the pH***
- ***Restricting access of air and water to the rebar***

SURTREAT GPHP also reacts with iron oxide on the surface of imbedded reinforcement to convert it into an inert mass resistant to water and air penetration.

The effects of **SURTREAT®** formulations on the corrosion process have been verified through field evaluation as well as lab analysis. The following is a brief summary of the test results performed in our laboratory as well as in the field. All tests are done using a silver chloride half cell, the threshold point for corrosion is -190mV.

LABORATORY EVALUATION

ID	CONDITION/EXPOSURE	mV	Kohm
A	Base Sample	+45	8.0
	Exposure to HCl/CaCl	-370	0.5
	5 applications of GPHP and 1 application of VCI	-115	2.2
B	Base Sample	-300	0.5
	3 applications of GPHP and 1 application of VCI	-200	1.0
	After one week	-125	1.5
C*	Base Sample	-325	0.4
	3 applications of GPHP	-300	0.4
	1 application of VCI	-275	0.5
	2 applications of GPHP	-235	0.6
	After one week	-200	0.7

*Sample labeled C came from a balcony of the Ocean Pines Complex in Cape Canaveral FL.

SUMMARY OF SILVER CHLORIDE HALF CELL MEASUREMENTS ON A BALCONY AT WINDJAMMER CONDOMINIUM, COCOA BEACH, FL

AREA	BEFORE mV	AFTER mV	NUMBER OF MEASUREMENTS
A	-326	-153	6
B	-350	-155	8
C	-229	-64	3
D	-285	-179	3

Surtreat application rate	50 sf/gal
Number of applications	2
Curing time	24 hours
Half cell corrosion point	-190 mV
Date performed	6/16 - 6/17/95.

SURTREAT

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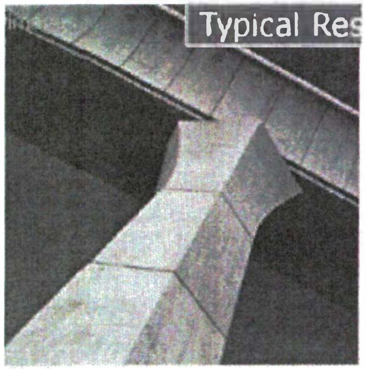
performance characteristics
environment



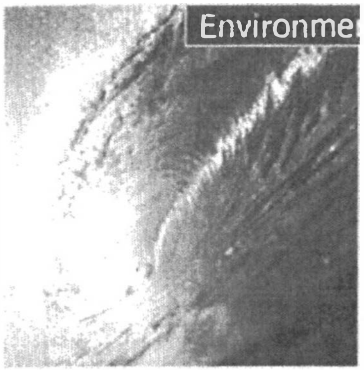
The performance of Surtreat's chemistry has been verified by numerous independent engineering-consulting firms in the field as well as through extensive independent laboratory testing. The results of the testing reflect the following typical result characteristics:

- **Reduced Rebar Corrosion Potential** - ASTM (American Society for Testing Materials) C-876 - Half-cell potential showed a reduced voltage by 70% in 14 days (0.8 to 0.3)
- **Water Penetration Reduction** - 100% resistance after 14 days exposure to 6-inch column of water. 75% resistance after 28 days exposure to 6-inch column of water. 90% resistance after 24 hours when 100 psi is applied.
- **Freeze Thaw Resistance** - ASTM C-672 -50 cycles with no surface loss. AASHTO (American Association of State Highway and Transportation Officials) T-161 - 146 cycles with no surface loss.
- **Chloride Penetration Resistance** - AASHTO T-250 -30% decrease at 1-inch depth.
- **Water-soluble Chloride Reduction** - Reduced by 58% and 67% at 1 and 2 inches, respectively.
- **Increase in Hardness** - ASTM C-418 - 14% increase in hardness of new concrete. ASTM C-414 - 64% increase in hardness of deteriorated concrete. ASTM C-501 - 1,000 cycles with a 38% increase in wear index.
- **Reduced Rebar Corrosion Potential** - ASTM (American Society for Testing Materials) C-876 - Half-cell potential showed a reduced voltage by 70% in 14 days (0.8 to 0.3)
- **Increased Surface Adhesion** - No failure of epoxy bonded to treated surface.
- **Reduced Chemical Reactivity** - Resists reaction with concentrated hydrochloric acid
- **Flexural Strength** - Increased from 423 to 543 psi.
- **Increased pH Level** - Edges of concrete increased from 5 to 9, center of concrete increased from 9 to 12.

*Comprehensive project reports for select projects are available upon request. To request further information click here.

Intranet Login

SURTREAT



Surtreat operates according to the principle that responsibility for the environment is an integral part of every project that we execute.

Surtreat Project Managers operate to comply with all applicable laws and regulations, with emphasis on prevention and to minimize adverse environmental impacts by identifying and controlling potential environmental risks in advance.

Furthermore, Surtreat uses water-soluble organic and inorganic materials that are environmentally safe. Our systems contain no VOC's (volatile organic compounds) and have been tested by leading environmental firms showing no effect on the turbidity, pH, or dissolved oxygen content levels in water.

Surtreat's formulations bond inorganic compounds to the structure where they become part of the steel and concrete matrix indefinitely. Leaving no residues, coatings or materials that could potentially harm humans, animals, fish and the environment. Surtreat has been granted waivers and exemptions from the Environmental Quality Act, California Costal Commission, and other state and county agencies for use of its chemical treatment formulas, due to their non-toxic nature.

Intranet Login

APPENDIX B

Half-cell results

[illegible]

DATE: 9/29/03

BRIDGE NO: 4621 0140 X NBI NO: 17601

TESTED BY: D. HUMPHREY

WEATHER:

HALF-CELL TEST

N

	0	5	10	15	20	25	30	35	40	45
25	112	43	109	73	71	137	254	520	466	364
20	89	54	135	60	34	67	248	156	423	233
15	121	68	126	125	55	93	170	222	418	390
℄										℄
10	151	108	100	90	78	149	253	221	210	428
5	196	134	98	76	71	138	445	305	263	429
0	184	76	92	54	94	154	494	478	441	516

MV

DATE: 9/29/03

BRIDGE NO:

TESTED BY:

WEATHER:

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	50	55	60	65	70	75	80	85	90	95
25	413	548	595	450	526	403	491	472	287	193
20	379	381	484	524	268	326	402	451	201	237
15	415	390	388	485	558	420	274	414	139	193
10	414	507	346	482	445	425	182	249	189	84
5	430	489	393	381	384	418	374	131	138	253
	518	541	584	449	485	576	490	558	236	226

DATE: 9/29/03

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WEATHER:

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	100	105	110	115	120	125	130	135	140	145
25	106	197	391	135	195	276	484	190	232	435
20	368	216	359	226	251	351	436	275	186	131
15	138	74	83	103	368	194	442	97	134	72
10	117	289	336	134	143	262	188	252	406	162
5	206	246	116	162	99	332	127	138	124	291
	150	428	323	500	480	372	434	396	267	358

DATE:
BRIDGE NO:
TESTED BY:

WEATHER:

	150	155	160	165	170	175	180	185	190	195
25	439	280	254	203	308	385	252	488	354	378
20	253	234	181	400	210	384	456	222	235	330
15	124	139	120	208	168	148	304	212	166	508
10	286	113	71	197	89	195	302	252	182	393
5	336	135	98	241	289	384	410	339	121	300
	418	530	300	311	221	530	356	367	413	389

DATE: 9/29/03

BRIDGE NO:

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WEATHER:

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	200	205	210	215	220	225	230	235	240	245
25	478	575	448	216	336	252	440	393	195	332
20	416	438	345	446	254	264	196	420	146	295
15	465	455	418	435	338	466	207	254	118	349
10	400	413	402	419	400	434	281	341	273	268
5	406	496	281	380	475	206	382	295	92	157
0	428	505	473	572	474	543	421	524	269	407

DATE: 9/29/03
BRIDGE NO:
TESTED BY:

WEATHER:

	250	255	260	265	270	275	280	285	290	295
25	405	423	250	346	272	496	523	325	458	566
20	446	469	203	314	376	272	405	298	471	356
15	425	182	145	182	388	161	342	204	223	218
10	248	198	175	354	348	418	300	138	252	338
5	209	290	218	333	312	196	235	115	256	401
	432	360	188	340	383	200	360	140	278	306

DATE: 9/29/03

BRIDGE NO:

TESTED BY:

WEATHER:

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	300	305	310	315	320	325	330	335	340	345
25	285	243	422	523	526	377	291	367	240	192
20	560	410	555	525	609	475	403	467	198	234
15	232	373	322	332	142	82	249	424	401	262
10	99	273	73	181	199	189	229	222	329	173
5	173	362	282	315	134	(3) -21	108	86	89	365
	273	226	136	241	334	152	226	101	163	278

DATE: 9/29/03

BRIDGE NO:

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WEATHER:

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	350	355	360	365	370	375	380	385	390	395
25	214	234	512	271	218	207				
20	445	285	297	332	204	221				
15	116	365	417	297	206	277				
10	182	237	308	460	192	120				
5	378	75	107	350	90	144				
	209	216	167	432	175	85				

DATE: 2/18/04

BRIDGE NO: 4621 0140 X NBI NO: 17601

TESTED BY: D. HUMPHREY

WEATHER:

HALF-CELL TEST

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	0	5	10	15	20	25	30	35	40	45
25	157	60	95	53	85	153	302	537	563	347
20	105	73	176	81	42	111	252	153	465	300
15	130	74	154	125	70	111	216	213	466	455
℄										℄
10	180	88	77	75	47	181	301	236	212	468
5	188	108	70	40	51	66	503	412	283	496
0	224	83	193	74	110	69	524	586	442	844

MV

DATE: 2/18/04

BRIDGE NO:

TESTED BY:

WEATHER:

	50	55	60	65	70	75	80	85	90	95
25	529	643	631	585	570	475	562	555	311	180
20	431	368	586	547	300	340	430	424	199	240
15	452	477	442	524	563	476	301	471	144	211
10	542	546	392	489	437	538	156	182	181	89
5	496	571	312	360	377	536	412	116	119	259
	659	653	666	665	635	643	622	529	239	287

DATE: 2/18/04

BRIDGE NO:

TESTED BY:

WEATHER:

	100	105	110	115	120	125	130	135	140	145
25	128	270	369	166	269	270	550	243	208	464
20	396	251	381	203	271	366	471	198	216	136
15	162	98	98	102	343	258	498	104	149	145
10	130	328	324	120	136	267	201	265	429	177
5	241	322	121	120	92	268	103	152	132	271
	152	423	476	497	430	377	436	369	310	420

DATE: 2/18/04

BRIDGE NO:

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WEATHER:

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	150	155	160	165	170	175	180	185	190	195
25	363	292	248	265	307	380	213	469	329	408
20	272	353	169	461	169	258	428	205	210	375
15	222	136	143	259	167	145	336	192	164	495
10	334	133	98	287	74	115	304	547	119	464
5	434	153	124	276	222	398	416	328	209	405
	440	516	333	320	214	557	353	407	430	304

DATE: 2/18/04

BRIDGE NO:

TESTED BY:

WEATHER:

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	200	205	210	215	220	225	230	235	240	245
25	497	579	519	220	344	273	467	486	410	431
20	452	477	297	407	272	207	137	463	136	248
15	490	476	415	448	353	455	219	316	96	506
10	464	453	396	526	402	442	559	355	296	275
5	387	519	313	425	408	222	343	362	119	219
0	529	504	866	484	536	532	477	501	236	507

DATE: 2/18/04

BRIDGE NO:

TESTED BY:

WEATHER:

	250	255	260	265	270	275	280	285	290	295
25	448	438	220	291	262	576	535	528	478	533
20	394	440	226	335	304	264	422	241	361	358
15	426	166	160	205	379	253	342	182	228	120
10	334	200	189	385	355	433	354	135	287	382
5	218	326	225	318	241	228	249	138	332	417
0	467	412	177	320	378	241	445	118	335	374

DATE: 2/18/24

BRIDGE NO:

TESTED BY:

WEATHER:

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	300	305	310	315	320	325	330	335	340	345
25	288	264	420	550	556	388	281	406	201	192
20	503	512	584	619	617	524	438	463	201	246
15	236	404	232	320	163	54	288	403	404	239
10	87	317	84	192	253	170	215	232	345	179
5	139	324	272	237	210	39	64	140	124	411
0	240	293	160	214	286	148	251	135	136	407

DATE: 2/18/04

BRIDGE NO:

TESTED BY:

WEATHER:

	350	355	360	365	370	375	380	385	390	395
25	221	306	389	312	193	268				
20	420	353	356	312	208	255				
15	115	373	417	320	192	244				
10	197	253	396	495	173	143				
5	380	85	109	435	92	147				
	193	256	206	460	167	111				