INORGANIC POLYMER FIBER COMPOSITES FOR PROTECTION OF STRUCTURES

by

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Prof. Perumalsamy Balaguru

and approved by

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New Brunswick, New Jersey

[May, 2010]
ABSTRACT OF THE THESIS

Inorganic Polymer Fiber Composites For Protection of Structures

by JEREMY BROWNSTEIN

Thesis Director: Dr. Perumalsamy N. Balaguru

The primary focus of this thesis is to demonstrate the suitability of an inorganic polymer composite for transportation structures. The three major themes are: field application, graffiti resistance, and evaluation of self-cleaning and de-pollution properties. Previous Studies have demonstrated the potential of the composite made of alumino-silicate polymer and carbon fibers for field applications. This thesis presents results of three field applications, evaluation of graffiti resistance including removal techniques and documentation for self-cleaning and de-pollution properties.

For field application, pigment combinations were developed to match the colors of existing structures or to blend with the surrounding areas. Two field applications were done primarily by the author and the third one was completed with the help of daily laborers supplied by a contractor. In all three cases the applications were completed without encountering any technical problems.

In the area of graffiti resistance, commercially available products are reviewed. After evaluation of various removal techniques the author recommends
the use of citric-based cleaner with high pressure washer or high pressure water with baking soda.

For self cleaning, both laboratory and filed tests were conducted. The results show that the coating effectively cleans organic pollutants and the results compare well with those reported for anatase Titanium Dioxide containing concrete and mortar. Performance in the field can be simulated in the laboratory by using UV lamps. The results of the de-pollution study also shows that the results are comparable to the results reported in the European PICADA study where they used concrete or concrete mortar containing Titanium Dioxide.

Based on the results obtained it can be concluded that the composite is ready for large scale field applications.
DISCLAIMER STATEMENT

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of Rutgers University. This report does not constitute a standard, specification, or regulation.
ACKNOWLEDGEMENTS

The author wishes to thank Dr. Perumalsamy N. Balaguru without whom this project would not have been possible. The author would also like to thank Paul Pospiech, Robert Sasor and Ms. Camille Crichton Summers of NJDOT for providing funding and help at the various stages of the project.
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1 Introduction

Results presented in this thesis deals with an inorganic polymer composite coating for protection of concrete structures. Unique properties of this composite include: high temperature resistance, high abrasion resistance, self-cleaning and de-polluting properties. The composite is also very conducive for application in terms of workability and the absence of volatile organic compound during mixing, application and curing. The composite adheres well to concrete, bricks and timber surfaces. Information presented in this thesis primarily focuses on field application and evaluation of graffiti removal, self cleaning and de-polluting properties.

Chapter 2 presents information in the existing and commercially available graffiti resistance coating systems. In addition, this chapter assembles information from various DOTs with regards to approved graffiti removal systems and the DOTs experiences with those systems.

Chapter 3 presents the authors experiences during three different field application projects. This chapter discusses the tasks and objectives of each project, details about the application of the inorganic coating, the color schemes used, and subsequent monitoring of the projects.

Chapter 4 presents six different graffiti removal techniques attempted on the inorganic coating and the results of each trial test. These tests include the use of a citrus based cleaner with cold water, hot water, and several power washer tests.
Chapter 5 presents the results of the self-cleaning tests. These tests were conducted both inside using a UV light bulb and outside using sunlight. The tests were conducted either over a 48-hour period or over a one month period.

Chapter 6 presents the results of the de-pollution tests. The chapter explains how the reduction in gases such as NO and NO₂ occur and then goes on to test the rate of reduction for each of these gases. This chapter also explores the effect that certain variables will have on the rate of reduction. Such variables include the initial concentration of gas, UV light bulbs vs. sunlight, and the presence of TiO₂.

The conclusions drawn from this study are presented in Chapter 7. In summary, the inorganic composite is a viable product for creating a graffiti resistant, self-cleaning and de-polluting coating.
2 Background Information

The maintenance of existing infrastructures is becoming a major concern for most of the developed world. Countries are allocating more and more funds and efforts towards the repair and rehabilitation of these structures. The results presented in this thesis deals with using an inorganic polymer composite for reducing the surface deterioration of structural elements. The composite originally developed for application for aircraft structures had been modified for ease of application to civil engineering structures. The unique properties of this composite include: graffiti resistance, self cleaning characteristics, de-polluting characteristics and a hard surface the can withstand abrasive effects of pollutants in the air. Background information, presented in this chapter focuses on the basic properties of the polymer and information regarding other composites that are available in the market.

2.1 Basic features of Inorganic Polymer Composite

The basic features of this material are as follows:

- The cementing part of the coating, developed for aircraft structures was subsequently modified for use as a coating material. The cementing part is a potassium alumina-silicate, or polysialate-silox with the general chemical structure:

\[ K_n \{ - ( SiO_{2z} - AlO_2 )_n \} \cdot wH_2O \]

(1)
Where \( Z \gg n \). The research conducted so far has focused on the mechanical, thermal, and durability properties of composites and durability of strengthening systems for concrete structural elements.\(^{[1-5]}\)

- The resin is prepared by mixing a liquid component with silica powder. Fillers and hardening agents can be added to the powder component. The two components are mixed to the consistency of paint.
- The matrix is water based; consequently tools and spills can be cleaned with water. All of the components are nontoxic and no fumes are emitted during mixing or curing.
- The pot life varies from 30-minutes to 3-hours for compositions that cure at room temperature.
- Common application procedures such as brushing and spraying can be used for the application. The product was successfully used to coat bridge substructures by brush, roller and a sprayer in New Jersey and Rhode Island.
- The matrix can withstand temperatures up to 100\(^\circ\)C, and is not affected by UV radiation. Fire tests show that the flame-spread index is zero.
- The base coating material is white and hence other color schemes can be easily formulated using pigments. Various color schemes, including concrete and brick color coatings have been successfully developed. In addition, to the color combinations already developed several more combinations were developed during this investigation.
- The system is compatible with brick, concrete, wood, and steel and therefore can be used to coat the surfaces made of these materials.
• Durability of the coating system is central to coating applications. Therefore, the system was evaluated for durability under wetting, drying and scaling conditions, where it was found to be durable

• The coating is expected to have self-cleaning and de-polluting properties because zinc oxide is one of the constituent materials\(^4,\ 5\). These two aspects were evaluated in the investigation reported in this thesis.

2.2 Review of existing graffiti resistant coatings

The marking of buildings and transportation structures with graffiti is unsightly and can be offensive. Graffiti is a common occurrence and has caused proposals by companies and researchers for a number of methods of graffiti removal and prevention. Unfortunately, some of these methods are time consuming, expensive, and may be hazardous to the health of the removal crew due to toxic fumes. For example, it was reported in a research study in Sweden that there was a high prevalence of symptoms such as fatigue and headaches, as well as irritation of the eyes and respiratory tract, among workers involved in graffiti removal\(^1,\ 2\). Because of the frequent occurrence of graffiti there is a strong need for either a coating that spray paints will not stick to or for a fast and economical method to remove the graffiti.

Products available in the market can be divided into two broad categories, namely, sacrificial and permanent coatings. In the following sections a brief description of these two types of coatings along with a description of the proposed system are presented. A list of products currently on the market and being used by various DOT’s is also presented in this chapter.
2.2.1 Sacrificial coatings

Sacrificial coatings are generally a wax-like polymer coating that is sprayed or mixed with water and then applied to surfaces that are vulnerable for graffiti. When the structure is tagged by graffiti the sacrificial coating along with everything on top of it is removed. The typical method for removal is melting off of the coating and graffiti with hot water under pressure. Once the surface has dried the sacrificial graffiti-resistant coating is then re-applied. Several companies offer sacrificial coatings for graffiti control. The use of sacrificial coatings can be expensive and is very time consuming since it takes time to coat a surface and then remove and reapply a new coat every time it is marked with graffiti.

2.2.2 Semi-Permanent coatings

Semi-permanent coatings are commonly based on acrylics or cross-linking systems, such as epoxy, urethane, or polyester. These coatings are called semi-permanent because they can withstand the use of chemicals for graffiti removal, however, after a few times the coating gets worn out and must be removed or coated over. Aggressive chemical removers are necessary to remove the graffiti. As mentioned earlier after each use of these aggressive chemicals the adhesion of graffiti to the coating becomes stronger making removal more and more difficult. Some of the semi-permanent coatings are applied as multi-layer coatings.

2.2.3 Permanent coatings

Permanent coatings provide a long-term solution to problems with graffiti. Most of the existing coating formulations are organic and generally use the same
chemicals as non-stick cookware. Soiling and graffiti can be removed from these surfaces using high-pressure water or some form of chemicals. In most cases the company will recommend (a) graffiti removal method(s). The company’s recommendation sometimes includes the use of chemicals patented by the company and designed to work well with their coating system. The various chemicals used in graffiti removal for permanent coating are claimed to be benign and do not have any harmful affects to the environment.

2.2.4 Inorganic Polymer Coating

The inorganic polymer coating developed at Rutgers provides a glassy hard surface and hence was used as a graffiti resistant coating. In a previous study a fiber reinforced-inorganic polymer composite was formulated\(^3\). The composite, based on an inorganic polymer, known as Geopolymer was evaluated as a protective coating material for transportation infrastructure\(^4,5,6,7\). The unique features of this composition are as follows:

- The matrix used in the composite is inorganic as well as fire and UV resistant\(^8,9,10\).
- The system is water-based and has no toxic substances. No toxins are released during the application or curing.
- The coating can be applied with minimum surface preparation.
- The permeability of the coating material is much less than the permeability of concrete but it allows the release of vapor pressure build-up. Therefore, the coating does not delaminate from the parent surface\(^11\).
- The matrix is compatible with concrete, bricks, steel and wood.
• The matrix cures to a glassy texture and hence organic paints do not adhere to the coated surfaces. This aspect can be effectively used to create a graffiti resistant surface, which was one of the primary motivations for this study.

The previous study established the viability of the inorganic coating for protective coating applications. The primary objectives of the current study are as follows:

• Evaluate field applicability using transportation structures. One of the primary tasks is to demonstrate the ease of application and removal of graffiti.

• Comparison of the coating with other commercially applicable materials. The product list below presents a compilation of the existing products on the market.

2.2.5 Graffiti Resistant Products Survey

2.2.5.1 Methodology

The primary sources for this survey were: published literature, web-search and the material collected by the New Jersey Department of Transportation (NJ DOT). First, all the information was collected and synthesized in a relatively uniform format. Then the information was analyzed to obtain information on:

• Type of coating related to permanency; permanent or sacrificial

• Number of constituent components; single component, two or three components

• Cost (if available)

• Type of graffiti removal; hot water, common cleaning solutions or special solutions supplied by the manufactures

• Durability study
• Field demonstrations with various transportation agencies in USA
• Experience of transportation agencies

2.2.5.2 Analyses of Data

The following literature review led to the identification of various products that are currently being used by the Departments of Transportation in different states for their graffiti resistant properties. Many of these states also use products that remove graffiti without the use of any coating. Data collected from various sources are presented in Appendix A. The analysis of the information is presented in this chapter. Overall information was collected for 47 products.

2.2.5.2.1 Permanent Vs Sacrificial coatings

There were 41 permanent and 6 sacrificial coatings. In the case of permanent coating, the graffiti is removed using high-pressure water or some form of chemicals. In most cases the company that supplies the coating material also supplies the cleaning liquid. The chemicals are applied to the graffiti and washed off with water.

Sacrificial coatings are generally coatings that use a wax material to coat any number of different surfaces. After someone sprays graffiti on this surface the Department of Transportation would then visit that site and remove both the graffiti and the waxed surface using different methods that will be discussed below. The coating would then be reapplied to the surface.
2.2.5.2.2 Organic vs. Inorganic:

All of the products listed in the appendix were either classified as organic coatings (27 products were classified as organic) or the type of coating was not mentioned. None of the coatings were classified as inorganic. Most of the materials were urethane-based materials.

2.2.5.2.3 Number of Coats:

Approximately 80 percent of the permanent coatings provided information regarding the number of coatings that were required for their anti-graffiti setup. Of the products that mentioned how many components were needed: one coat was recommended for 13 products, two coats were recommended for another 13 products, two to three coats were recommended for two products, three coats was recommended for one product and more than three coats were recommended for three products. Nine products did not specify how many coats should be used.

Some of the products varied on the number of components needed based on information such as the surface to be coated. In some cases a company would suggest using their primer before applying subsequent coat(s). Before using any of these products the manufacturer of the product should be consulted to decide how many coats should be applied given the surface to be coated and other conditions of the site.
2.2.5.2.4 Cleaning Procedures:

Of the six sacrificial coatings three suggest their own cleaner to be used along
with a hot water blaster. Literature on the MU87 product listed below for the
Texas DOT was not available. Other sacrificial cleaners required a power hot
water sprayer to remove graffiti and some of the coating could even be removed
with cold water and a power blaster.

Most of the permanent coatings offer their own cleaning product to remove
graffiti. Some of the companies recommend common citrus-based cleaners to be
used along with hot water and a scrubbing tool. Some products advise allowing
time for the graffiti remover to lift the paint from the coated surface (~5-30
minutes) before removing. Aside from citrus-based cleaners a power washer can
also be used.

2.2.5.2.5 Durability Studies:

Most of the products list durability as one of their products benefits. Each product
varies with regards to the products level of durability. However, although the
claim that their coatings are durable, durability studies were virtually nonexistent
for almost all the products listed. Only one product had a durability study in which
the coating has been in place for 12 years.

2.2.5.3 Products List

2.2.5.3.1 Listed by DOT with notes on Field Demonstrations
and Their Experiences

Review of literature indicates that the following transportation departments have
had some form of interest in graffiti resistant coatings. The information from these
departments is presented in the following section. Unfortunately, there are very few departments that have tried field demonstrations. Information on their experience is also very limited.

*California Department of Transportation*

The California transportation department recognizes the following products. Information regarding their experience with any of the products could not be found.

- Soy Away, Model: B2013
- Graffiti Remover and Degreaser, Model: SPC-801
- FluoroGrip, Model P
- FluoroGrip, Model F
- FluoroGrip, Model E
- Defacer Eraser Graffiti Wipe, Model 57056
- Klean Release
- GPA-200-Cal (A & B - 2 part coating)
- GR-TWL
- GR-SYS
- GR-SPRAY
- GR-GEL
- GPC-101
- GPC-100
- Soy Away Graffiti Wipes, B4035
- GR II
- Starpower SPG10
- Tagaway
- Taginator
- GT-1000; GT-2000
- Multi-Master
- BG-Solv 762 - Graffiti Remover
- Bio Shield II
- Bio-Blast Cleaning System
- KICK (Superior Graffiti Remover (J-46))
- GPR-1 (Graffiti Klean (J-45))
- Graffiti-Pruf (Graffiti Protector (J-44))
- Scram-It
- Bio-T Graffiti Buster II
- Goop Off
- Krystal Kote CTF
- Repello
- ZEP - Big Orange
- Talon
- Motsenbocker's Lift Off
- Werth Graffiti Remover & Degreaser
Delaware Department of Transportation


- Tamms Industries 800-654-0402 or 301-470-3377
- Fox Industries FX441 Anti Graffiti System
- MAB Ply-Thane Products

In a memo from Najase George (Delaware DOT) to Sue Leedom (NJDOT) on 7/25/2006: “performance wise, we do not have a good history,… recoat in the event of graffiti instead of cleaning”

Florida Department of Transportation

- “no manufacturer have qualified as non-sacrificial coatings on the QPL”,
- “only one manufacturer has been able to qualify as a sacrificial coating”

Georgia Department of Transportation

- TexCote Graffiti Gard IIIS System
- Tex Coat Ty-Cote Clear
Minnesota Department of Transportation

- *Invisi-Shield
- Graffiti Guard III W
- Permaclean

New Hampshire Department of Transportation

- Professional Products of Kansas Inc.
- *Professional Water Sealant Anti-Graffiti
- *Graffiti Free Cleaner

Nevada Department of Transportation

- GPC-100 Graffiti Proofer & Curing Agent

New York Department of Transportation

- Dumond Anti Graffitian
- MAB Paints and Coatings
- Fox Industries
New Jersey Department of Transportation

- Tagaway
- GAT Graffiti Repellent
- Protectosil
  - A memo from Mr. John J. Corbo to Mr. Jim Duffe from the NJDOT on June 28, 2006 said this product was, “not acceptable”.

Tennessee Department of Transportation

- GRAFFITI SOLUTION SYSTEM
- TAGGUARD
- TAGPRUF
- Graffiti-Blok
- GRAFFITI GUARD
- GLASS-HIDE
- FORMULA 249 PREVENT
- TEXCOTE SACRIFICIAL GRAFFITI GARD
- PRMAKOTE
- GRAFFITI-PRUF
- CRYSTAL CLEAR
Texas Department of Transportation

- **(Sacrificial)**
  - MU 87
  - Sacrificial Graffiti Gard
  - Graffiti-Melt
  - Graffiti-Pruf
  - Monochem Permashield D.O.T. Sacrificial

- **(Permanent)**
  - Armaglaze
  - Graffiti Gard IIIS
  - CPU 647
  - B65
  - Scram-It Guardian P.
  - TPU-122 Duraplate
  - 800 Series
  - IGP Graffiti-Resistant Paint
  - Lotus-Thane 200
  - Acrylithane H/S HI-SLICK
  - Devthane 379
  - Enamo Grip

- **(Permanent, Water-Cleanable)**
  - Si-Coat 530
- Si-Coat 579
2.2.5.3.2 List of Companies That Offer Graffiti Resistant Coatings

The information presented below was synthesized from company literatures. The following is the alphabetical list of companies and details regarding their products.

2.2.5.3.3 Sorted by Company

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<td>American Polymer Corporation</td>
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<td>Aquarius Coatings Inc.</td>
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<tr>
<td>BASF Building Systems</td>
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</tr>
<tr>
<td>BASF Building Systems</td>
<td>85</td>
</tr>
<tr>
<td>CSL Silicones Inc.</td>
<td>80</td>
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<tr>
<td>CSL Silicones Inc.</td>
<td>81</td>
</tr>
<tr>
<td>Degussa Corporation</td>
<td>77</td>
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<tr>
<td>Devoe Coatings (ICI-paint)</td>
<td>39</td>
</tr>
<tr>
<td>Dumond Chemicals</td>
<td>33</td>
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<tr>
<td>Dumond Chemicals</td>
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<td>Ecological Coatings</td>
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2.2.5.3.4 Detailed Information on Commercially Available Products

The information was obtained either from the published literature or from the Internet. To keep uniformity, all the information presented was taken from the materials provided by the companies. The information should not be considered as complete and the authors do not endorse or imply that all the claims are correct. The details provided are for information purposes only.

1. 1700 & 1800 Series

Company:

Ecological Coatings
P.O. BOX 4202
CLIFTON PARK, NY 12065
PHONE: 518-664-3468

Product Description:

This coating is water-based, green, contains low voc products, and is formulated for effective graffiti protection. It exhibits high cross-linked densities, non-stick properties and excellent chemical resistance. Graffiti paint, marker and pen sit on
the surface of the coating but do not penetrate. Graffiti removal is simple using our Water-based, Non-toxic Graffiti Remover. Our coatings are permanent.

Huge Cost Savings: Single Product, Single Coat Coverage!

Availability options: Pigmented and Optically Clear Waterborne Anti-Graffiti Coatings

**Typical Applications:**
A few of the typical applications in various industries where our protective non-stick coatings are protecting equipment, buildings and structures
- Anti-Graffiti
- Corrosion Resistance
- Friction Reduction
- Foul-Release
- Hydrophobic
- Ice phobic
- Marine
- Mold Release
- Non-Stick, Easy Clean
- Power Generation
- Pulp & Paper
- Vehicle Protection
- Waste Water
- Zebra Mussel Protection

Comments: The typical applications list covers their entire range of products. The product that specializes in Anti-Graffiti has been listed in only the Anti-Graffiti section of their website and not in other sections like 'Friction Reduction' or 'Corrosion Resistant'.

2. AC-740G-Graffiti Guard
Product Description:

A clear coating used to form a barrier between surfaces and graffiti. This product makes graffiti less damaging to surfaces it is applied to. Graffiti guard creates a barrier so paints do not penetrate surfaces. This action makes a graffiti remover work quick and easy. Coverage is about 400 sq' ft' per gallon and good for all porous surfaces as protective barrier ands makes graffiti removal easy.

Comments: Data is not mentioned on site regarding product specifications or real time application results. Based on the description provided, the product seems to provide limited resistance.

3. Acrylithane QuickClean™ HS CLEAR URETHANE ENAMEL

Company:
Product Description

QuickClean™ HS CLEAR is a low VOC specially modified polyurethane coating formulated for use in applications requiring anti-graffiti, non-stick and high surface slip characteristics. QuickClean™ HS CLEAR can be used to ease removal of graffiti on buildings, allow simplicity of cleaning equipment such as cement trucks, or provide a high slip (low coefficient of friction) surface for dry bulk material container surfaces.

Features

- Very low surface energy (non-stick)
- Low VOC
- SKYDROL resistance
- Abrasion resistant
• Excellent color and gloss retention
• Resistant to chemical splash/spillage
• Lead and Chromate free
• Fast dry

http://www.jones-blair.com/NEWJBITD/QuickCleanHSClearTD.pdf

4. ACRYSHEEN

Company:

United Coatings | coatings and paints

19011 E. Cataldo

Greenacres, WA 99016

Toll Free 800-541-4383

Phone: 509-926-7143

Fax: 509-928-1116

Product Description:

ACRYSHEEN is a water-based epoxy, penetrating sealer designed to produce a clear, semi-gloss surface sheen. It is manufactured from non-yellowing, 100% acrylic resins to form a durable finish that provides long-term water repellency, dirt and graffiti resistance, and weather protection.
Advantages:

- Facilitates graffiti removal
- Protects against industrial airborne chemicals
- Reduces soil and fume absorption
- Minimizes run-down discoloration
- Non-yellowing
- Prevents moisture staining of surfaces
- Minimizes efflorescence
- Excellent ultraviolet resistance
- Conforms to all VOC regulations
- Reduces spalling and deterioration
- Single package – No shelf or pot life problems
- Water-Based – No flammable solvents
- Long term durability

**ESTIMATED COVERAGE RATES***

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Square Feet/Gallon Estimated Total*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>125 to 150 (3.0 to 3.9 m²/l)</td>
</tr>
<tr>
<td>Exposed Aggregate</td>
<td>75 to 100 (1.8 to 2.4 m²/l)</td>
</tr>
<tr>
<td>Brick, Stone</td>
<td>125 to 150 (3.0 to 3.9 m²/l)</td>
</tr>
</tbody>
</table>
Stucco 60 to 75 (1.4 to 1.8 m²/l)

Existing Coating 150 to 175 (3.9 to 4.2 m²/l)

These estimates are totals for two separate applications.

**Limitations & Precautions:**

ACRYSHEEN should not be applied over wet surfaces or wood substrates, however, concrete and masonry surfaces can be coated while slightly damp. Care must be taken during storage and shipment to ensure that temperatures do not fall below 32°F (0°C). Do not apply ACRYSHEEN at temperatures below 50°F (10°C). Cool temperatures and high humidity will retard cure. Avoid breathing of vapor or spray mist.


5. Armaglaze

**Company:**

Aquarius Coatings Inc.
7700 Pine Valley Dr., Unit 206
Woodbridge, Ontario L4L 2X4, Canada
Phone: 905-264-1168
Fax: 905-264-1169
Main customers are downtown associations, school boards, municipalities, institutions and franchise restaurants. But Armaglaze is also good for industrial buildings because of its resistance to chemicals. It could also be used on concrete floors.

**Armaglaze WB 6000:**

**Product Description:**

Armaglaze® WB 6000 is a waterborne, two-component aliphatic polyurethane coating system, supplied in two pre-weighed, color coded units ready for mixing.

**USES**

Armaglaze® WB 6000 is an architectural protective coating system designed for industrial/commercial application on concrete, masonry and many standard construction materials and surfaces in non immersion service. Armaglaze coatings are attractive, easy to clean and maintain, offering exceptional levels of weathering, durability, color and gloss retention.
ADVANTAGES

- Excellent aesthetics
- Very low odor, suitable for interior / exterior application
- Outstanding exterior durability, gloss and color retention properties
- Good resistance to solvents and chemicals
- Exceptional anti graffiti properties and asset protection capability

http://www.paintcoatings.com/data/Armaglaze%206000-datasheets.PDF

Armaglaze 9000:

Product Description:
ARMAGLAZE 9000 coating is an exterior grade, two-component aliphatic polyurethane coating system, supplied in two pre-weighed, color coded units ready for mixing.

USES
ARMAGLAZE 9000 is suitable for interior and exterior applications. It is used to seal and topcoat steelwork, concrete and most standard construction materials.
ARMAGLAZE coatings are attractive, easy to clean and maintain. They offer exceptional levels of weathering, durability, color and gloss retention.

ADVANTAGES

- Excellent aesthetics
• Outstanding exterior durability, gloss and color retention properties
• Good resistance to flame spread, solvents and chemicals
• Exceptional anti-graffiti properties and asset protection capability

http://www.paintcoatings.com/data/Armaglaze%209000-datasheets.PDF

Anti Graffiti Test Conducted:

http://www.dot.state.ri.us/programs/research/PE/Reports/Anti-Graffiti_Test.pdf

6. CLP Anti-Graffiti System

Company:

U.S Coating Solutions

(386) 313-3033

Product Description:

US Coating Solutions' CLP Anti-Graffiti System is a self cross-linking, water-born silicone polyester that has super nonstick properties, thus providing excellent anti-graffiti protection, as well as a protective coating for interior and exterior surfaces. The excellent clarity makes it ideal for bulletin boards, signage, and murals. It also contains a UV package that will protect the coating below it from fading. It will not yellow like most urethane and epoxy coatings have a tendency to do over time.
**Advantages:**

- Resists scuff marks, graffiti, gummy adhesive tapes, all stains
- Easy to clean
- Nonstick, slippery coating
- Abrasion-resistant
- Non-yellowing
- Mildew and mold resistant
- Insect-resistant
- Weather-resistant
- Lubricious
- Water-based
- Cures at room temperature
- Durable
- Cleans up with water
- Earth friendly (non-regulated)
- Easy to apply
- Non-sacrificial (does not lose its properties after cleaning)

**Price:** 500 sq. ft. @ $219.00

http://www.uscoatingsolutions.com/anti-graffiti.html
7. CPU 147 Dumond Graffiti Barrier Coat

Company:

Dumond Chemicals
1501 Broadway NY, NY 10036
Phone (212) 869-6350
Fax: (212) 764-5762

Product Description:

Watch Dog™ CPU-147 is a water based, low VOC fluorochemical emulsion which forms a clear, breathable, barrier from graffiti attacks. CPU-147 is a deep penetrating product that does not change the appearance of the substrate. It is a low odor, non-flammable, voc compliant product. CPU-147 is UV stable. In addition to its anti-graffiti properties, CPU-147 prevents water absorption into the surface, thereby reducing crackling, spalling, freeze/thaw damage, efflorescence, mildew growth and dirt pickup.

Features & Benefits:

• Provides both Anti-Graffiti and Weather-Proofing Protection
• Clear, No-Sheen, Ready-to-Use Formulation
• Penetrates the Surface, Breathable, Enables Moisture Vapor to Escape
• Ideal for Stucco, Concrete, Brick, Block, Wood, and other Porous Surfaces
8. **CPU 347 Anti Graffitiant**

**Company:**

Dumond Chemicals  
1501 Broadway NY, NY 10036  
Phone (212) 869-6350  
Fax: (212) 764-5762

**Product Description:**

Watch Dog™ CPU-347 is a silicone rubber based sealant that provides a clear, non-sacrificial, penetrating barrier against graffiti and water intrusion. Formulated and tested to provide superior protection, and easy removal of unwanted graffiti on concrete, block, brick, wood, stone, stucco and other porous building materials that allow penetration of the product.

**Features & Benefits:**

- Provides both Anti-Graffiti and Weather-Proofing Protection  
- Clear, No-Sheen, Ready-to-Use Formulation  
- Penetrates the Surface, Breathable, Enables Moisture Vapor to Escape  
- Ideal for Stucco, Concrete, Brick, Block, Wood, and other Porous Surfaces
Maintenance:

Graffiti Removal: Allow 5 days curing time prior to applying or removing graffiti; once the substrate has cured, remove the graffiti as soon as possible. Apply Watch Dog Lift Away Graffiti Remover directly to the graffiti and allow it to work for 5-30 minutes. Agitate with a nylon scrub-brush and rinse thoroughly with water. A power washer (not to exceed 1400 PSI) may also be used to remove graffiti.

NOTE: Use of any product other than Watch Dog Lift Away Graffiti Remover to remove graffiti may damage the protective coating, thereby necessitating reapplication.

Limitations:

Not suitable for extremely dense or polished stone, glass, plastic, metal, asphalt, painted, below-grade, or horizontal surfaces. **Surface must be free from moisture.**


9. CPU 647 GRAFFITI BARRIER COAT

Company:
Product Description

“DUMOND CPU 647 Graffiti Barrier Coating is a two component waterborne polyurethane, exhibiting superior abrasion and chemical resistance. As a clear or pigmented treatment, 647 is resistant to embrittlement and other environmental and weather related exposures. A two-coat treatment of CPU 647 will enhance the appearance and extend the life of a variety of surfaces that can be easily maintained.

DUMOND CPU 647 is a ready to use and mix coating. Dry films based on this unique dispersion provide exceptional chemical and abrasive resistance, hardness and flexibility. CPU 647 provides the ultimate in surface protection against graffiti, harsh chemicals, solvents, chalking and severe environmental elements.

In addition to its unique chemistry, CPU 647 is formulated with DuPont Zonyl® Fluor Additive for extremely durable, long lasting films. DuPont Zonyl® attaches itself to the polyurethane portion of the product for improved beading and repellency properties – making maintenance and graffiti removal quicker and easier. DuPont Zonyl® Fluor Additive will continue to migrate to the surface of the coating for long term protection unlike wax additives that are quickly worn or
washed away.” (Zonyl is a registered trademark of E.I. duPont de Nemours and Company.)

Features & Benefits

• Ideal for All Painted Surfaces, Interior or Exterior

• Easy Graffiti Removal….Beading and Repellent Properties

• Enhances and Maintains Uniform Appearance

• Provides Exceptional Chemical and Abrasion Protection

Surface Preparation:

Surface must be clean, dry, and free from dirt, grease, oil

Maintenance:

Graffiti Removal: Allow 7-10 days curing time prior to applying or removing graffiti; once the substrate has cured, remove graffiti as soon as possible. Apply Watch Dog Lift Away Graffiti Remover directly to the graffiti and allow it to work for 5-30 minutes. Agitate with a nylon scrub-brush and rinse thoroughly with water. Note: Use of any product other than Watch Dog Lift Away Graffiti Remover to remove graffiti may damage the protective coating, thereby necessitating reapplication. The use of this chemical graffiti remover before the coating has cured (7-10 Days) will affect the integrity of the coating.
10. CRYSTAL CLEAR

Company:

Visual Pollution Tech, Inc.
P. O. Box 12833
Scottsdale, AZ 85267-2833

Product Description:

CRYSTAL CLEAR is an exclusive formulation that protects interior and exterior surfaces from graffiti, stains from pollutants and other unwanted surface markings. CRYSTAL CLEAR is effective on natural or painted, porous and non-porous surfaces, brick, tile, concrete, stucco, wood, stone, metals, granite, precast concrete, exposed aggregate, split face block, etc. It can be used on walls, signs, statues, sculptures, restroom partitions, interior day care and school walls. In fact, any surface that is a potential target for graffiti, AND IT WILL NOT TURN YELLOW.

CRYSTAL CLEAR works as a barrier between graffiti and the underlying surface. Graffiti removal is made simple with the use of KICK. CRYSTAL CLEAR will withstand multiple graffiti removals while continuing to protect. We warranty that for five years....No matter how many graffiti removals.
CRYSTAL CLEAR is a clear, penetrating sealer and water repellent that is formulated to provide durable, long lasting protection.

**Features/Benefits**

- One Step Application
- No Thinning or Mixing
- Single coat application
- Remains clear
- Non yellowing
- Moisture prevention
- Retards efflorescence
- Fast Drying - dries and protects in 24 hours.

http://www.visualpollution.com/Graffiti%20Products/CRYSTAL%20CLEAR.htm

11. Devthane 379

**Company:**

Devoe Coatings (ICI-paint)

ALTEX COATINGS

91-111 Oropi Road

Greerton, Tauranga

PO Box 142
Product Description:

Devthane 379® is a high gloss, high performance, two component, chemically cured aliphatic urethane designed for use in areas where maximum gloss and color retention are required. Devthane 379® will provide excellent gloss and color retention as well as resistance to moderate to severe corrosive environments for:

- Transportation industry
- Chemical processing industry
- Pulp and paper industry
- Dairy industry
- Bridges and storage tanks
- As an anti-graffiti coating

Devthane 379® is recommended for use on suitably primed steel, aluminum, masonry or fiberglass.

Note: Light colors and clear may be used as anti-graffiti coatings due to their excellent solvent resistance - refer also to Devclean 99 Graffiti Remover and Easy Clean SX Additive

12. Dupont Anti Graffiti Coating

Company:

Dupont
Barley Mill Plaza, Bldg. 21
4417 Lancaster Pike
Wilmington, DE 19805
Phone: 800-GETDUPONT
Fax: 800-872-3448

24-hour Corporate Information Center (U.S. callers only) 1-800-441-7515 or 1-302-774-1000

Product Description:

Graffiti-resistant urethane polyester powder

Spotless coatings will dull if solvents stronger than IPA are used to remove graffiti.
Abrasive cleaners will mar the coating and reduce its stain resistance.
The ease of cleaning graffiti from the coating surface is reduced by surface breaks or irregularities such as fine scratches made by rough marker tips, non-
smooth surface profiles, porous metal surfaces, or poor application techniques resulting in increased orange peel.
When extreme resistance to graffiti and strong chemicals is a priority over weatherability, DuPont Powder Coatings has very chemical-resistant epoxy coating powders that should be considered.

Comments: The product does not seem to be very effective for long term application from their website

13. Enamo Grip

Company:

Superior Products International

50 Briar Hollow Lane

Suite 490E

Houston, TX 77027

Phone: (713) 960-0400

Fax: (713) 960-8649

Description:
ENAMO GRIP is a two-part polyurethane enamel that forms a uniquely hard and durable coating film, which demonstrates unsurpassed semi-gloss retention, color retention, and chalk resistance when used in exterior applications. It is resistant to water and humidity, stains, acids, solvents, and chemicals, as well as having tremendous scuff, mar- and impact resistance.

Although available in colors, ENAMO GRIP (clear) provides exceptional graffiti resistance and protection. Krylon spray paints, magic markers, etc. can be removed completely with SPI's GRAFFITTI CLEANER. ENAMO GRIP can withstand repeated incidents of graffiti removal, as it is resistant to solvents. It can provide tremendous cost savings by eliminating blasting and re-painting of graffiti affected surfaces on trains, buses, trams, and buildings.

The formula of resins in ENAMO GRIP will spread and self-level into an even, and smooth finish. No brush marks when applied by brush.

**Typical Uses:**

* For architectural and maintenance situations that require the utmost in exterior durability.

* As a topcoat for RUST GRIP and MOIST METAL GRIP.

* As a coating system for graffiti protection.

* As a floor covering where a tough, long-lasting finish is required. The coating has non-skid characteristics built into the formulation.

* Anywhere that a UV-resistant topcoat is required.
Used by companies in the transportation, construction, property management, manufacturing and distribution industries, EnamoGrip is the ideal coating for the control of graffiti and vandalism, and additional provides resistance to rust and corrosion.

EnamoGrip is a tough, medium speed, moisture curing, two component polyurethane enamel, which produces a uniquely hard and durable coating film. EnamoGrip demonstrates unsurpassed semi gloss retention, color retention, and chalk resistance, when utilized for exterior coating situations. This coating provides outstanding resistance to water and humidity, stains, chemicals, and solvents, as well as protection from scuffing and impacts.

EnamoGrip provides optimal protection on bridges when applied over RustGrip or used by itself to completely encapsulate the metal, protecting the coated surface from rust and corrosion for a minimum of 20 years in normal circumstances. This coating resists hail damage and similar abuses that create opportunities for rust and corrosion. Completely UV-controlled and weather resistant, EnamoGrip is a self-leveling formula for an outstanding finish. EnamoGrip can be used on flooring for a tough; long wearing surface but precise measures must be taken to insure a completely clean surface, free from moisture and residues, for it to adhere to. In summary, the overall toughness, durability, and weather resistance of EnamoGrip polyurethane enamels, make them the
ideal choice for demanding product applications for architectural maintenance situations that require the utmost in exterior durability.


14. FX-441

Company:

Fox Industries, Inc.

888.760.0369 | 410.243.8856 | FAX 410.243.2701

3100 Falls Cliff Road | Baltimore, MD 21211

Product Description:

FX-441 Anti-Graffiti System is an aliphatic urethane, manufactured and packaged as an integrated protective system: FX-441 Primer (single component), Intermediate Coat and Top Coat (two component). The Top Coat of the FX-441 Anti-Graffiti System contains special modifiers that allow removal of graffiti without harming the system.

Features & Benefits:

- Excellent graffiti and chemical resistant properties.
- Resists stains from many common items such as spray paint, indelible marker, nail polish, food, etc.
• Requires no "induction time," just mix A and B together and begin to apply.
• Can be applied by brush, roller, or spray.
• Resists acid rain and is rain-cleaned of airborne pollutants.
• Can be applied to wood, concrete, stucco, brick, block, fiberglass, epoxy coatings, and steel.

**Shelf Life:**
1 year in unopened containers

**Limitations:**
Surfaces must be dry; do not apply to wet surfaces. Do not apply below 40°F surface temperature. Do not use when humidity is above 90%. Top Coat should not be recoated after 7 days without consulting a Fox Industries Technical representative


**15. GAT Graffiti Repellent**

**Company:**
Global Kinetics, Inc.
1951 W. Camelback Road
Suite #220
Phoenix, AZ 85015
Phone: (888)222-6783
Fax: (510)339-2668

Products:
Gat Guard

Product Description
GAT GUARD is a non-sacrificial anti-graffiti treatment. It is a clear penetrating water and oil repellent. GAT GUARD implements our core technology of altering the electrostatic charge of a surface to make it the same as that of water and oil. Like two magnets that repel one another due to the like charges, surfaces protected with this treatment repel water and oil, the main ingredients of paint, making graffiti removal possible. Since all electrostatic charges require an energy source, GAT Guard is designed to pull its energy from ultraviolet (UV) light. Where most every other surface is degraded by UV exposure, GAT protected surfaces actually require it.

Features/Benefits
- Hydrophobic-Water repellent
- Oleophobic-Oil Repellent
- VOC Compliant
- 100% Vapor Permeable
- Superior UV resistance
- Non-Sacrificial
- Dries Undetectable
- Non-yellowing
- Inhibits Efflorescence

**GAT GUARD Plus 50**

**Product Description**

GAT GUARD plus 50 is a clear, non-sacrificial, water-based acrylic graffiti protective system. Graffiti is easily removed from protected surfaces by using GAT ERASER plus 50, Graffiti Abatement Technologies specially formulated graffiti remover. The GAT GUARD plus 50 system delivers a durable barrier between the substrate and graffiti and other elements that offers effective graffiti remediation but remains vapor permeable. GAT's core technology is incorporated into GAT GUARD plus 50 giving the protective system and the underlying surface superior UV light protection.

**Features/Benefits**

- Anti-Graffiti System
- Non-Sacrificial
- Vapor Permeable
- Hydrophobic / Oleophobic
- Excellent Durability
• Stain Resistant
• Clear-Matte or Gloss Finish
• Water-borne
• Excellent Weatherability
• VOC Compliant
• Dries Rapidly
• Non-Hazardous
• Superior UV Resistance
• Non-yellowing
• Inhibits efflorescence

GAT SHIELD

Product Description
GAT SHIELD is a clear, high performance water-borne, anti-graffiti coating with added chemical and abrasion resistance. GAT SHIELD allows for complete and easy removal of graffiti from painted surfaces without affecting the underlying surface. GAT's core technology is incorporated into GAT SHIELD giving the protective coating and the underlying surface superior UV light protection.

Features/Benefits
• Anti-Graffiti System
• Excellent Chemical Resistance
• Excellent Durability
• Stain Resistant
• Clear-Matte or Gloss Finish
• Non-Sacrificial
• Non-Hazardous/Non-Corrosive
• Excellent Weather-stripped
• DOC Compliant
• Excellent Abrasion Resistance
• Hydrophobic / Oleophobic
• Water-borne
• Superior UV Resistance
• Non-yellowing
• Inhibits efflorescence

http://www.aecinfo.com/1/resourcefile/00/27/17/graf04.htm

16. **GPC-100 Graffiti Proofer & Curing Agent**

**Company:**

SEI Chemical

Laboratory, Manufacturing & Warehousing

3430 Union Pacific Avenue

Los Angeles, CA 90023
Product Description:

The SEI Graffiti Proofer & Concrete Curing Agent is a penetrating, permanent weatherproofing and Graffiti Proofing treatment. The SEI Graffiti Proofer & Concrete Curing Agent is a certified and accredited concrete curing agent as specified by ASTM standards. The SEI Graffiti Proofer & Concrete Curing Agent shows no deterioration from ultraviolet rays, ozone, salt spray or acid rain. SEI Graffiti Proofer allows for expansion, contraction, building movement and temperature extremes. The SEI Graffiti Proofer will allow moisture vapor to escape while not allowing moisture to enter the structure. This product is non-toxic, environmentally friendly, non-reactive and Personal Protection has been rated as a B.

Note: The Alameda Corridor in California is the largest structure on record to be coated with an anti-graffiti treatment and the GPC-100 Graffiti Proofer & Curing Agent was the product of choice.

17. GPA-200

Company:

SEI Chemical
Laboratory, Manufacturing & Warehousing
3430 Union Pacific Avenue
Los Angeles, CA 90023
Tel: 323 263 4575
Fax: 888 273 4489

Prices:

- 6 oz @ $89.40
- 1 gallon @ $617.97
- 5 gallons @ $3037.15

Product Description:

GPA-200 is a high-performance, highly fluorinated and durable clear gloss coating formulated for applications requiring extremely high-slip characteristics and chemical resistance. This product exhibits outstanding anti-stick, long-lasting performance properties. The GPA-200 is the world's first graffiti deterrent coating, many spray paints simply will not stick to it. When a tagger attempts to vandalize a structure protected with the GPA-200 the paint will crawl together and run off the surface, thus deterring the vandal from continuing. The fluorinated polymer
makes this coating impervious to UV degradation and it is highly resistant to hydrocarbons, graffiti and a wide variety of chemicals

**Performance Characteristics:**

- Outstanding Hydrophobic and Oleophobic surface properties.
- High end anti-stick and release properties.
- Highly flexible, non-stick and outstanding impact and abrasion resistance.
- Highly resistant to attack by micro-organisms, hydrocarbons, chemical products and UV radiation.
- Its complex vehicle gives excellent durability and adhesion with interior and exterior use.
- Provides protection and penetration of water.


18. **Graffiti Gard IIIW**

**Company:**

Tex-Cote

Textured Coatings of America, Inc.

2422 East 15th Street

Panama City, Florida 32405

Phone: (850) 769-0347
Fax: (850) 913-8619

**Description**

Tex Cote Graffiti Gard IIIW System is a multi-step system with an aliphatic urethane topcoat that resists graffiti and staining from a variety of materials including food, ink, spray paint, and markers. The slick surface is easy to clean with an appropriate compound. Many contaminants wipe off with soap and water. Ink-based or paint based graffiti is removed with Tex Cote Graffiti Gard Cleaner.

**Features**

- Breathable aliphatic polyurethane
- Waterbased formulation
- Low VOC

**Benefits**

- Protects underlying substrate
- Easy to clean surfaces
- Able to use in all states

19. Graffiti Gard IIIS

Company:

Tex-Cote

Textured Coatings of America, Inc.

2422 East 15th Street

Panama City, Florida 32405

Phone: (850) 769-0347

Fax: (850) 913-8619

Description

Tex Cote Graffiti Gard IIIS System is a multi-step system with an aliphatic urethane topcoat that resists graffiti and staining from a variety of materials including food, ink, spray paint, and markers. The slick surface is easy to clean with an appropriate compound. Many contaminants wipe off with soap and water. Ink-based or paint based graffiti is removed with Tex Cote Graffiti Gard Cleaner.

Features

- Breathable aliphatic polyurethane
- Solvent based

Benefits

- Protects underlying substrate from graffiti
• Easy to clean surface


20. Graffiti-Melt

Company:

Genesis Coatings, Inc.
2780 La Mirada Dr, #D
Vista, CA 92081
(800) 533-4273

Product Description:

Graffiti Melt is a ready-to-use, low odor, “sacrificial” coating used to protect exterior surfaces from graffiti, posters and atmospheric pollution. Graffiti Melt is composed of water and food grade materials, and creates a tough barrier without altering the appearance or texture of the treated surface. Once the surface is coated, graffiti can be removed with a hot water pressure washer or one of our removers and cold water. After removal, reapply the Graffiti Melt to the affected area. Removal by any other means will void the Graffiti Melt warranty.

Note: Certain paints, inks and cleaning agents contain harsh solvents and other chemicals that can alter Graffiti Melt by affecting its performance or removing it
from the surface altogether. Genesis Coatings makes no guarantees as to system compatibilities -- this information must be determined by applying a test patch to the appropriate substrate.

Graffiti Melt Coating is a zero VOC, nontoxic, biodegradable, paraffin-based emulsion. It can be removed from the surface with a hot water pressure washer or one of our non-toxic, biodegradable removers:

- Gold Remover cleans Graffiti Melt from porous, unpainted surfaces such as concrete and masonry.
- Eaze Away Remover cleans Graffiti Melt from baked & painted delicate surfaces.
- Terminator Remover cleans Graffiti Melt from metal, some brick and painted surfaces.

Features:

- Graffiti Resistant
- Odorless
- Non-flammable
- Breathable
- Fast drying
- Zero VOC
- USDA Compliant
- Solvent Free
21. Graffiti-Shield® Plus

Company:

Gemite® Products Inc.

160-3480 East Robinson Rd.

Amherst, New York 14228

Phone 888-443-6483

Fax 888-443-6329

Features:

- Superior graffiti-protection
- Easy to clean
- Superior durability
- High abrasion resistance
- Excellent UV resistance
- Superior bond
- Fungus and mold resistant
- Highly freeze/thaw resistant
- Non-flammable
- Economical
· Spray, roller or brush applied
· High chemical resistance

**Limitations:**

Do not apply Graffiti- Shield Plus when the surface temperature is lower than 5°C (41°F), when rain is imminent or when relative humidity is likely to exceed 90% at the time of application and several hours there after. Cold conditions or condensation adversely affect the appearance of the dried film.

All surface voids should be filled and any existing coating should be removed before the application of the graffiti- Shield Plus. Do not apply over glazed surfaces.

**Packaging:**

Both Graffiti- Shield Plus Primer & Top Coat consist of 2 components. Component A, pack aged in a 2.0 L (0.53 USG) can and Component B pack aged in a 2.0 L (0.53 USG) can.

**Yield:**

Graffiti- Shield Plus Primer Kit covers approximately 6.1 - 7.3m2/L (250 - 300 ft2/USG) @ 75 - 66 microns (3 - 2.5 mils) per one (1) coat. Graffiti- Shield Plus Top Coat Kit covers approximately 4.9 - 6.1 m2 /L (200 - 250 ft2/USG) @ 110 - 90 microns (4.5 - 3.5 mils) per one (1) coat
22.  **GRAFFITI SHIELD SYSTEM™**

**Company:**

New Dimensions Solutions, LLC  
3960 Howard Hughes Parkway, Suite 500, Las Vegas, NV 89169  
(800) 731-2231, (702) 990-3978, FAX: (866) 361-1558  
sales@ndclean.com

**Product Description:**

GRAFFITI SHIELD SYSTEM™ of protective coatings dries water clear and enhances the natural appearance of all materials and underlying paints while preventing paints from fading/oxidizing for many years! It is also resistant to attracting soils and dust.

Part 1 is our water based primer/sealer, **ONE COAT™**, protective coating which is applied as the base/primer coat, and Part 2 is our water based, **ND GRAFFITI SHIELD™** - anti-graffiti coating, which is applied in 4-5 top coats.

<table>
<thead>
<tr>
<th><strong>PRODUCT</strong></th>
<th><strong>SIZE</strong></th>
<th><strong>SHIPPING WEIGHT (lbs)</strong></th>
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<td>PRODUCT</td>
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<tr>
<td>ND GRAFFITI SHIELD™</td>
<td>QUART (32 oz)</td>
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<tr>
<td></td>
<td>CASE of 12 QUARTS</td>
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<tr>
<td></td>
<td>GALLON (128 oz)</td>
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<td></td>
<td>CASE of 4 GALLONS</td>
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<td></td>
<td>5-GALLON PAIL</td>
<td>48</td>
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<tr>
<td>GRAFFITI SHIELD SYSTEM™</td>
<td>Quart of ONE COAT™ Water Based Sealer/Finish, Quart of ND GRAFFITI SHIELD™ Water Based Sealer/Finish Quart of DISAPPEAR Organic Graffiti/Adhesive Remover™</td>
<td></td>
</tr>
<tr>
<td>DISAPPEAR</td>
<td>QUART (32 oz)</td>
<td>3</td>
</tr>
</tbody>
</table>
Real Time Applications:

The City of San Francisco invited us to assist in their efforts to remove graffiti vandalism in 1992
Paul Carpentier, Carpentier Automotif, Milwaukee, Wisconsin  May 2nd, 2006
Donald Remmel, TSgt, 222CBCS, DP, Costa Mesa, California  March 1st, 2006
EMERALD FUND, California October 23, 1991

Pasted from <http://www.ndclean.com/graffitishieldfinish.html>

Comments: Not used in transportation structures

23. GRAFFITI-PRUF

Company:
Visual Pollution Tech, Inc.
P. O. Box 12833
Scottsdale, AZ 85267-2833
Product Description:

GRAFFITI-PRUF is an exclusive formulation that protects interior and exterior surfaces from graffiti, stains from pollutants and other unwanted surface markings. It is non-toxic, odorless, biodegradable and NON-HAZARDOUS. GRAFFITI-PRUF is effective on natural or painted, porous and non-porous surfaces, brick, tile, concrete, stucco, wood, E.I.F.S., stone, metals, granite, split face block, etc. It can be used on walls, signs, statues, sculptures, restroom partitions, interior day care and school walls. In fact, any surface that is a potential target for graffiti.

GRAFFITI-PRUF works as a barrier between graffiti and the underlying surface. Washing or spraying the surface with hot water melts the barrier, eliminating the graffiti. Graffiti removal and re-application of Graffiti-Pruf is fast and simple. Using a power hot water sprayer or GPR-1 and cold water the user can clean and re-protect 100 sq. ft. of wall surface in about 10 minutes.

Features/ Benefits

- Vapor Permeable-allows moisture to escape without damage
- No Thinning or Mixing
- Fast Drying-dries and protects in minutes.
- RETARDS THE GROWTH OF MOLD, MILDEW & ALGAE
- NO HAZARDOUS INGREDIENTS
24. **GSS Graffiti Resistant Coatings**

Company:

American Polymer Corporation

9176 South 300, West #4

Sandy, Utah 84070

USA

Phone: 800.676.5963

Fax: 801.255.7123

American Polymer’s easy-to-apply, easy-to-clean Graffiti Solution System (GSS) provides the most thorough and risk-free solution for your organization, leading to lower maintenance and capital costs. With the American Polymer Graffiti Solution System (GSS), you will invest in a protective anti-graffiti solution that will meet your organization’s needs today and tomorrow.

- Graffiti can be removed repeatedly without the need to reprotect or recoat the surface for up to 25 years;
- Removing graffiti is now immediately and complete—no shadowing or ghosting like most other anti-graffiti coatings or graffiti proof paint;
- Maintains the natural look of the underlying surface with a non-glare, invisible finish;
• Requires no special equipment for removing graffiti;
• Environmentally friendly product promotes safe clean up. Great for all graffiti removal programs.

One of the main reasons that American Polymer Graffiti Solution System (GSS) is great for all graffiti removal programs, besides the fact that it makes removing graffiti simple and easy, is that it protects a wide range of graffiti targets including but not limited to the following:

1. Architectural CMU buildings and wall
2. Concrete pillars and barrier walls
3. Brick buildings and walls
4. Historic sandstone and granite buildings
5. Metal bathroom partitions or any metal surface

Any painted surface (can be substituted for standard paint and used as the primary paint in any color or finish).

Copied from: <http://www.americanpolymer.com/productsAdvantage.php>

25. **Krystal Kote CTF**

**Address:**

TradeWinds International, Inc.

1374½ Colorado Street

Glendale CA 91205-1475
Product Description:

KrystalKote™ CalTrans Formula (CTF) Gloss, is a clear two-component, high-solids, low VOC, cross-linked, aliphatic polyurethane coating possessing outstanding resistance to harsh environmental conditions; graffiti; mold, mildew & microbe growth; caustic chemicals; abrasion; impact; and flexing. KrystalKote™ CTF is resistant to the effects of U-V and I-R: clear will not yellow, clear-coated underlying colors and custom-tinted KrystalKote™ will not noticeably fade for 10-years. KrystalKote™ CTF has proven flexibility and tolerance to expansion & contraction, providing a crack-resistant surface, desirable in harsh environments such as salt-air coastal, high heat desert, frigid mountainous, and high humidity of the Northwest & the Southeast. KrystalKote™ CTF is completely resistant to hydraulic, lubricating and cutting oils, alcohols, food stains, normal acids & alkalis, salts, solvents, fuels, paints, inks, asphalt, wet concrete, algae, mildew, fungal molds, pesticides, fertilizers, creosote, etc., and temperatures to 450°F. KrystalKote™ CTF is CalTrans-Approved and specified as a Graffiti-Resistant clearcoat for traffic signs & sound walls, and is impervious to graffiti solvents & pigments, cleaning efficiently with approved graffiti removers, such as GT-1000™ or GT-2000™.
26. **MicroGuard AD00 from Adsil**

**Company:**

ADSIL Inc  
1901 Mason Avenue, Suite 101  
Daytona Beach, FL 32117  
Phone: 1-800-549-2539  
info@adsil.com

**Product Description:**

MicroGuard® AD00 is a high-performance surface treatment that provides protection against graffiti. The treatment is also resistant to chemical attack and exhibits outstanding resistance to solvents, acid and alkali exposure. The unique formulation of MicroGuard® AD00 will not break down from UV exposure.

MicroGuard® AD703 Concrete Clear Gloss Treatment is ideal for clear coating many organic floor paints where additional abrasion and chemical resistance is needed.

Real Time Application
27. Monochem Permashield D.O.T Sacrificial

Company:

Monopole Inc.

4661 Alger Street

Los Angeles, CA 90039

Tel: 818-500-8585

Fax: 818-502-0818

Product Description:

Permashield Sacrificial is a modified Wax Emulsion that dries to a clear, non-yellowing tough film. It shields the surface from the penetration of spray paint, marking pens, chemical attacks, crayons and lipstick into the substrate. It can be removed by either hot water or by using our Citrus Clean (water base, biodegradable Cleaner/Remover).

Permashield is also available in NON-SACRIFICIAL and PERMANENT Anti-Graffiti Systems. For more information please contact your distributor or the manufacturer.
Basic Uses:
Permashield Sacrificial offers the lowest cost and easiest graffiti protection on the market today. It may be used on interior or exterior, painted or unpainted vertical surfaces including: concrete walls, highway structures, shopping malls, civic or mass transit, municipal facilities, factories, office buildings, apartments and schools.

Removal of Graffiti: Using Waterblasting
1. Set up pressure washer to provide a water temperature between 130-190°F at 800-900 psi pressure. Do not use pressure over 2,000 psi and avoid temperatures over 200°F.
2. Proceed from top to bottom allowing the water to heat the wall and the pressure to carry away the graffiti.
3. Allow the stripped areas to dry damp, then reapply a fresh coat of Permashield Sacrificial in a uniform manner.

Removal of Graffiti: Using Monochem Citrus Clean
1. Use Citrus Clean or a mild solvent using a hand sprayer or brush. Allow it to stand for one to five minutes. Agitate the surface with brush to loosen all graffiti from the coating. Do not allow cleaner to dry on surface. Rinse immediately with water and wipe clean with a cloth.
2. Make a note of all areas in which graffiti was stripped for the reapplication of Permashield Sacrificial.

3. Allow the stripped areas to dry damp, then reapply a fresh coat of Permashield Sacrificial in a uniform manner. Slightly overlap the previously coated surface that was not removed by waterblasting or a remover.

http://www.monopoleinc.com/catalog/index.php?search=graffiti&action=listcat&cat=&x=0&y=0#

27. PermaClean

Company:

TK Products, Division of Sierra Corporation
11400 West 47th Street
Minnetonka, MN 55343
Phone: 952-938-7223
Fax: 952-938-8084

Product Description:

The PermaClean Anti-Graffiti Products feature unique blends of aliphatic urethane resins specifically formulated to protect various surfaces from graffiti vandalism.

All PermaClean products are single component, non-yellowing permanent coatings. No recoating after removal of the various types of products used to deface the surface is necessary. Spray paint, or lipstick, marker, nail polish or
multiple component paint products will not adhere to the Permaclean protected surface.

http://www.tkproduct.com/Permaclean.PDF

28. Ply-Thane 1200 Urethane Finish

Company:

MAB Paints
1623-1625 Stelton Road
Piscataway, NJ 08854 (732) 650-1200

Description:
A superior, ultra-long lasting, fast drying, ambient temperature cured, two component, fluoropolymer urethane coating which provides exceptional gloss and color retention. Recommended for surfaces exposed to weather extremes such as bridges, stadiums, sports complexes, storage tank exteriors, water tanks, municipal buildings, museums, schools, fascias and other high visibility areas. Resistant to graffiti, chemicals and abrasion. Applicable by brush, roller or spray.

Product Attributes:

- Ultra-Long Lasting and Fast Drying
- Resistant to Graffiti, Chemicals and Abrasion
• Provides Exceptional Gloss and Color Retention


29. Ply-Thane 890 High Solids Coating Urethane Finish

Company:

MAB Paints
1623-1625 Stelton Road
Piscataway, NJ 08854 (732) 650-1200

Description:

Ply-Thane 890 High Solids Coating Urethane Finish is a high solids, OTC VOC compliant, two component, aliphatic acrylic urethane coating that provides exceptional weatherability with good gloss and color retention. Resistant to industrial fumes, moisture condensation, salt air, impact, abrasion and staining. An accelerator can be used to speed the cure if temperatures are 40°F - 50°F.

Features

• Applicable by brush, roller or spray
• Can be applied directly over organic (epoxy) or moisture (urethane) cured zinc rich primers
• Meets OTC VOC regulations
• Outstanding topcoat for tanks, bridges, concrete, structural steel, rail cars or locomotives
• Low HAP content

30. Ply-Thane OTC Compliant Clear Coat

Company:

MAB Paints
1623-1625 Stelton Road
Piscataway, NJ 08854 (732) 650-1200

Description:

Ply-Thane OTC Compliant Clear coat is a high solids clear coat finish that provides excellent long-term UV protection over MAB pigmented coatings. This coating provides the highest standards for color and gloss retention. Ply-Thane Clear Coat is VOC compliant and meets all current OTC Regulations. Available in either gloss or matte finish, this coating can also be used wherever the ultimate in graffiti protection is required. Ply-Thane Clear Coat can be used as a clear protective finish or as a topcoat for latex, epoxy or urethane coatings to provide extended service life.

Graffiti Removal

Remove graffiti easily with any appropriate solvent or cleaner. After graffiti is discovered, clean using the following steps. After determining the best removal solvent*, wipe or power wash the effected areas. The gloss should remain the same and will be ready for the next cleaning. Ply-Thane Clear Coat may soften
slightly with strong solvents while removing graffiti, but will recover. Do not use abrasive devices to remove graffiti.

*Test a small area with water, heavy duty cleaner like MAB Power Wipe, or solvents such as mineral spirits, denatured alcohol, MEK or xylene.


28. PRMAKOTE

Company:

Visual Pollution Tech, Inc.

P. O. Box 12833

Scottsdale, AZ 85267-2833

Product Description:

PRMAKOTE is an exclusive formulation that protects interior and exterior surfaces from graffiti, stains from pollutants and other unwanted surface markings. PRMAKOTE is effective on natural or painted, porous and non-porous surfaces, brick, tile, concrete, stucco, wood, stone, metals, granite, precast concrete, exposed aggregate, split face block, etc. It can be used on walls, signs, statues, sculptures, restroom partitions, interior day care and school walls. In fact, any surface that is a potential target for graffiti.

PRMAKOTE works as a barrier between graffiti and the underlying surface. Graffiti removal is made simple with the use of a pressure washer or KICK.
PRMAKOTE will withstand multiple graffiti removals while continuing to protect. It is not a sacrificial coating.

PRMAKOTE is a clear, penetrating sealer and water repellent that is formulated to provide durable, long lasting protection.

ADVANTAGES

- One Step Application
- No Thinning or Mixing
- Single coat application
- Non yellowing
- Moisture prevention
- Vapor permeable
- Retards efflorescence
- No color change
- Fast Drying—dries and protects in 24 hours.
- RETARDS THE GROWTH OF MOLD, MILDEW & ALGAE
- Can use over painted surfaces
- Can be applied at temperatures above zero degrees F

http://www.visualpollution.com/Graffiti%20Products/prmakote.htm
Professional Products of Kansas, Inc.

Company:

Professional Products of Kansas, Inc.

4456 S. Clifton, Wichita, KS 67216

800-676-7346

Professional Water Sealant & Anti-Graffitiant is a "Dual Purpose" silicone rubber sealant that provides invisible protection from graffiti as well as water damage.

- Clear, long lasting protectant, easily applied by spray, roller or brush.
- Permits expansion and contraction caused by building movement and temperature extremes.
- Breathable. Permits moisture vapor to escape while protecting the surface from paint penetration.
- Dries to the touch within an hour. Drying time subject to temperature and humidity.
- Elastomeric bridging of hairline cracks.
- Protects stucco, concrete, brick, block and other porous building surfaces.
- VOC compliant.

Caution:
Use of any product other than Professional Phase II Cleaner is not recommended.

Availability:
Packaged in 1 gallon (3.785 liters) cans, 5 gallon (18.93 liters) pails and 55 gallon (208.20 liters) drums. Contact manufacturer for a distributor list and price.

30. Protectosil Anti Graffiti Coating

Company:
Degussa Corporation
Aerosil & Silanes
379 Interpace Parkway, P.O. Box 677
Parsippany, NJ 07054-0677
Phone: 1 (800) 828-0919

Product Description:
Protectosil Anti Graffiti Coating is a water-borne breathable, anti-graffiti treatment for use on concrete, brick, concrete masonry units and natural stone. Protectosil Antigraffiti protects surfaces to allow the easy removal of a wide variety of graffiti, including spray paint, permanent marker, ink, bituminous paints, asphalt sealers, and other solvent or water borne paints. Because of the superior performance,
standard non-hazardous cleaners and low pressure water blasting is sufficient to remove most graffiti.

**Benefits:**

- Non-sacrificial
- Zero VOC
- Breathable
- Clear
- Excellent UV stability
- Resistance to alkali attack
- Tack-free after drying
- Will not blush, peel or yellow
- Easy to apply

**Graffiti Removal:**

Protectosil® ANTIGRAFFITI makes removing graffiti easy. Graffiti are often just a tag. These can be removed by hand using commercial graffiti cleaner, a brush and a rag. No special equipment and large volumes of water are required.

Larger areas that have been protected with Protectosil® ANTIGRAFFITI can be cleaned using equipment, such as pressure washers. Some substrates may not even require graffiti cleaners. However, it’s important to match the cleaning equipment to the building material so that too high a water pressure does not damage sensitive substrates.
**Simple cleaning means:**

- No special equipment required for small tags
- No specially-trained personnel required
- Large areas can be cleaned quickly and completely by machine


### 31. Rodda Paint

6123 N. Marine Dr.
Portland, OR 97203
Toll Free: 800-452-2315
Phone: 503-737-6033
Fax: 503-737-6004


Comments: Though epoxy based paints and coatings are manufactured by Rodda Paint no mention is made regarding the anti-graffiti properties of their products
32. **Si-Coat 530**

**Company:**

CSL Silicones Inc.

144 Woodlawn Road West

Guelph, ON, Canada N1H 1B5

TEL +1 519 836 9044

FAX +1 519 836 9069

TOLL FREE (from USA) +1 800 265 2753

**Introduction:**

Inherent characteristics of quartz. (Just like glass)

Due to Si-Coat 530's low surface free energy, spray-paints and markers "bead up" instead of flowing together.

Even after 2000 hrs it still retained its low-surface free energy properties.

**Applications:**

TxDOT: mainly used for Anti Graffiti and to provide a non-adhesive surface to discourage swallow birds from building mud nests on infrastructure.

All data collected from CSL Silicones Inc newsletters years 2005 and 2006
33. **Si-Coat 729**

**Company:**

CSL Silicones Inc.
144 Woodlawn Road West
Guelph, ON, Canada N1H 1B5
TEL +1 519 836 9044
FAX +1 519 836 9069
TOLL FREE (from USA) +1 800 265 2753

**Product Description:**

Si-COAT Anti-Corrosion Coatings are one-part, room temperature vulcanizing (RTV) organosiloxane rubber protective coatings and display superior resistance to UV light, ozone, many chemicals and normal weathering. This leads to unparalleled longevity of the product.

**Application**

Surfaces must be thoroughly cleaned of all loose rust and oil. Sandblasting is the recommended method of cleaning. Oil must be removed by hand wiping with solvent. All surfaces must be dry.

Recommended application method is airless spray to a final dry film thickness of 375μ (15 mil). Each coat can be applied as soon as the previous coat is tacky.
Packing

Si-COAT Anti-Corrosion Coatings are available in

- 3.8L (1 US gallon) cans
- 19L (5 US gallon) metal pails
- 189L (50 US gallon) drums

Technical Data Sheet available [here](#)

Greg Dickens at SPARC (the Social and Public Arts Resource Center) has been conducting an ongoing study and testing of anti-graffiti coatings. He established a test section of a concrete block wall behind their offices where he has had representatives of various products come and apply their protective coatings to a brightly painted multi-colored wall surface.

Pasted from [http://www.lamurals.org/MCLATechnical/Mortimer.html](http://www.lamurals.org/MCLATechnical/Mortimer.html)

**34. SignGold**

**Company:**

SignGold Corporation

53 Smith Road

Middletown, NY 10941
"Is SignGold graffiti resistant?"

Yes. Use soap and water, stain removers, or even paint thinner to clean SignGold, then just wipe the surface dry.


Comments:

Though SignGold is graffiti resistant, it comes essentially in gold color to make signs on buildings, automobiles etc, hence might have very limited use in transportation structures and also as an anti graffiti coating.

35. TAGGUARD

Company:

    BASF Building Systems
    889 Valley Park Drive
    Shakopee, MN 55379

Product Description:

TagGuardTM is a unique multi-polymer, invisible, formulation that protects interior and exterior walls from graffiti and other unwanted surface markings.
TagGuard™ can be effective on a variety of concrete and masonry surfaces. TagGuard™ Cleaner is specifically formulated to attack and remove the most stubborn marks and paints.

**Features:**

- Invisible, non-staining, non-yellowing
- Breathable
- Fast drying
- Withstands multiple graffiti removals
- One coat application on most substrates
- Suitable for low temperature application, down to 20° F (-7° C)
- VOC compliant

**Benefits:**

- Does not alter surface appearance
- Allows walls to dry thus preventing peeling and blistering
- Allows time saving and job site schedule flexibility
- Simplifies graffiti removal, thus reducing costs
- Reduces labor costs
- Extends application window in cooler climates
- Environmentally friendly
36. TAGPRUF

Company:

BASF Building Systems
889 Valley Park Drive
Shakopee, MN 55379

Product Description:

TagPruf™ is a clear, water-based formulation that protects interior and exterior walls from graffiti and other unwanted surface markings. Effective on concrete, masonry and painted surfaces TagPruf™ works as a sacrificial barrier between graffiti and the underlying surface. TagPruf Cleaner is specifically formulated to remove graffiti from surfaces protected with TagPruf.

Features:

- Transparent, non-yellowing
- Breathable
- Fast drying in 30 minutes
- One coat application on most substrates
- Water-based, VOC compliant
Benefits:

- Does not alter significantly surface appearance. It may leave a barely visible sheen, or slightly darken the surface
- Allows walls to dry thus preventing peeling and blistering
- Allows time saving and job site schedule flexibility
- Reduces labor cost
- Environmentally friendly


37. TEXCOTE SACRIFICIAL GRAFFITI GARD

Company:

Textured Coatings of America, Inc.

2422 E. 15th St.

Panama City, FL 32405

Product Description

SACRIFICIAL GRAFFITI GARD® System is a specially formulated and blended water based resin for optimum performance as a protective sacrificial system over new or previously painted substrates.

For Removal:
Hot water blast all surfaces which have graffiti using 180°-190° hot water at 800-1,000 P.S.I pressure.

Features

• Water based formulation

• Blend of waxes, resins

Benefits

• Protects underlying surface

• Easy to remove graffiti

• Quickly reapplied

• Immediate protection

http://www.texcote.com/PDF/SACGRA_1.PDF

38. TexCote Ty-Cote Clear

Company:

Textured Coatings of America, Inc.

4101 Ravenswood Road

Suite 105A

Fort Lauderdale, FL 33312

Phone: 954-581-0771
**Product Description:**

TY-COTE CLEAR is an aliphatic polyurethane dispersion, acts as a “Fill Coat” for the substrate and maintains clarity of the substrate. A continuous, pinhole-free film must be created before application of the GRAFFITI GARD® IIIS, GRAFFITI GARD®IIIW or Sacrificial GRAFFITI GARD® System. TY-COTE CLEAR is the natural choice for a sealer for murals, natural stones, architectural block or brick, and other decorative surfaces that need protection from graffiti.

**Features:**

- Aliphatic urethane dispersion
- Clear coat finish
- Water based

**Benefits:**

- Provides fill and protection of underlying surface for GRAFFITI GARD® system
- Stain resistant topcoat

http://www.texcote.com/PDF/TYCOTE_1.PDF
39. Unichem Anti Graffiti Coatings

Company:

20 Paint Ln
New Ringgold, PA, 17960-9774
Phone: 570-943-2600
Phone: (+1) 570-943-2600
Fax: (+1) 570-943-2041

Products Description:

Unichem Coatings provides: Latex, enamel, stain, water & oil base, varnish & lacquer paints; corrosion & heat resistant, protective, chemical, metallic & anti-graffiti coatings Protective socks or hosiery, Safety apparel, Protective aprons, Bullet proof vests, Protective coveralls, Protective gloves.

40. Unique Shield Products, LLC

Company:

722 Apex Road, Suite C
Sarasota, FL 34240
(941) 684-0160 or (888) 558-3724
info@uniqueshield.com

Fluoropolymer coatings are blends of high performance resins and
Fluoropolymer lubricants. These single coat thin films provide excellent corrosion and chemical resistance. Other benefits of Fluoropolymer coatings include reduced friction, resistance to galling, non-stick, non-wetting, electrical resistance and abrasion resistance. Fluoropolymer coatings are also applied to fasteners and various OEM components to provide a longer life before replacement. The super hard surface of SKU20059VCF makes it almost impossible for graffiti to penetrate the surface. The product is easy to apply and is especially good in areas that are tagged and hit repeatedly.

Apply one coat of SKU20059VCF by adding 4 oz crosslinker per gallon and mix for 2-3 minutes. Apply second coat when first coat is tack free. Allow 7 days cure time before putting into service for removing graffiti. The coating will dry in 30-45 minutes. Its pot life is 3-4 hours. For best graffiti removal results the tagged area should be cleaned within 24 hours or shadows may remain.

Application:
Some of the most recognizable brands in America have used our product to protect their businesses:
- McDonald's
- Burger King
- Taco Bell
- Kentucky Fried Chicken
- Wendy's
- Red Lobster

Tests:
Tests methods and results have been described here:
http://www.uniqueshield.com/test.html

41. VandlGuard Anti Graffiti Coatings

Company:

RainGuard
1079 Culpepper Drive
Conyers, GA 30094
949-6752811 Ext 511
Fax: 949 675 3450
rainguardinfo@rainguard.com
Toll Free 1-888-765-7070

VandlGuard is produced by the RainGuard Company it has several anti graffiti
options including:

- VandlGuard
- VandlGuard One System
- VandlGuard Five System
- VandlGuard Ten System
- VandlGuard Ten Coat
- VandITop Sacrificial

RECOMMENDED USES:

- Concrete, Brick, Stucco
- Stone
- Metal
- Wood
- Plastic
- Aggregate panels
- EFIS and cement plaster
- Water Borne and Solvent Based Coatings
- Previously or newly painted surfaces.

VANDLGUARD is a Non-Sacrificial Anti-Graffiti Coating is a single part system that provides a tough and durable graffiti resistant finish. This is a cross-linking co-polymer material coating that dries clear (non-yellowing) with a low luster sheen. Protects a variety of interior and exterior vertical surfaces from
permanent graffiti staining and damage. Will protect your surface from graffiti defacement caused by commercial available spray paints.

Features and Benefits of VANDLGUARD:

- Backed by the best warranty available in the market
- Supplied ready to use - no mixing needed
- V.O.C. compliant - less than 20 g/l
- Treated surfaces will sustain unlimited graffiti removals for a period up to ten years
- Will retard the growth of mildew, mold, fungus or bacteria
- Surfaces require no particular maintenance.
- No expensive sand blasting needed.
- Meets Master Painters Institute (MPI) #105 - Graffiti-Protection, Top Coat
GRAFFITI REMOVAL:

In many instances non-abrasive household cleaners safely and effectively remove tagging. However, in the event tagging can’t be removed with these cleaners please contact manufacturer and purchase Rainguard Graffiti Remover SprayÆ. Follow manufacturers recommendations and instructions for use. In addition, warm water power washing has also been known to assist in the removal of tagging. Please refer to the manufacturer for additional assistance. All surfaces to be coated shall be structurally sound, clean and dry.

VANDLGUARD ONE Non-Sacrificial Anti-Graffiti Coating is a single coat product that provides a tough and durable graffiti resistant finish. This is a cross-linking co-polymer material coating that dries clear (non-yellowing) with a low luster sheen. Protects a variety of interior and exterior vertical surfaces from permanent graffiti staining and damage. Will protect your surface from graffiti defacement caused by commercial available spray paints.

Features and Benefits of VANDLGUARD ONE:

- A single coat is all that’s needed
- Backed by the best warranty available in the market
- Supplied ready to use - no mixing needed
- V.O.C. compliant - less then 20 g/l
- Treated surfaces will sustain unlimited graffiti removals for a period up to one year
- Will retard the growth of mildew, mold, fungus or bacteria
- Surfaces require no particular maintenance. Damaged or abraded areas are easily restored with an additional coat of VANDLGUARD ONE.
- No expensive sandblasting needed.
- Meets Master Painters institute (MPI) #105 - Graffiti- Protection, Top Coat

**VANDLGUARD FIVE** Non-Sacrificial Anti-Graffiti Coating is a two-coat system, which requires one coat of VANDLGUARD FIVE and one coat of VANDLGUARD FINISH COAT. This system provides a tough and durable graffiti resistant finish. This is a cross-linking co-polymer material coating that dries clear (non-yellowing) with a low luster sheen. Protects a variety of interior and exterior vertical surfaces from permanent graffiti staining and damage. Will protect your surface from graffiti defacement caused by commercial available spray paints.

Features and Benefits of VANDLGUARD FIVE:
- A single coat application of VANDLGUARD FIVE and one coat of VANDLGUARD FINISH COAT is all that's needed
- Backed by the best warranty available in the market
- Supplied ready to use. No mixing needed
- V.O.C. compliant. Less then 20 g/l
- Treated surfaces will sustain unlimited graffiti removals for a period up to five years
- Will retard the growth of mildew, mold, fungus or bacteria
• Surfaces require no particular maintenance. Damaged or abraded areas are easily restored with an additional coat of VANDLGUARD FINISH COAT.
• No expensive sand blasting needed.
• Meets Master Painters institute (MPI) #105 - Graffiti- Protection, Top Coat

**VANDLGUARD TEN** Non-Sacrificial Anti-Graffiti Coating is a three-coat system, which requires two coats of VANDLGUARD TEN and one coat of VANDLGUARD FINISH COAT. This system provides a tough and durable graffiti resistant finish. This is a cross-linking co-polymer material coating that dries clear (non-yellowing) with a low luster sheen. Protects a variety of interior and exterior vertical surfaces from permanent graffiti staining and damage. Will protect your surface from graffiti defacement caused by commercial available spray paints.

Features and Benefits of VANDLGUARD TEN:
• A two coat application of VANDLGUARD TEN and one coat of VANDLGUARD FINISH COAT is all that is needed
• Backed by the best warranty available in the market
• Supplied ready to use. No mixing needed
• V.O.C. compliant. Less then 20 g/l
• Treated surfaces will sustain unlimited graffiti removals for a period up to ten years
• Will retard the growth of mildew, mold, fungus or bacteria
Surfaces require no particular maintenance. Damaged or abraded areas are easily restored with an additional coat of VANDLGUARD FINISH COAT.

No expensive sand blasting needed.

Meets Master Painters institute (MPI) #105 - Graffiti-Protection, Top Coat

Rainguard VANDLTOP Sacrificial Anti-Graffiti Coating is a water base emulsion that dries to a clear and non-yellowing matte finish that provides a temporary or sacrificial protective shield against graffiti damage caused by most spray paints and markers.

VANDLTOP

- Is V.O.C. compliant - less than 20 g/L
- Is non-flammable
- Graffiti defacement is removed from VANDLTOP coated surfaces using low-pressure hot water to strip or melt the VANDLTOP from the surface
- VANDLTOP must be reapplied to stripped or cleaned surfaces to restore graffiti resistant protection.

GRAFFITI REMOVAL:

Graffiti can be easily removed by using hot water on the tagged areas. In some instances non-abrasive household cleaners safely and effectively remove tagging. However, in the event tagging can’t be removed with these cleaners please contact manufacturer and purchase Rainguard VANDLCLEAN SUPER.
Follow manufacturers recommendations and instructions for use. Please refer to the manufacturer for additional assistance. Once cleaned another coating of VANDLTOP on the clean area is recommended.

Packing:
One Gallon
Five Gallon Pails
55 Gallon Drums

All information taken from: <http://www.rainguard.com/anti-graffiti.html>

42. **Wearlon® 711/722 - Anti-Graffiti Coating**

**Company:**

Plastic Maritime Corp.
PO Box 2131
Wilton, NY 12831
Telephone
Phone: (518) 587-7624
Fax: (518) 587-7434

**Product Description:**

Wearlon 711 is water-born silicone polyester that has non-stick properties, thus providing excellent anti-graffiti properties, as well as a protective coating for
interior and exterior surfaces. The excellent clarity makes it ideal for bulletin boards, signage, and murals.

Wearlon 711/722 can also be pigmented to suit a particular color scheme or cover up any existing graffiti.

**Advantages:**

- Resists scuff marks, graffiti, gummy adhesive tapes, all stains
- Easy to clean
- Non-stick, slippery coating
- Abrasion-resistant
- Mildew and mold resistant
- Insect-resistant
- Weather-resistant
- Lubricious
- Water-based
- Cures at room temperature
- Durable
- Cleans up with water
- Easy to apply
- Non-sacrificial (does not lose its properties after cleaning)

**Protective Applications:**
• Vinyl and paper billboards
• Signage
• Metal, wood, cement, plastic, brick, and tile
• Anti-corrosive and stain resistant for garbage dumpsters
• Gymnasiums and ice rinks (interior and side boards) to reduce scuff marks
• Racquet ball courts
• Auto paint

Unlike other graffiti coatings, Wearlon-coated surfaces resist stains and when used outdoors, rain makes them generally self-cleaning.

Wearlon 711/722 can be applied on high speed print machines or converting machines. The fast drying and excellent flexibility of Wearlon permits folding and rolling up without cracking of the coating. This Wearlon flexibility is especially valuable in the manufacture and protection of labels, printed paper, and vinyl billboard designs.

**Series V626 | Dur A Pell GS**

Manufacturer: TNEMEC
<table>
<thead>
<tr>
<th><strong>Generic Type</strong></th>
<th>RTV Silicone Rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Common Usage</strong></td>
<td>Series 626 Dur A Pell GS has been formulated to provide superior protection against, and easy removal of unwanted graffiti. This product is intended for use in conjunction with Series 680 Mark A Way to provide a complete Graffiti Protection System. Dur A Pell GS is a clear, silicone rubber based formulation.</td>
</tr>
<tr>
<td><strong>Colors</strong></td>
<td>Clear</td>
</tr>
<tr>
<td><strong>Finish</strong></td>
<td>Flat to slight sheen, depending on substrate.</td>
</tr>
<tr>
<td><strong>Primers</strong></td>
<td>Apply directly to uncoated concrete and masonry substrates.</td>
</tr>
<tr>
<td><strong>Volume Solids</strong></td>
<td>15%</td>
</tr>
<tr>
<td><strong>Recommended DFT</strong></td>
<td>Penetrating coating system, no DFT recommended. Two flood coats required for graffiti protection. One coat for water repellent applications.</td>
</tr>
</tbody>
</table>

*Volatile Organic Compounds (lbs/gallon) 0.81*

*Volatile Organic Compounds (grams/litre) 97*

*Number Of Components One*
2.2.6 Non-Stick Surfaces

Non-stick systems are premanufactured antigraffiti systems. They cannot be applied as a coating. The main types of non-stick systems are Fluorine and Silicon based systems. These two systems are discussed below. Installing non-stick surfaces can be costly and time consuming. If damaged the system must be replaced anew.

2.2.6.1 Fluorine Based Non-Stick Systems

Fluorine is commonly used in household items such as non-stick frying pans and baking utensils. One of the most well known examples of a fluorine-based polymer is Teflon, a PTFE polymer that owes its non-stick characteristics to its high fluorine content. Although the addition of fluorine yields high degrees of non-stick surfaces to the polymer resin systems it is added to, fluorine is expensive and extremely difficult to apply.

2.2.6.2 Silicon Based Non-Stick Systems

Due to the difficulties of Fluorine based non-stick systems an alternative of Silicon based non-stick systems can be implemented. Silicon atoms, joined to oxygen atoms in long molecular chains, produce silicon molecules with variants called silanes and siloxanes. In long chains, these molecules can result in non-stick systems. Although the degree to which chemicals can stick to Silicon systems is slightly lower than that of Fluorine the price and ease of application are greatly improved.

2.3 SELF-CLEANING AND DEPOLLUTING SYSTEMS

In addition to its self-cleaning, and graffiti resistant properties the inorganic
Coating discussed in this report is also de-polluting. The components that comprise the coating are photocatalytic, they are activated by UV light and act as a catalyst for the chemical reactions that lead to de-pollution, self-cleaning- and graffiti resistance. These particles, because they act only as catalysts are not used up during the chemical reaction, therefore, continued use of the coating will not deplete or lessen the coatings ability to continue to function at the same rate.

The amount of energy that reaches the earth from the sun is about $5 \times 10^{24}$ J per year, which is approximately 104 times the amount of energy, consumed worldwide. Photocatalysis is the study of the processes of compounds that facilitate a chemical reaction by the absorption of sunlight and is regenerated in the process. This area of study has received wide academic interest over the last three decades because of its potential to be used for pollution control in air and water. These photocatalytic processes allow for the decomposition of organic compounds and removal of harmful gases. The most widely known photocatalysts used for such applications are Titanium Dioxide (TiO$_2$), Zinc oxide (ZnO), and Cadmium Sulfide (CdS).

Photocatalysis has been used to disinfect water, and oxidize numerous organic chemicals in water into non-hazardous by-products. Among the air pollutants, nitrogen oxides (NOx), hydrocarbons and organic chlorides have received the most attention. Reactions in the atmosphere between NOx and several hydrocarbons in the atmosphere under solar irradiation are known to create the condition referred to as “photochemical smog”, a mixture of chemicals and oxidants which have been linked to asthma, cardiac and pulmonary health effects. 
within heavy traffic urban areas. In addition, sulfur oxides (SOx), formaldehyde, ammonia, chloroform, gasoline components, e.g., benzene, toluene, and tobacco smoke and have been subjects of research by photocatalytic radiation for their removal.  

Titanium Dioxide is found commonly in three different forms, namely, brookite, rutile, and anatase. Although rutile is the most common of the three its photocatalytic activity is lower than that of anatase. Brookite, on the other hand, has no photocatalytic abilities. Anatase, while being the rarest of the three forms, is the most widely researched form of titanium dioxide for the use of de-pollution because of its strong oxidizing power when exposed to UV light, its chemical stability, and the absence of toxicity.

2.4 DURABILITY OF THE PROPOSED COATING SYSTEM

The effectiveness and durability of the coating was evaluated using strength tests of flexural concrete prisms strengthened with carbon reinforcement and the inorganic polymer to be used for the coating. The tests were conducted before and after exposure to wet-dry and scaling conditions. Strengthening of prisms was done by bonding carbon toes or fabrics to the tension side of the prisms using the inorganic polymer. This strengthened face was subjected to wet-dry and scaling conditions.

A more recent study conducted under the sponsorship of NJDOT led to the following conclusions.

The inorganic matrix coating can be applied to smooth or rough concrete surfaces with minimal surface preparation.
Only excess dirt and standing water need to be removed before the application.
The coating cures in 24-hours if the ambient temperature is more than 10° C.
The coated surface has to be protected for 24-hours from direct rain or running water.
Basalt, glass and carbon fibers can be added to the matrix to improve the performance.
Four different sets of students were able to apply the coatings without any problems. Therefore the field crew can be easily trained.
These conclusions were based on more than 30 applications in walls and curbs on the Rutgers University campus and demonstration applications on New Jersey Barriers and walls near Douglass College.
3 Field Applications

3.1 INTRODUCTION

A number of field applications were carried out to demonstrate the applicability, effectiveness, and long term performance of the proposed inorganic composite polymer coating system. Details of four projects are presented in this report. These projects were all completed in New Jersey and consist of; two bridge houses in Wildwood, a retaining wall along Route 280 near the Garden State Parkway, a retaining wall next to a parking lot for Woodbridge mall off of Route 1, and an overpass along Route 1 in Milltown.

The first project provided an opportunity to study the durability of the coating, as it was applied to two bridge houses, in a saltwater environment. The bridge houses operate a drawbridge on Rt 46 near Wildwood. The wall surfaces deteriorated due to salt ingress. A number of different methods are being tried to attempt to reduce the effects on structures that salt water can have. During this project we coated parts of the bridge house to help prevent future spalling and we caulked areas in the north tower to prevent water leakage. The coating was used to improve the performance of walls exposed to salt water\textsuperscript{14}.

The second project was a retaining wall off of Route 280 with a surface area of about 7200 square feet. This project was the largest project and took 8 days to complete. In part the purpose of this project was to demonstrate the ease of application of the coating. In addition, the retaining wall was in a part of the town that was often tagged with graffiti. Therefore, another aspect of this project was to demonstrate the graffiti resistant properties of the coating.
The third project was a retaining wall under a ramp going into the Woodbridge mall on Route 1. In this project, a light grey color was used to match the existing color and was meant to demonstrate the self-cleaning properties of the coating.

The fourth project was an overpass in Milltown on Route 1. This location is often tagged with graffiti and is a major problem for the township because of that. Often people who spray the graffiti in this area spray offensive things on this overpass and the township must go out immediately and clean up the graffiti which costs a good deal of the townships time and money. This project, therefore, was to demonstrate the graffiti resistant properties of the coating as well as the ease of removal of graffiti.

3.2 COLOR SCHEMES

Prior to the application of the coating for the Route 280 and Route 1 sites various color schemes were created. Several patches of paint were applied to the outside of the Livingston lab in order to produce the desired shades of color that were requested at the sites. Originally a carbon black powder was used in order to produce the requested shades of grey. The hope was that the carbon black powder would become a part of the inorganic matrix while the coating was curing so that the original grey color would not diminish over time. Although the grey shades came out as desired when applied to the wall after a week or two it was realized that these products did not fit into the lattice matrix as initially desired. Instead the self cleaning properties of the coating deteriorated the carbon black powder and the next time it rained most of the color was washed away leaving a white coating instead of a grey one.
Of the various pigment used, iron oxide provides the best workability and color for red, yellow and brown. Chromium based green pigment can be used to create brown and green tinted colors. Yellow iron oxide also works well.

3.3 WILDWOOD BRIDGE HOUSE PROJECT

3.3.1 Primary scope and objective

The primary scope and objective of this project was to demonstrate the use of inorganic protective coatings and fiber reinforced polymers for repair and rehabilitation of transportation structures located near the ocean. The structures selected were two bridge houses (towers) that were used to facilitate ship movement at the Route 47 Wildwood drawbridge. The two towers located on either side of the bridge were built from the water level all the way up to a level where the operator can see both ship and automobile traffic. The towers rise from the water level to about 918 feet (south tower about 18 feet and north tower about 9 feet) above the bridge roadway level. The bases were built with reinforced concrete and some parts of the top structures were built using timber
and other conventional building materials such as sheetrock and floor-tiles. Both towers experienced deterioration mainly due to water ingress; primarily from the roof and window openings. In the North Tower, the degradation of concrete occurred due to salt ingress in concrete walls. The salt-water source and deterioration was more acute around window openings. In the South Tower, the water is entering near the roof and around window openings. In this tower an addition was constructed to house the bridge operating personnel, and detailing on the four corners seems to be the source of the water entry. It is possible that the design details may not have been followed accurately.

The work involved in the repair and rehabilitation of these structures consisted of identifying and stopping the water ingress, and providing an inorganic coating on the inside walls. This coating protects the interior concrete surface and reduces water penetration, resulting in lower humidity inside the buildings. Fiber reinforced polymers (FRP) with highly extendable polymers were used to seal the joints between the concrete, timber beams and roof connections to the timber beams. Other repairs to improve the aesthetics of the buildings were also made.

In this project the concept of fiber reinforced polymer was used to create watertight junctions between the concrete, timber and aluminum alloy used for the roof. Highly extendable polymers with an extension capacity of 50% were used as a polymer for sealing various junctions.

### 3.3.2 Primary tasks and Execution of the Project

The following were the primary tasks.

- Patch walls with fiber reinforced repair mortar.
• Apply a durable and breathable inorganic coating to all walls in both towers.
• Apply materials to the inside and outside of the towers to fix cracks and prevent future deterioration.
• Use fiber-reinforced polymers to seal the various junctions between the steel beams and bottom concrete surface, steel beams and timber beams, timber beams and joists, and timber beams and roof sheets made of aluminum alloy.
• Remove the drop ceiling and seal the entire perimeter with a flexible sealer between the timber, roof, and the steel beams.
• Seal the space between the roof and the new cement composite sections with a flexible sealer.
• Monitor performance of the rehabilitations.
• Prepare quarterly progress reports and a final report detailing the rehabilitation of each tower and evaluating the performance of the repairs over the monitoring period.

The work was completed by faculty and students of Rutgers University and NJDOT personnel and contractors. NJDOT personnel and contractors helped to remove the old sheet rock panels, apply the coatings, place new sheet rock panels and tiles, and apply final finishes.

The following Figures show some of the work that was done at the bridge houses.
Figure 3-2: View of North Tower

Figure 3-3: Finished Inside Surface Including Treatment Around Window (North Tower)
Figure 3-4: Details Near Steps (South Tower)

Figure 3-5: Details Near Fixtures (South Tower)
Figure 3-6: Details Near a Large Window (South Tower)

3.3.3 Summary

Details of the field demonstration project presented in this report show that the use of inorganic protective coatings and fiber reinforced polymers can be used for the repair and rehabilitation of structures located near the ocean. This demonstration shows that:

- Both inorganic and organic polymer based composites were used successfully for both protection and sealing of junctions made with different construction materials such as concrete, steel, aluminum alloy, sheet rock, and ceramic tiles.
- The inorganic polymer coating was used successfully for coating deteriorated concrete surfaces.
• The coating was applied using rollers and brushes by both students and laborers not skilled as painters.

The inorganic polymer system adhered to all the parent surfaces; namely, concrete, timber, aluminum alloy, tiles, and sheetrock. (The long-term performance of these applications will continue to be monitored by Rutgers and NJDOT beyond the end of this research study).

3.4 ROUTE 280 RETAINING WALL PROJECT

3.4.1 Primary Scope and Objective

The primary scope and objective of this project was to demonstrate the viability of the new coating for relatively large surfaces encountered in transportation structures. The structure chosen is located at I-280 and Garden State Parkway in South Orange, New Jersey. The coated surface consisted of a pre-cast surface with a surface area of about 7200 square feet. The surface was in excellent condition and was pressure washed before the application of the coating in order to remove limited amount of dirt and possible residue from oil. The work schedule and the observation made during the execution of the coating are described in the following sections.

3.4.2 Additives/Paint Materials

During the project additives were used in the coating in order to increase the pot-life. If the coating is exposed to the sunlight for extended periods of time a thin layer of skin forms over the top surface. It is not recommended that this skin be remixed into the liquid because that results in a lumpy and inconsistent finish. As the day gets hotter this skin will form quicker and in thicker layers. It was noted
that by keeping the tray in the shade this problem could be minimized. However, because the temperature midday climbed into the mid-80s it was necessary to add increasing amounts of retarder to the mixture. Rubbing alcohol was one such retardant. After the rubbing alcohol was added to the mixture and then painted on the wall the alcohol would evaporate into the air as the coating cured. Rubbing alcohol helped to increase the pot-life of the paint more than the other retarder. Even after the use of both the rubbing alcohol and retarder a skin would still form over the paint after 45 minutes or so.

While painting the Route 1 and Route 280 walls several different application techniques were used to apply the coating. Originally, a foam roller was used in order to cut down on the total time would take to complete the project of painting the retaining wall. However, after some time the painters decided that they would rather use other painting methods such as the use of wire rollers or brushes. The main reason for this was the presence of rubbing alcohol used in the coating was beginning to chew up the foam. Another reason was that the painters found it more difficult to get hard-to-reach places with the foam rollers. One of the painters decided to use a brush. Even though the use of a brush was the most time consuming it did a better job than any of the alternatives. Upon follow up inspections it has been noted that those areas which were done with a brush are more uniform, have less micro cracks, have a more glossy look, and overall these areas still look like they did the first day they were painted. The other painters decided to use wire rollers. The reason for this was that the rubbing alcohol did not cause the wire rollers to deteriorate as they had done to the foam
rollers. In addition the wire rollers were able to complete the job quicker than a brush could.

3.4.3 Color Schemes

The existing inorganic formulation was modified using pigments to obtain brownish color to blend with the shale next to the retaining wall. Typical trial patches were prepared using the wall at Rutgers-Livingston campus. The color shows changes depending on the concrete quality. Earlier attempts to obtain three distinct darker and gray shades were not successful. The matrix was destroying the carbon black that was added as a pigment. The destruction of carbon particles made the surface porous and thus less graffiti resistant.

Based on the results of coatings at Livingston campus, a brown color was chosen to match the shale found at the site. A small amount of green Engelhard die was used with a large amount of red Engelhard die. These polymer dyes accounted for less than 1% of the total weight so the effect of the polymer on the inorganic matrix was minimal. The color came out as the shale-like color that had originally been planned. The match at close-up and at a distance is shown in Figure 3-8.
3.4.4 Application

The Rutgers team under the supervision of Professor Balaguru applied the matrix. Essentially liquid and powder parts and the pigment were mixed in a high shear mixer. The painting process was started right after mixing. The contrast between uncoated concrete surface and coated surface is shown in Figure 3-9. This figure also shows the close up of the contrast. The finished surface is shown in Figure 3-10.
Figure 3-9: Coated wall
Figure 3-10: Rutgers team with working crew
3.4.5 Details about application and observations

The coating operation was started on August 12, 2008 and finished on August 22, 2008. The coating was applied by 3 or 4 persons over a period of approximately 8 days. The mixing was primarily done by Mr. Jeremy Brownstein. He also helped to clean up some of the trays. The following observations made during the coating operation are noteworthy.

- Coating operation was started around 7.30 am each day and finished around 3 pm.
- In the morning hours, up to around 11 am, no retarder was needed due to cool weather. In the afternoon, the temperature reached above 90°F for the first four days. During this time a retarder in the amount of 2% by weight was used to increase the pot life. For the last three days the weather was cooler with a maximum temperature below 85°F.
• On the first day, there was a thunderstorm around 5 pm, which lasted for about 15 minutes. This did not cause any damage to the coatings.

• On the third day, the thunderstorm that occurred around 5 pm was stronger than the first storm. A few squares of the last panel that was coated around 2.30 pm developed some streak marks. This is consistent with the earlier observation that the coating should be protected against direct water contact for a period of 3 hours. Addition of retarder to compensate for the high temperature during the application also contributed to the delay in curing.

• The application rate was about 200 square feet per person per day. Since the wall is about 12 feet tall at some locations, part of the coating was applied using a ladder.

• The coverage is about 15 square feet per pound of the mixed coating matrix.

• The application was carried out using either brushes or rollers.

• Thicker or second coating resulted in a darker brown color

• The grooves were not coated and this provided brick and mortar appearance.

• The persons who applied the coating were comfortable with the process and did not have any complaints.
3.4.6 Develop the formulation for NJDOT approval

The test sites mentioned above in Chapter 3 are monitored for their graffiti resistant properties over a number of years. In the case of the Milltown overpass (on Route 1) the patch was almost immediately tagged by graffiti artists.

3.4.7 Monitoring

The performance of the coating will be monitored for a period of at least one year. The main issues are durability, aesthetics and self-cleaning properties of the coating.

3.4.8 Summary

Details of the field demonstration project presented in this report show that the inorganic-polymer coating can be easily applied to large surfaces. The system is easy to work with and the applications can be carried out using paint rollers or brushes.

Extensive surface preparations are not needed prior to the application of the coating. Only pressure washing was done prior to the application of the coating and it is recommended that pressure washing is done prior to application to clean the surface.

Finished surfaces provide an aesthetically pleasing appearance as shown in the photographs.

3.5 WOODBRIDGE MALL RETAINING WALL - ROUTE 1

3.5.1 Primary Scope and Objective

The primary scope and objectives of this project are to demonstrate the durability of the new coating for relatively large surfaces encountered in transportation
structures, to provide a graffiti-resistant coating in an area that is commonly used for graffiti, and to measure the self cleaning properties of the geopolymer coating. The retaining wall chosen is located on the side of the exit ramp for the Woodbridge Mall off of Route 1 and is adjacent to a rear parking lot at the Mall. The coated surface consisted of rough pre-cast panels a surface area of about 600 square feet. The surface was pressure washed before the application of the coating. The in-field self-cleaning properties of the coating were determined at this site and can be found in chapter 5 of this report.

### 3.5.2 Color Schemes

The mixture used at the Route 1 site has a more balanced amount of red and green dye in it. In addition, the ratio of the weight of the polymer to that of the rest of the geopolymer was much less for this site than for the Route 280 site. However, because the amount of green and red dye used were so close the grey color of each mix was different from the previous mix. A possible explanation for this is the small molecular size of the particles used in the green polymer solution. The green tint quickly settled at the bottom of the mix. It is possible that the size of the Chromium Oxide particles were able to escape from the matrix structure when it rains.

### 3.5.3 Application

The Rutgers team consisted of two people and was supervised by Dr. Balaguru. The retaining wall took approximately 3 days to coat. This demonstration began just a few days after the Route 280 demonstration. Preparation of the coating
consisted of liquid and powder parts mixed in a high shear mixer along with the grey pigment.

Figure 3-12: Left Side of Retaining Wall

Figure 3-13: Center of retaining wall
3.5.4 Monitoring

The performance of the coating will be monitored for a period of at least one year. The main issues are durability, aesthetics and self-cleaning properties of the coating.

3.5.5 Summary

The main lesson learned during this project occurred from the color scheme formulation. From the inconsistency of the colors it can be seen that the green
dye was ineffective and did not behave as desired. It should also be noted that those panels with a double coat better retained their color while those panels painted with brushes instead of rollers are more durable, have less micro cracks, and retain the same appearance as when they were just applied.

3.6 MILLTOWN OVERPASS – ROUTE 1

3.6.1 Primary Scope and Objective

The primary scope of this project was to coat small panels of our coating onto a bridge abutment in Milltown. The area coated over is constantly being tagged by graffiti. The objective of this project is to monitor the graffiti resistance of our coating on a surface that is always being sprayed with graffiti. This location will also be used to test our geopolymer with various methods of graffiti removal in the field. The coated surface is several years old concrete that is already stained from pollution. The panels coated over will also act to test the durability of the geopolymer matrix in slowing down the spalling and overall weakening of the concrete structure from age.
3.6.2 Application

The application of the coating took a couple of hours to complete by both Mr. Jeremy Brownstein and Dr. Balaguru. Several rectangular sections were coated on both sides of the bridge abutment.
3.6.3 Monitoring

The performance of the coating will be monitored for a period of at least one year. The main issues are durability, aesthetics and self-cleaning properties of the coating. The panels were quickly marked with graffiti approximately one month after coating. The Rutgers team has split the tagged areas into rectangular pieces to test graffiti resistant properties.
4 Evaluation of Graffiti Removal Methods

4.1 INTRODUCTION

Due to the high volume of graffiti on structures dozens of different products exist to attempt to remove the graffiti. These materials include citrus-based graffiti strippers as well as graffiti resistant coatings. The citrus-based strippers are applied on top of the graffiti. Once this is done the solution lifts the graffiti off of the structure and is then washed away. The coatings can be either a sacrificial coating that is removed along with the graffiti or a permanent coating. All of the coatings currently on the market are organic coating. All of these products use either a power washer or hot water to remove the graffiti and in some cases the company produces its own graffiti removal product.

The geopolymer coating developed by Rutgers University is the only permanent inorganic coating. In order to compare it to the other graffiti resistant/remover products in existence three graffiti removal methods were performed. These three methods are hot water (steam) removal, citrus solution removal, and removal via a power washer. Each of these three methods yielded positive results. The hot water (steam) removal would create a thin layer of water in between the paint and the surface and the paint would peel off. This occurs only on smooth surfaces. On rough surfaces the hot water must be applied with a wire sponge in order to get out the graffiti. The citrus remover was also very effective. It is recommended that a five-minute interval be placed in between the application of the citrus solution and washing the graffiti off of the coating.
4.2 STATE-OF-THE-ART (COATING TYPES)

The state of the art on graffiti resistant coatings is presented in Chapter 3. In all cases where these coatings are applied, a graffiti removal technique is needed to remove the graffiti effectively. This chapter deals with the evaluation of various techniques for removing graffiti from surfaces coated with inorganic matrix composites. Typically techniques used for removing graffiti are:

- Chemical and pressure wash
- Hot water, and
- Abrasives and water under pressure

For the inorganic polymer coating the following techniques were evaluated.

- Citrus chemicals with cold water
- Hot water
- Pressure wash with cold water
- Pressure wash with hot water
- Citrus chemicals plus pressure washer with cold water
- Baking soda plus pressure washer

In the area of chemicals, citrus based chemicals that are approved for indoor use and readily available in commercial stores was chosen both for environmental friendliness and cost. For the abrasives backing soda was chosen so that the environmental impact is minimal.
4.3 LABORATORY RESULTS - REMOVAL TECHNIQUES

Pressure washing with cold water took considerable amount of time for the removal of graffiti and hence this process is not recommended for field use. The other techniques are discussed in the following sections.

4.3.1 Citrus solution and cold water

In this method of graffiti removal, a citrus-based solution, obtained from the local Lowe’s department store, and cold-lukewarm water were used. As can be seen in the picture shown in Figure 4-1(right) the supplies needed for this test were water, the citrus-based cleaner and a sponge. The citrus cleaner is available in spray cans or in liquid form. The steps for removal are as follows:

Step 1: Mark the desired area for graffiti removal and collect all of the supplies that are needed for removal.

![Initial Setup](image)

**Figure 4-1: Initial Setup**

In this experiment the “ R U 08 “, sprayed on the inorganic coating with a black spray paint, shown in Figure 4-1 was removed. The ‘R’ that can be seen above
and to the left will be removed using the citrus-based spray can shown in the picture above and to the right.

Step 2: Spray or apply the citrus-based solution over the graffiti. Wait for about 20 minutes (minimum 10 minutes) before removal. With the sponge remove the graffiti and citrus based solution.

![Image of citrus spray application](image)

**Figure 4-2: Application of Citrus Spray**

Figure 4-2 shows the ‘R’ after it has been sprayed with solution. A few minutes later a sponge was used to remove the graffiti and cleaner. After the first pass most of the graffiti had been removed as can be seen but a little bit of extra effort was needed to fully remove the rest of the graffiti.

Step 3: Once the graffiti and cleaner have been spread over the area use water to completely remove them from the surface.
Figure 4-3: Removal of Graffiti

After the cleaner removed the graffiti some residual paint remained on the surface. Using the sponge and water this residual paint was removed from the surface.

Figure 4-4: Final Product

Figure 4-4 shows the end result and this experiment. As can be seen the ‘R’ has been completely removed from the surface. The graffiti removal took approximately two minutes.
4.3.2 Hot water

The next graffiti removal experiment involved the use of only hot water and a sponge. The hot water was taken from the sink in the lab. The steps for removal are as follows:

Step 1: Mark the desired area for graffiti removal and collect all of the supplies that will be used for removal.

![Figure 4-5: Graffiti Setup](image)

This experiment will remove the 'U' described in the above section as shown in Figure 4-5 above and to the left. The hot water is contained in the bucket to the right.

Step 2: Using the sponge apply the hot water to the area marked with graffiti.
Figure 4-6: Graffiti Removal with Hot Water

Figure 4-6 above show the process of removing the graffiti. Although the hot water took a little more work to remove than the citrus cleaner it wasn’t difficult to remove and entirely came off the coating surface.

Figure 4-7: Final Product

Figure 4-7 above shows the end result of removing graffiti using hot water and a sponge. As can be seen the ‘U’ has been completely removed. This experiment took one and a half minutes to do.

4.3.3 Cold Water Power Washer and Citrus Solution

Step 1: Clear excess dirt off the surface.
Figure 4-8: Two Boards for use in Power Washer Graffiti Removal

Figure 4-8 above contains two coated pieces of plywood (the boards are two feet high by 4 feet long). One board is coated with the Route 1 coating and the other board by the shale color used for the Route 280 site. In addition, two different spray paints were used to see if there was any difference in the removal process between the different paints.

Step 2: Spread citrus solution on the graffiti

Figure 4-9: Application of Citrus Solution
Figure 4-9 above shows the author applying citrus solution on top of the graffiti. As can be seen from the photo below only the inside halves of each panel was covered with citrus solution to demonstrate any differences between using theStep 3: Allow ten minutes (preferably 20 minutes) in between the application of citrus solution and cleaning of the graffiti with the power washer.

Figure 4-10: Designation of Areas That Will be/won’t be Removed of Graffiti

Figure 4-10 above shows the two panels ten minutes after the citrus solution has been applied.

Step 4: Turn the power washer on and apply it to the surface for the amount of time needed to effectively remove all of the graffiti.
Figure 4-11: Power Washer

The power washer seen in Figure 4-11 above has a pressure of 3000psi. The photos shown below were taken 10 seconds (left) and 20 seconds (right) after the power washer was first applied to the panels.

Figure 4-12: Graffiti Removal with Power Washer (Part A)
Figures 4-12 and 4-13 above show the end result of using both a power washer by itself as well as using one with a citrus solution. It can be seen that the use of the citrus cleaner greatly helps in graffiti removal. The use of a power washer using cold water did remove a small amount of the graffiti but not enough to be used in the field. The total amount of time it took to remove the graffiti with the power washer was a minute and a half. It should also be noted that this time would be quicker in the field where the parent surface is concrete instead of plywood. The inorganic matrix used is not very strong in flexure so that when it is applied to a thin sheet of plywood that bends under the pressure of our power washer the matrix can crack (as can be seen in the photo above to the right where the bottom of the ‘R’ used to be). This will not occur when the parent surface is concrete because the concrete will not bend under a pressure of 3000 psi.

4.3.4 Hot Water Power Washer

The next graffiti removal experiment involved hot water and a power washer. This graffiti removal test was unsuccessful. As can be seen from the photos below only some of the graffiti was removed.

Step 1: Apply graffiti to the coated surface
Step 2: Connect hot water to power washer and turn the power washer on. Apply nozzle to marked surface.

As can be seen from Figures 4-15 a and b above the graffiti did not come off very easily. The photo to the left was taken after the first few seconds of the test. No graffiti had been removed yet. The photo to the right shows the end result with some 30% of the graffiti being removed. In an attempt to remove additional
graffiti the power washer was placed so close to the coating that they practically touched and a small piece of the coating was removed.

4.3.5 Hot Water Power Washer and Citrus Solution

The next graffiti removal experiment involved the use of a hot water power washer as well as citrus solution. This experiment was a success as can be seen from the photos below.

Step 1: Allow the graffiti time to dry and then apply the citrus solution

![Figure 4-16: Citrus solution](image)

The photo above shows the coated surface after being coated with citrus solution. As can be seen the citrus solution alone helped wipe off small amounts of the spray paint from the surface.

Step 2: Connect the power washer to the hot water and turn the power washer on. Apply sprayer to the coated surface.
Figure 4-17: Graffiti removal with power washer

Figure 4-17 above was taken just seconds after the graffiti process began. As can be seen the graffiti was removed almost immediately by the power washer.

Figure 4-18: Final result

Figure 4-18 above shows the coating after its been cleaned. As can be seen the hot water power washer and citrus solution method left a small outline of the sprayed “R” but otherwise did an excellent job removing the graffiti.
4.3.6 Use of Baking Soda (Abrasive) with Hot Water or Wadu (Hot Water)

The next graffiti removal experiment uses a Wadu to remove the graffiti. This experiment was also successful. Armex makes the machine called Wadu. The Wadu utilizes baking soda to remove graffiti by attaching the Wadu spray gun to the connector hose of a power washer. The Wadu wand is also connected to a cylinder that contains the baking soda that is sucked out of the container into the wand and sprayed out as a baking soda and water mixture.

![Figure 4-19: Coating marked with graffiti](image)

Step 1: Connect the hot water to the power washer, the power washer hose to the Wadu, and turn the Wadu knobs to flow. Turn on the power washer and apply the Wadu mixture to the marked area with the wand.
Figures 4-19, 4-20 and 4-21 above show the effectiveness of the Wadu system. In just a few seconds almost all of the graffiti was removed.
The final solution is shown in Figure 4-22 above. Although a small shadow remains in some parts the Wadu did an excellent job of removing the graffiti quickly and with little effort.
5 Self Cleaning Properties

5.1 INTRODUCTION

Everyday the air is contaminated and polluted by fossil fuels burned off by cars and factories. Dust and mold from natural processes are also carried in the air. These soiling particles make their way to the concrete and steel structures. These soiling agents corrode the steel and deteriorate the surfaces of the concrete. The steel will rust and the concrete will spall and become unsightly. Concrete deteriorates with time due to the effects of various salts and mold present in the air.

The inorganic coating used in the current investigation is photocatalytic. One of the components of the inorganic matrix, when activated, self-cleans and prevents or slows down the above-mentioned deterioration mechanisms. Many of the soiling agents responsible for the erosion of concrete are unable to stick to the surface of this inorganic coating and end up being washed away by rainwater.

5.2 STATE-OF-THE-ART

At the CIB World Building Congress in 2004 the European Project PICADA, Photocatalytic Innovative Coverings Applications for De-pollution Assessment, put forth a research report on the development of a new self-cleaning and de-polluting material\textsuperscript{15}. The self-cleaning properties of this material were measured by monitoring the photocatalytic decomposition of an organic dye called rhodamin B. rhodamin B has an anthracene moiety and because of that is placed in the category of PAHs, Polycyclic Aromatic Hydrocarbon. In other words the rhodamin B dye is very similar to those soiling agents that cause the degradation
of structures and lead to structural failure in the future. The rhodamin B dot can be placed on a surface and with the use of a colorimeter its color can be recorded over time. The self-cleaning properties of the mortar removed the dot from the surface a rate that was then calculated by the colorimeter’s recordings taken at set intervals. In their laboratory the PICADA team placed concrete samples one meter from a UV light to correspond with the desired 3700 Lux intensity. This intensity was chosen to limit the direct photocatalysis of rhodamin B and simultaneously allows photocatalytic decomposition to continue.

5.3 RESEARCH PROGRAM

Since self-cleaning tests in the laboratory have already been evaluated in previous studies only limited tests were conducted in the laboratory. The primary focus of the current study was field evaluation. Most of the experiments were conducted outside at either the Livingston lab or at the Route 1 site near Woodbridge Mall by using sunlight.

5.4 TEST SETUP

5.4.1 Indoor Tests

The indoor rhodamine-B tests require a UV light set-up and plywood coated with the inorganic coating. The plywood planks were painted over using our inorganic coating. One of the planks has TiO2 added in to the mixture while the other plank has the regular inorganic coating applied to it. These boards are placed under a UV light and then small red dots are placed on the boards as can be seen in Figure 5-1. Measurements are then taken with the Colormeter at 0, 1, 2, 4, 8, 12, 24, 36, and 48 hrs.
5.4.2 Outdoor Tests

There was little setup required for the outside tests since the sun instead of UV light initiated the photocatalysis. Two sets of tests were run outdoors. The first set of tests was a 48-hour test run outside the Livingston lab and the second set of tests were done over a 1 or 2-month period at the Route 1 (Woodbridge Mall) site and outside the Livingston lab.

The first set of tests consisted of a piece of plywood placed in the sunlight. This piece of wood was coated over in two different areas. In one area it was coated with our inorganic coating with TiO2 added in and in the other area it had no TiO2. Measurements were then recorded at 0, 1, 2, 4, 24, and 48 hrs. Less tests were done for the 48-hour outdoor test than for the 24-hour indoor tests because the reading had to be taken during the day.

The second set of tests were done by placing dozens of dots on the retaining wall at the Route 1 (Woodbridge Mall) site, on color schemes outside the

Figure 5-1: (a) Setup for Rhodamine B Tests (b) Rhodamin B Dot
Livingston lab, and on test samples inside the Livingston lab. These dots are measured with a ColorMeter at 0hrs, one hour, 24hrs, seven days, one month, and possibly two months.

5.5 TEST PROCEDURE

The test procedure was as follows.

1. Prepare data sheets as follows:
   a. Record changes using colormeter. Each recording consisted of five readings at 0 hrs, 1 hr, 1 day, 7 days and one month.
   b. The Livingston lab data sheet had 7 recordings
   c. The Route 1 data sheet had 18 recordings
   d. The 48-hour tests had 4 recordings.

2. Mix Rhodamin B powder with recommended amount of water.

3. Place dots on coated surfaces and record the time.

   a. If test is done inside then turn on UV light.

4. Place colormeter over dot to take the readings and then record those readings.

5. Repeat step 4 for all of the dots.

5.6 TEST RESULTS

5.6.1 48 hour test results - Indoor

The graph in Figure 5-2 below shows the color change of the specimens due to the degradation of the Rhodamin B dye caused by a UV light bulb. This test was conducted over a 48-hour period for two boards that contain TiO2 and two boards that do not contain TiO2. Specimens one and two have TiO2 in the
inorganic matrix. In these samples approximately 74% and 68% of the dye was destroyed within a 24-hour period. Similarly specimens three and four contain the inorganic coating without any TiO2 added and they recover approximately 72% and 89% of their original color within the first 24 hours. As can be seen from the graph below those boards that do not contain Titanium Dioxide self-clean more effectively since they have a higher rate of regaining their original color.
Figure 5-2: 48 Hrs Indoor Tests
5.6.2 48 hour test results - Outdoor

The graph in Figure 5-3 below shows the color change of the specimens due to the degradation of the Rhodamin B dye caused by UV rays from the sun. This test was taken over a 48-hour period for two dots placed on our inorganic coating that contains TiO2 and two dots were placed on our inorganic coating that do not contain TiO2. Specimens one and two from Figure 5-3 do not have TiO2 in the inorganic matrix. It can be seen from Figures 5-3 and 5-2 that the degradation of the rhodamin b dye due to UV light was consistent regardless of whether the UV light came from a light bulb or from the sun. As can be seen from the graph the difference between those samples with TiO2 and those without is negligible.
Figure 5-3: 48 Hrs Outdoor Test
5.6.3 Outdoor Livingston results

The graph in Figure 5-4 below shows the color change of seven samples of different colors due to the degradation of the rhodamin-B dye over a two-month period. These various samples contained different mix proportions in addition to different types of dying agents. None of these samples contain TiO2. These seven samples recover approximately 43%, 28%, 82%, 84%, 93%, 94%, 98% of their original color within a two-month period.
Figure 5-4: 2 month Livingston Lab test results
5.6.4 Outdoor Route 1 results

The outdoor test results were taken over a one-month period and can be seen in the graphs below. The rhodamin B dye had to be used in a higher concentration in these tests in order to get high enough values for an accurate analysis of the dye destruction. The initial ‘a’ values ranged from about 10-20 in these tests, which was still lower than in other tests but is still high enough for an accurate analysis. As can be seen below the dye had virtually disappeared after a week. The ‘a’ values changed very slightly after that. All of the dots were placed on the wall in places where only one coat had been applied.

Two dots, which were placed on the wall in places that had more than one coat yielded values that were not high enough for an analysis to be done. In these locations the dye did not stick to the coated surface because the surface was so smooth and the dye would simply run off the wall. This is a positive sign because it means that a second coat will be able to prevent the soiling of those structures that are protected with the inorganic coating. Any dirt or depollutants will run off the surface quickly.
Figure 5-5: Graphs of Route 1 test results
Figure 5-6: Graphs of Route 1 test results
Figure 5-7: Graphs of Route 1 test results
Figures 5-6 and 5-7 below were taken of the Route 1 retaining wall after it had been coated and the rhodamin B dots had already been placed on the wall. In order to quickly find the dots for future readings a blue permanent marker was used to trace the edge of each dot. These pictures were taken the day the dots were placed on the wall. It can be seen that these dots are difficult to locate from a distance. At the end of the one-month period the dots in most places were extremely difficult to find. Both the permanent marker and the rhodamin B dots had faded away over the month.

Figure 5-8: Route One wall with Rhodamin B dot
6 Evaluation of De-Polluting Characteristics

6.1 INTRODUCTION

As cars burn fossil fuels many Volatile Organic Compounds, VOCs as well as NO_x particles are released into the environment. The Nitrogen cycle reduces most unstable or harmful forms of NO_x into stable NO_x forms. For example, nitrogen dioxide, which is a volatile gas, can be reduced to nitrate or nitric oxide as will be discussed later in this chapter, which in turn can be reduced to nitric acid and nitrous oxide. Nitrous oxide and nitrogen (N_2) are the main components of air and are good for the environment. However, nitric oxide as well as nitrogen dioxide can be very harmful to the atmosphere and to human beings. This study attempts to speed up the conversion of nitric oxide and nitrogen dioxide into more stable gases in the nitrogen cycle and in so doing to reduce the pollution in the air.

The inorganic coating being used in this research project is photocatalytic. This means that UV light from the sun activates the inorganic matrix. Recent research has suggested that Titanium Dioxide, TiO_2 is the best photocatalyst to be used though others such as Zinc Oxide, ZnO can also be used. The purpose of this study is to measure the amount of NO and NO_2 that is reduced.

6.2 STATE-OF-THE-ART

At the CIB World Building Congress in 2004 the European Project PICADA, Photocatalytic Innovative Coverings Applications for De-pollution Assessment, put forth a research report on the development of a new self-cleaning and de-polluting material. This material would have several different functions including
the increase of the life cycle of buildings, self-cleaning properties of the cement, and de-polluting properties. As building get older the concrete will begin to spall and becomes stained. This weakens the concrete and reduces the lifetime of a structure. The process of façade soiling and staining is worsened by the impact of industrial pollution.

The self-cleaning properties of the material therefore become very important in order to clean any staining from pollution off of the surface and would allow the building to retain its initial look. By adding TiO₂ the material will also help to clean the air. It is a safe material that is used in many commercial products such as, toothpaste, sunscreen, and cosmetics. Titanium dioxide when exposed to UV light acts as a photocatalyst for the decomposition of organic molecules adsorbed or occluded on its surface. The mechanisms involved in removing volatile gases from the air are not simple. It is assumed that NO in the air is oxidized when the TiO₂ is exposed to UV light. The result of this is nitrogen dioxide, which is in turn converted to nitrate. While some of the NO and NO₂ particles may escape into the air from the photocatalytic surface, most particles that come in contact with the surface will be effectively trapped together with the nitrate salt formed (Cassar 329). This new material was engineered as binders for cement-based materials and organic-based coatings. Its effectiveness as a de-pollutant of volatile organic compounds (VOCs) and nitrogen oxides is typically increased in canyon street settings where pollutants are generally trapped.
The uses of these photocatalytic materials are numerous. According to estimates from the American Lung Association one out of every three members of the US population lives in an area with unhealthful levels of ozone. Ozone is comprised mainly of nitrogen oxides and VOC that most photocatalytic cement can reduce by levels of 20 to 80%. “It’s estimated that in Milan, Italy, where air quality standards sometimes force local administrators to shut down automobile traffic for a full day at a time, could become 50% cleaner if just 15% of the buildings and roads were resurfaced with photocatalytic cement products” (Barbesta p50). Due to the low costs of these materials and their extensive benefits for both the environment and the life times of infrastructure many new application for photocatalytic self-cleaning and de-polluting materials have been researched over the past few years. In 2003 over 800 international patent applications were published.

An article published in the Feb2009 Concrete International\textsuperscript{16} describes the current applications, availability, and uses of self-cleaning and de-polluting cements currently on the market or in some stage of the development process. Photocatalytic cement can be used for sound barriers, concrete pavers blocks, and façade elements. The article also outlines several of the environmental aspects of cementitious photocatalytic materials. For example, the final products of the reactions in the de-pollution process include quantities of nitrates and sulfates that studies have shown to be of negligible quantities that do not contribute significantly to soil and ground water nitrification.
Recently, the Italcementi Group has patented a new self-cleaning cement product called TX Active. This product is one of the many self-cleaning and de-polluting compound that removes both nitrogen oxides and volatile organic compounds (VOCs) from the air. This newly patented product can be used as cement or plaster that helps save the environment and reduces maintenance costs. In addition, to the TX Active which is available in gray and white colors and comes in Portland cement type I, II, and III Italcementi offers TX Aria adds de-polluting properties to the self-cleaning properties. Several structures have been built in the United States using such materials. For example, a white precast concrete carillon tower constructed in Dalton State College in Georgia. In Hyacinth Place (a “green” housing project in Highland Park, IL) has an area with concrete pavers made with Photo catalytic cement. Lastly, photo catalytic cement was recently used to create two 30ft tall gateway elements at the entrances to the new I-35W Bridge in Minneapolis, MN.
6.2.1 Mechanism

One of the most important properties of the anatase form of titanium dioxide is the energy band gap. The energy band gap is an energy range in a solid where no electron state exists. In other words it is the distance that exists in between the valence band and the conduction band of a solid that an electron must jump over to occupy one of those bands. The larger the band gap, the more difficult it is for a valence electron to jump to the conduction band or valence band. It is an important property in condensed matter physics.

When a photon has enough energy to match or exceeds the band gap energy, E, an electron is promoted from the valence band into the conduction band leaving a hole. In this excited state one of three things can happen. The first case is that the conduction-band electron can recombine with the valence-band hole and dissipate the input energy as heat. In the second case, the conduction-band electron and valence-band hole can get trapped in a meta-stable surface state. In the third case, the conduction band electron and the valence-band hole can react with electron donors and electron acceptors absorbed on the solids surface or within the surrounding electrical double layer of the charged particle.

The concept of electron band gap is useful in understanding the interaction of light with matter. The size of the band gap relates inversely to the amount of light that can be absorbed by the material. This means that a larger band gap will absorb light in the short wavelength UV region while a small band gap will absorb light in the high wavelength visible range.
The band gaps of the anatase and rutile forms of titanium dioxide are 3.02 and 3.23eV, respectively. A band gap of less than 4eV is defined as a semiconductor. Semiconductors (e.g., ZnO, Fe₂O₃, CdS, ZnS, and TiO₂) can act as sensitizers for light induced redox processes due to their electronic structure, which is characterized by a filled valence band and an empty conduction band.

Primary steps in the photoelectrochemical mechanism are:

1. Formation of charge carriers by a proton
2. Charge carrier recombination to liberate heat
3. Initiation of an oxidative pathway by a valence-band hole
4. Initiation of a reductive pathway by a conduction-band electron
5. Further thermal (e.g., hydrolysis or reaction with active oxygen species) and photocatalytic reactions to yield mineralization products;
6. Trapping of a conduction band electron in a dangling surficial bond to yield Ti (III)
7. Trapping of a valence-band hole at a surficial titanol group

When the conduction band electron and the valence-band hole reacts with electron donors and electron acceptors absorbed on the solids surface such as NO the resultant chemicals are generally non-toxic. For example nitrates are a very common transformation product for photocatalysis of NO. In addition, nitrates are not harmful to the environment since they are easily consumed and recycled by plants. The level of nitrates converted from NO increases with the photocatalytic activity of the material. Pollutants such as NO and NO₂ produce HNO₃ when completely oxidized. In addition to nitrates a small part of the NO is
converted into N₂O upon desorption. The process of NO and NO₂ oxidizing to HNO₃ was taken from (Dalton 2002) and is shown below:

(1) Photocatalysis

\[
\text{TiO}_2 + h\nu \rightarrow \text{TiO}_2^*(h^+_{vb} + e^-_{cb})
\]

\[
\text{OH}_{\text{ads}} + h^+_{vb} \rightarrow \text{OH}_{\text{ads}}
\]

\[
\text{O}_2(ads) + e^-_{cb} \rightarrow \text{O}_2^-(ads)
\]

(2a) Oxidation using hydroxyl radicals: OH

\[
\text{NO}_2(g) + 2\text{OH}_{\text{ads}} \rightarrow \text{NO}_2(ads) + \text{H}_2\text{O}(ads)
\]

\[
\text{NO}_2(ads,g) + \text{OH} \text{ (ads)} \rightarrow \text{NO}_3^- (ads) + \text{H}^+ (ads)
\]

(2b) Oxidation using “active oxygen”: O₂⁻

\[
\text{O}_2^- \quad \text{NOx(ads)} \rightarrow \text{NO}_3^- (ads)
\]

(2c) Reaction with Ti-OH via dispropriation

\[
3\text{NO}_2 + 2\text{OH}^- \rightarrow 2\text{NO}_3^- + \text{NO} + \text{H}_2\text{O}
\]

(3) Removal of HNO₃ complex from surface of block by water

\[
\text{HNO}_3 \text{ (ads on block)} \rightarrow \text{HNO}_3(\text{aq})
\]

6.2.2 Air Purification

As harmful substances continue to pollute the air we breathe it is important to attempt to clean the air. The use of titanium dioxide in pavement, concrete, and paint mixes is a viable option to accomplish this. The use of titanium dioxide reduces not only NOx gases but also Volatile Organic Compounds (VOCs) such as benzene, toluene, ethylbenzene, o-xylene, aldehydes, and carbonals to create
clean air. When exposed to sunlight the titanium dioxide transforms these volatile gases into non-toxic compounds.

Outdoor pollutant concentrations typically are in the low ppm range. Studies have shown that because of the easy dispersion of volatile gases in open environment de-pollution is most effective in canyon streets. In a recent study, researchers set up TiO2-mortar panels 5.2m high with a gap of 2m in between the panels and then introduced NOx gases into the setup. They variables of this experiment were pollution source emission, wind direction, and the orientation of the wall. The reduction in NOx gases was between 40-80% when compared to a reference canyon street setup that contained ordinary panels18.

6.2.3 NO absorption of TiO2

NO is an important molecule from the point of view of its environmental impact as a component of NOx from motor vehicle emissions. First principles calculations based on density functional theory have been performed to determine the binding configuration and the binding energy for NO on the TiO2 single crystal surface. The most stable configuration is a tilted one, with the NO molecules bound to surface Ti sites as Ti-NO species. The calculated binding energy of the NO molecule is 43.7 KJ/mol at one-half the saturation coverage19.

While most of the NO desorbs without reaction, above a critical NO coverage a small part of the NO produces N2O upon desorption. As the N2O begins to be produced at higher coverages, there is an associated decrease in the NO yield. It is likely that the onset of NO dimmer formation, predicted in the density functional calculations at high coverages, is associated with the N2O product6.
6.2.4 Reaction Variables

There are many variables that will increase or decrease the efficiency of the photocatalytic reaction of titanium dioxide other than the form of titanium dioxide used. These variables include:

- Semiconductor concentration
- Reactive surface area
- Porosity of aggregates
- Concentration of electron donors and acceptors
- Incident light intensity
- pH
- Presence of competitive sorbates
- Temperature

6.2.5 Effect of UV-Light Intensity

Semiconductors such as titanium dioxide can absorb just enough sunlight (they absorb light with wavelengths between 300 and 365nm) to have sufficient energy to overcome the band gap between the valence and conduction bands. Because of the bandgap size of titanium dioxide it only absorbs UV light. As the intensity of the UV light increases more energy is absorbed by the surface to create valence-band holes and conduction-band electrons, which in turn react with the volatile gases in the surrounding air. This means that as the UV light intensity increases the energy absorbed by the titanium dioxide molecules will also increase resulting in a higher level of photocatalysis, de-pollution and cleaner air.
6.3 RESEARCH PROGRAM

The aim of the de-pollution research reported in this thesis is to evaluate the reduction of NO and NO2 particles by the inorganic coating in a closed environment. The self-cleaning inorganic matrix has ZnO as one of the constituent materials. For the purpose of de-pollution, TiO₂ was also added to the inorganic coating. In this project, the effects of additional amounts of TiO₂ to the de-pollution properties were also evaluated. Several recent studies have shown that the anatase form of Titanium Dioxide is the most active compound for reducing the amount of volatile gases in the air. These studies have added several other particles to see whether or not the added particles enhance the ability of the compound. Variables in this study include the differences in reduction levels of NO and NO₂ gases based upon their exposure to UV light or sunlight, the initial concentration levels of NO and NO₂, and the presence of ZnO combined with TiO₂ or the presence of ZnO alone.

6.4 TEST SETUP

A special test set-up was fabricated for the current study. An air tight transparent bag was fabricated in which various concentration of NO and NO₂ were placed. In this bag samples coated with the composite were placed to study the effectiveness of the coating. The plywood planks are painted over using our inorganic coating. Half of the planks have TiO₂ added in to the mixture. These boards were then placed into the polyethylene bags along with the sensor on to a desk as shown in Figure 6-1. This project required the same test to be conducted inside as well as outside to observe the differences in NO and NO₂ reduction.
from a UV light vs. the UV rays of sunlight. For this reason the setup described above would be placed under the UV light in our lab or it would be placed on a box outside where it would be exposed to sunlight. As soon as the gas is put into the bag the test begins.

Figure 6-1: Setup for De-Pollution Tests

6.5 TEST PROCEDURE

The test procedure was as follows.

1. Prepare data sheet for 7 recordings in the case of NO and 33 recordings for NO₂
2. Place board into the polyethylene bag on the desk (inside test only)
   or
   Place board into the polyethylene bag on box outside (outside test only)
3. Place the sensor into the bag
4. Turn on the UV light (for inside test only)
5. Place the gas canister in a secure place next to the bag
6. Close the bag so that there is only a small area for the gas to enter the bag
7. Open the gas valve and begin the stop watch
8. When the bag is full turn off the gas valve
9. Take recordings for either the:
   a. NO test at 15 minutes, 30 minutes, 45 minutes, 1 hr, 2 hrs, 4hrs, and 6 hrs for the NO test
   or
   b. NO₂ test every half a minute up to ten minutes, every minute up to 15 minutes, every minute up to 30 minutes and at 45 minutes.
10. Repeat steps 1-9 for each trial.

6.6 TEST RESULTS

6.6.1 Indoor Results

6.6.1.1 Nitric Oxide Reduction

The tests were conducted at two concentrations.

30ppm concentration

The indoor nitric oxide tests were done a total of three times. One of these trials for each setup was conducted with a low initial value of NO (the trial with TiO₂ contained 13ppm while the trial without began at 7ppm). These two trials can be seen in blue in Figures 6-2 and 6-3 below. The trials where Zinc Oxide
was the only depolluting agent showed a more gradual reduction in NO gas while the TiO$_2$ combined with the Zinc Oxide had a steeper reduction in NO towards the end of the trials. For the first hour of measurement there was virtually no reduction at all. Overall the trials with TiO$_2$ showed a slightly higher level of depollution reduction than the trials without TiO$_2$. 
Figure 6-2: 30PPM Indoor Nitric Oxide Tests
Figure 6-3: 30PPM Indoor Nitric Oxide Tests
The test results showed positive improvement in the reduction of the NO gas. As can be seen from the graphs attached the addition of TiO₂ showed a 13ppm or 100%, 14ppm or 54%, and 17ppm or 59% reduction in NO gas over a 6 hr period. This shows that as long as the level of NO concentration is 14ppm or less the inorganic coating will be able to completely depollute the air of the NO gas. The inorganic coating itself showed a 7ppm or 100% reduction, 10ppm or 50% reduction, and a 15ppm or 56% reduction in NO gas over a 6 hr period. This shows that as long as the level of reduction of NO concentration is around 10ppm or less the coating will be able to completely depollute the air of the NO gas.

60PPM concentration

The nitric oxide tests shown below were taken at a concentration of 60 ppm of NO gas. In order to keep the results analogous to previous tests these tests were conducted over a 6-hour period even though it would have taken longer than that to eliminate all nitric oxide from the bag. Over the six-hour period the percent reduction of those trials that contained TiO₂ was 47%, 46%, and 42% while those trials that did not contain TiO₂ were 37%, 42%, and 40%.
Figure 6-4: 60PPM Indoor Nitric Oxide Tests
Figure 6-5: 60PPM Indoor Nitric Oxide Tests
It can be seen from the graphs in Figures 6-4 and 6-5 that those trials that included the use of titanium dioxide reduced the amount of nitric oxide at slightly higher rates than those trials that did not include titanium dioxide.

6.6.1.2 Nitrogen Dioxide Reduction

The indoor NO₂ depollution tests were done a total of three times. In addition to these tests an additional test was run without any board in which the NO₂ sensor was placed inside the bag that was then filled with NO₂ gas. This was done to demonstrate any improvements of the inorganic coating over the natural processes that reduce the amount of NO₂ in the air. In the graphs below the yellow line indicates the reduction of NO₂ gas due to natural processes. As can be seen Figure 6-6 the graph without any board in it is not nearly as steep as the other graphs. This demonstrates that the use of either Zinc Oxide alone or the use of Zinc Oxide and TiO₂ yields a much quicker reduction of the NO₂ gas. It can also be noted that it took approximately 45 minutes to complete these tests at 30ppm of NO₂ while the NO tests took 6 hours to run. After 45 minutes the NO₂ was completely reduced while the NO tests had reduced nearly 60% of the original amount of NO. This shows that while the coating does a very good job of reducing the amount of NO in the air it does an even better job of reducing NO₂ in the air. In these tests it can also be seen that the presence of TiO₂ did not have a major effect on the reduction of the NO₂ gas.
Figure 6-6: 30PPM Indoor Nitrogen Dioxide Tests
Figure 6-7: 30PPM Indoor Nitrogen Dioxide Tests
The test results showed positive improvement in the reduction of the NO$_2$ gas. As can be seen from the graphs above the addition of TiO$_2$ showed a 12.1ppm or 100%, 10.8ppm or 94%, and 14.9ppm or 100% reduction in NO$_2$ gas over a 45 min period. The inorganic coating itself showed a 11.6 or 100% reduction, 16.4ppm or 95% reduction, and a 14ppm or 100% reduction in NO$_2$ gas over a 45-minute period. In most cases the NO$_2$ is completely removed, however, in one trial that was not the case. This would indicate that as the initial concentration increases (to above 16ppm) the amount of time it takes to completely eliminate all NO$_2$ in the air would also increase. Due to the results in later tests it will be demonstrated that this is not the case. The trial shown above is merely a deviation from the norm and does not indicate that the maximum concentration that can be reduced in a 45-minute period has been reached.

**60PPM concentration**

The indoor NO$_2$ depollution tests were done a total of three times. During the 45-minute tests less than 4% of the original amount was left in the bag. This demonstrates that the coating is very effective at reducing the amount of NO$_2$ in the air. As discussed earlier the NO$_2$ has two conversion processes. One converts NO$_2$ into HNO3 and the other converts NO$_2$ into NO and oxygen. The tests shown in Figures 6-8 and 6-9 below created small quantities of NO though these quantities never reached above 6ppm. In the tests that included the use of TiO$_2$ the amount of NO in the bag was slightly lower than those tests that did not have TiO$_2$. 
Figure 6-8: 60PPM Indoor Nitrogen Dioxide Tests
Figure 6-9: 60PPM Indoor Nitrogen Dioxide Tests
The test results showed positive improvement in the reduction of the NO\textsubscript{2} gas. Figure 6-9 shows a 38.1ppm or 96%, 36.6ppm or 98%, and a 35.4ppm or 99% reduction in NO\textsubscript{2} gas over a 45 minute period for those tests which used TiO\textsubscript{2}. Similarly, the graph in figure 6-8 shows a 41.2ppm or 98%, 37.7ppm or 99%, and a 40.6ppm or 99% reduction in NO\textsubscript{2} gas for those tests which did not include the use of TiO\textsubscript{2}. These values show a negligible difference in the use of TiO\textsubscript{2}. As mentioned earlier the tests which contain TiO\textsubscript{2} has a slightly lower concentration of NO in the bag so the reduction of NO\textsubscript{2} was also slightly less. In other words, those tests that contain TiO\textsubscript{2} reduce NO slightly better and reduce NO\textsubscript{2} slightly slower than those which do not contain TiO\textsubscript{2}.

6.6.2 Outdoor Results

6.6.2.1 Nitric Oxide Reduction

30ppm concentration

The outside tests were conducted from approximately 10 am to 4pm where the temperatures range was between 70°F and 80°F. Three tests were done with the regular inorganic mix (which includes ZnO) and another three test were done with the inorganic mix (which included ZnO) and the addition on TiO\textsubscript{2}. The NO percent reduction of these tests can be seen in the graphs below. Those tests that involved only ZnO have a more rounded graph while the tests with TiO\textsubscript{2} are more of a straight-line graph.

The results attached in the Appendix shows a drastic reduction in the amount of NO by the TiO\textsubscript{2} setup between two and four hours into the test. In each case concentration of NO in the bag reduced 20ppm in this region. During the first two
hours of the test there was virtually no reduction at all. In fact during the first two hours of the tests the numbers went above the initial concentrations and then began to fall back down to their initial values towards the end of the first two hours. The last two hours was similar to this, showing reductions of 5 ppm in each case. So that the reduction of NO gas in the bag barely reduced at all during the first and last two hours of the test while during the middle two hours enormous reduction of NO was observed. A possible explanation for this could be found in observing that the middle two hours of the test would always occur around noon to 2pm at which point the sun is highest in the sky, the temperature is highest throughout the day and the energy in the UV rays from the sun is also highest. This means that during these two hours the TiO$_2$ received UV rays that were high enough to activate the TiO$_2$ photocatalyst and in so doing caused very high levels of NO reduction. However, during the last two hours of the test the TiO$_2$ particles seem to have deactivated due to a reduction in the magnitude of the sun’s UV rays.

Similarly during these couple of hours the test samples that were composed of only the depolluting ZnO particle were also activated by a higher magnitude of UV sunlight. However, the reduction was not as sharp because ZnO is not as strong of a photocatalytic depolluter as TiO$_2$ is. During the first two hours of the tests the amount of NO reduction was 4ppm, 1ppm, and 0ppm respectively while during the last two hours the NO reduction was 8ppm, 12ppm, and 9ppm respectively. During the middle two hours the NO reduction was 12ppm, 10ppm, and 15ppm. It can be seen that while the ZnO particles may not have been very
active during the first two hours of the three trials once they had become active they did not become deactivated during the last two hours as the TiO$_2$ trials appears to have done. During the last two hours NO reduction continued at a moderate rate although reduction did not always occur as quickly as it had during the middle two hours.
Figure 6-10: 30PPM Outdoor Nitric Oxide Tests
Figure 6-11: 30PPM Outdoor Nitric Oxide Tests
The test results showed positive improvement in the reduction of the NO gas. As can be seen from the graphs in figures 6-10 and 6-11 the addition of TiO2 showed a 28ppm or 85%, 26ppm or 90%, and 28ppm or 100% reduction in NO gas over a 6 hr period. Similarly, the inorganic coating itself showed a 24ppm or 89%, 23ppm or 77%, and 23ppm or 77% reduction in NO₂ gas over a 6 hr period. A possible reason for the increase in efficiency during the first trial is from the increase in temperature during that day.

**60ppm concentration**

The nitric oxide tests shown in Figures 6-12 and 6-13 were taken at a concentration of 60 ppm of NO gas. In order to keep the results analogous to previous tests these tests were conducted over a 6-hour period even though it would have taken longer than that to eliminate all nitric oxide from the bag. Over the six-hour period the percent reduction of those trials that contained TiO₂ was 27%, 36%, and 30% while those trials that did not contain TiO₂ were 27%, 27%, and 32%.
Figure 6-12: 60PPM Outdoor Nitric Oxide Tests
Figure 6-13: 60PPM Outdoor Nitric Oxide Tests
6.6.2.2 Nitrogen Dioxide Reduction

30 ppm concentration

The outdoor NO\textsubscript{2} depollution tests were done a total of three times. It took 45 minutes or less to complete the reduction of NO\textsubscript{2} gas. It may be noted that in a couple of the cases that did not include the use of Titanium Dioxide it only took 25-30 minutes to eliminate all of the NO\textsubscript{2}. The inorganic coating used in this study speeds up the natural nitrogen gas cycle. In this cycle NO\textsubscript{2} is converted to in part into NO and oxygen as well as being converted into HNO\textsubscript{3}. This is important to understand when considering the differences between those trials that included TiO\textsubscript{2} and those that did not. Although it is clear from the graphs below that the trials that did not include TiO\textsubscript{2} were more effective in the reduction of NO\textsubscript{2} these trials did contain excess nitric oxide at the end of 45 minutes in each case. In comparison, the trials that did include TiO\textsubscript{2} took a little longer to reduce the concentration of NO\textsubscript{2} to zero but did so by converting the NO\textsubscript{2} particles to HNO\textsubscript{3} instead of NO. In other words, the first trials quickly converted NO\textsubscript{2} into NO and then took a long time to get rid of the nitric oxide whereas the later trials converted less of the NO\textsubscript{2} into NO and was also able to completely eliminate all of the NO and NO\textsubscript{2} in the bag. For example, the trial that reduced the NO\textsubscript{2} concentration in only 25 minutes had an NO concentration that went from 0 ppm at the beginning of the trial to 9 ppm at the end of a 45-minute period. From the data recorded above it could take an additional 4-5 hours for this level of NO to be eliminated. These tests were started at 10 in the morning and finished around 3. The three tests conducted without TiO\textsubscript{2} were done first.
followed by the three tests that did include TiO$_2$. During the final test it got somewhat cloudy which was not an issue for earlier tests. This resulted in a slightly slower reduction in NO$_2$ gas as can be seen in the graph below (The yellow line in the left graph).

What the graphs in Figures 6-14 and 6-15 don’t show is the increase and reduction in NO gas as it is converted from the NO$_2$. Those graphs on the bottom right reduced the level of NO$_2$ quickly but the amount of NO in the bag continued to increase as the amount of NO$_2$ decreased. The graph in Figure 6-15 stayed steady around 2-3ppm about 15 minutes into the test but then went back down to zero by the end of the tests.
Figure 6-14: 30PPM Outdoor Nitrogen Dioxide Tests
Figure 6-15: 30PPM Outdoor Nitrogen Dioxide Tests
**60ppm concentration**

The outdoor NO$_2$ depollution tests were done a total of three times. It took 45 minutes or less to complete the reduction of NO$_2$ gas. As mentioned above the nitrogen cycle converts the NO$_2$ gas into NO, oxygen, and HNO$_3$. During all trials shown in the graphs below as the amount of NO$_2$ was reduced the level of NO shot up drastically. Despite this the length of the test was kept to 45 minutes long even though it would have taken a lot longer to reduce the remaining nitric oxide in the bag. It is interesting to note that the tests took the same amount of time to complete as those whose initial concentration was much lower. There was even one case where the initial concentration was 46 and it still only took 30 minutes to completely reduce the level of NO$_2$ in the bag. At the end of all the outdoor NO$_2$ tests there was no NO$_2$ left in the bag with the exception of one case. In this case, the initial concentration of NO$_2$ was 51.8ppm, higher than any other test, which would indicate that our inorganic coating can eliminate approximately 50ppm in 45 minutes!
Figure 6-16: 60PPM Outdoor Nitrogen Dioxide Tests
Figure 6-17: 60PPM Outdoor Nitrogen Dioxide Tests
6.6.3 UV vs. Sunlight

It can be seen above that the sunlight does a much better job activating the ZnO and TiO\textsubscript{2} particles than UV light bulbs. The strength of the UV rays causes these particles to speed up the process of de-polluting the air. It should also be noted however, that the increase in the efficiency of the inorganic coating occurs not throughout the entire day while the sun is out but only during certain times of the day when the sun's rays are high enough in magnitude. In New Jersey this time is mostly between the hours of noon and 2pm. However, depending on the location of the structure with respect to the equator and the time of year the amount of time when these depolluting particles are active throughout the day may increase or decrease.

All of the results for the NO tests can be seen in Appendix A below. It is clear from this table that the outdoor tests were more aggressive in their reduction of the NO gas. The outdoor tests have rates of reduction 30\% higher than the indoor tests. In addition, it can be seen from the graphs in the results section that the outdoor tests were more dependant on the time of day. As the UV index increases so does the rate of reduction. It can also be seen that the first hour of all NO tests show very little reduction in the amount of nitric oxide. This could mean that it takes about an hour for the depollution particles to become active and begin NO reduction.

It can be seen from the nitrogen dioxide tests above that the outdoor and indoor trends are different. The outdoor tests are slightly concave but are straight-line graphs for the most part. The indoor tests, on the other hand, are all concave
tests that do the majority of the NO₂ reduction early on in the trials and reduce slightly less over time. The NO₂ tests, because they are only 45 minutes long, were done consecutively with six tests being done each day. It is therefore interesting to note that the outdoor tests were very consistent when compared to the NO tests. During the NO tests the ppm reduction depended on the time of day. The NO₂ tests were done from approximately 10am-3pm or from 11am-4pm. If the NO₂ tests were as dependent on the UV index throughout the day as the NO tests are then the NO₂ tests taken around noon would have reduced the NO₂ concentration faster than those trials done at 10am or 4pm. However, the UV index does not seem to have the same affect on NO₂ as it does on NO.

6.6.4 Presence of TiO₂

The presence of TiO₂ appears to have little difference in the reduction of nitric oxide particles. As can be seen from the NO table in Appendix A the percent reductions of those trials that include the use of TiO₂ show a slight improvement over those that do not contain TiO₂. It can be seen from the graphs above that the indoor cases especially show very little difference between those trials that contain TiO₂ and those that did not. In the outdoor trials however, there was a notable difference in the results. Those tests that did not contain TiO₂ were smoother and more consistent graphs while the trials that contained TiO₂ were more straight-line graphs. This can also be observed in the NO table in Appendix A since the trials which include TiO₂ vary in the level of reduction a lot more than those which do not.
The presence of TiO₂ appears to have little difference in the reduction of nitrogen dioxide particles. The NO₂ table found in Appendix A shows that those trials that contain TiO₂ particles reduced the same level of NO₂ particles in as much time. The graphs above are slightly more concave during those trials that do not contain TiO₂ meaning that their rate of reduction is slightly higher. However, this difference is negligible since the concentration of NO particles increases where the concentration of NO₂ particles decreases during those trials.

From the results above it can be seen that the presence of TiO₂ is minimal when the UV light bulbs are used but is much more efficient than ZnO when exposed to sunlight. Therefore, it depends on the structure and whether the coating would be exposed to sunlight or would be exposed to a UV light. It may be useful to use UV light bulbs that are stronger than those used during this research project as a stronger UV light bulb would be able to cause a higher rate of de-pollution in the ZnO and TiO₂ particles.

6.6.5 Initial Concentration of NO and NO₂ gases

The NO chart found in Appendix A shows a higher rate of reduction for the lower initial concentration tests. At the same time the ppm reduction was much higher for higher concentration tests. At times the ppm reduction for the 60ppm tests were double that of the 30ppm tests! This could mean that the higher the level of initial concentration the more particles come in contact with the coated surface and are then eliminated. Because the initial concentration was double in the 60ppm case twice as many particles came in contact with the surface. It can be seen from the graphs above in the nitric oxide sections of part 6.1 and 6.2 that
the 60ppm tests show a higher level of reduction in the first hour than do the 30ppm tests. The 30ppm tests have almost no reduction of NO at all.

The NO₂ chart found in Appendix A shows a similar percent reduction for an initial concentration of 30ppm and 60ppm. In almost every setup the percent reduction was over 95% and over half the trials had a percent reduction of 100%.

It is interesting to note that even though the initial concentration was doubled for half the trials it still took approximately 45 minutes to complete the tests. It occurred in only a small number of cases that the concentration of nitrogen dioxide was reduced to zero within a 25-30 minute period though it did happen even during a 60ppm test. It can be seen that the indoor trials that contained an initial concentration of about 40ppm were not able to completely reduce all of the NO₂ to zero over the 45-minute period. The graphs trends are very similar for the 30ppm and 60ppm tests.
7 Conclusions

Based on the results reported in this thesis and observations made during the investigation the following conclusions can be drawn.

7.1 DEMONSTRATION PROJECTS

A total of four field applications were carried out to demonstrate the applicability, effectiveness, and long term performance of the proposed coating system. These projects were all completed in New Jersey and consist of; two bridge houses in Wildwood, a retaining wall along Route 280 near the Garden State Parkway, a retaining wall next to a parking lot for Woodbridge mall off of Route 1, and an overpass along Route 1 in Milltown.

The first project provided an opportunity to study the durability of the coating, as it was applied to two bridge houses, in a saltwater environment. Many structural failures occurred in the bridge houses since they were built due to the high salinity of the environment. This project showed the ability of the Rutgers team to set up a workstation that can provide the inorganic mixture to painters with ease. During this project we coated parts of the bridge house to help prevent future spalling and we caulked areas in the north tower to prevent water leakage. The preliminary assessments of the bridge house done by the Rutgers team have all been positive. However, a long-term assessment will need to be done to more accurately assess the coatings ability to fight off the effects of an environment with high salinity.

The second project was a 7200 square foot retaining wall off of Route 280. This project was the largest project and took 8 days to complete. In part the purpose
of this project was to demonstrate the ease of application of the coating. The surface that was coated was a precast facade made up of small brick like tabs protruding from the surface making the coating of the surface very detailed. Nevertheless, the four person painting crew provided by the DOT was efficient in coating the wall and there were no major obstructions that delayed the completion of this project.

The third project was a retaining wall under a ramp going into the Woodbridge mall on Route 1. This project used a light grey color and was meant to demonstrate the self-cleaning properties of the coating. The precast panels of this retaining wall were nearly identical to that of the Route 280 site. The Rutgers team did the application of the coating over a two-day period. Once again there were no major obstacles that prevented this project being done in a time efficient manner. The one-year assessment of the wall done by the Rutgers team showed very positive results. The wall shows no sign of aging or coloring. It has not been marked by graffiti and looks exactly as it did the day it was coated.

The fourth project was an overpass in Milltown on Route 1. This location is often tagged with graffiti and is a major problem for the township because of that. The Rutgers team applied the coating quickly. The wall was soon marked with graffiti, however the crew in charge of the graffiti in that area painted over the graffiti with their own paint before the Rutgers team was able to run any graffiti removal tests.

7.2 GRAFFITI RESISTANCE
Due to the high volume of graffiti on structures dozens of different products exist to attempt to remove the graffiti. Current graffiti removal tests involve the use of power washers, citrus-based graffiti strippers, graffiti resistant coatings, and any other system that is recommended to the crew in charge of that site. The geopolymer coating developed by Rutgers University is the only permanent inorganic coating. In order to compare it to the other graffiti resistant/remover products in existence the same graffiti removal techniques used in practice were attempted to remove graffiti on the inorganic coating. These methods include removal with a cold water and citrus solution, hot water, citrus solution with a cold water v. hot water power washer, a hot water power washer, and a Wadu. The Wadu was referred to Rutgers by a crew team working in Burlington who had found it useful in removing graffiti. Each of these tests yielded positive results with the exception of a hot water power washer. However, when the hot water power washer was combined with citrus solution it worked perfectly. During the first couple of tests (those that did not involve a power washer) a little bit of elbow grease was needed to remove the graffiti but removal was not difficult and was achieved quickly.

7.3 SELF-CLEANING

Everyday the air is contaminated and polluted by fossil fuels burned off by cars and factories, by natural processes, and by other manmade pollutants. These soiling agents corrode the steel and alter the chemical properties of the concrete making the buildings and infrastructure of this nation unsightly and at times structurally deficient. The inorganic coating being used in this research project is
photocatalytic; UV light from the sun activates the inorganic matrix. The component of the inorganic matrix, when activated, self-cleans and prevents or slows down the above-mentioned issues. Many of the soiling agents responsible for the erosion of concrete are unable to stick to the surface of this inorganic coating and end up being washed away by rainwater. This was seen throughout the tests as the soiling dye used was unable to stick to vertical surfaces and would end up beading and running down the wall. The rhodamin-b dye, due to its similarity to such soiling agents was used to measure the efficiency of the inorganic coatings’ self cleaning properties. Most of the specimens were tested outside at either the Livingston lab or at the Route 1 site near Woodbridge Mall by using sunlight. These tests yielded positive results. Within a four-hour period most samples had regained a substantial quantity of their original color. This means the coating was able to clean itself of these soiling agents within a four-hour period even without any rain to wash away the soiling agents.

7.4 DE-POLLUTION
As cars burn fossil fuels many Volatile Organic Compounds, VOCs as well as NO\textsubscript{x} particles are released into the environment. The Nitrogen cycle reduces most unstable or harmful forms of NO\textsubscript{x} into stable NO\textsubscript{x} forms. Nitric oxide as well as nitrogen dioxide are two forms of NO\textsubscript{x} that can be very harmful to the atmosphere and to human beings. This study attempts to speed up the conversion of nitric oxide and nitrogen dioxide into more stable gases in the nitrogen cycle and in so doing to reduce the pollution in the air.
The inorganic coating being used in this research project is photocatalytic. This means that UV light from the sun activates the inorganic matrix. The aim of this de-pollution research project is to evaluate the reduction of NO and NO\textsubscript{2} particles by our inorganic coating in a closed environment. The self-cleaning inorganic matrix has in it quantities of ZnO. For the purpose of de-pollution, a variation of the self-cleaning inorganic coating is used with quantities of both ZnO and TiO\textsubscript{2}, since each of these are well known compounds for their photocatalytic, self-cleaning and de-pollution properties.

This project measured the effects that additional amounts of TiO\textsubscript{2} would have on the de-pollution properties of the inorganic coating. Variables in this project include the differences in reduction levels of NO and NO\textsubscript{2} gases based upon their exposure to UV light or sunlight, the initial concentration levels of NO and NO\textsubscript{2}, and the presence of ZnO combined with TiO\textsubscript{2} or the presence of ZnO alone.

As mentioned in Chapter 6 above the use of sunlight does a much better job activating the inorganic matrix than the UV bulbs. The results clearly indicate that the outdoor tests were more aggressive in their reduction of NO and NO\textsubscript{2} particles. In addition, it was noticed that during the middle of the day between 12-2PM when the UV rays from the sun are strongest throughout the day that the reduction in NO particles took place at a much higher rate than at other times throughout the day. It was also noticed that it would take about an our to get the inorganic matrix fully active in its reduction of NO gas. These two trends were not noticed in the reduction of NO\textsubscript{2}. There appears to be no correlation between the
reduction of NO2 and the time of day or the amount of time the coating has been exposed to the light as depollution began immediately at a quick rate. The presence of TiO2 appears to have little difference in the reduction of nitric oxide particles. However, the percent reductions of those trials that include the use of TiO2 show a slight improvement over those that do not contain TiO2. It was noticed that the indoor tests especially showed very little difference between those trials that contain TiO2 and those that did not. In the outdoor trials, there was a notable difference in the results. Those tests that did not contain TiO2 were more consistent graphs while the trials that contained TiO2 vary in the level of reduction a lot more.

The presence of TiO2 appears to have little difference in the reduction of nitrogen dioxide particles. The NO2 table found in Appendix A shows that those trials that contain TiO2 particles reduced the same level of NO2 particles in as much time. Those trials that altered the initial concentration of NO gas show a higher rate of reduction for the lower initial concentration tests. At the same time the ppm reduction was much higher for higher concentration tests. This could mean that the higher the level of initial concentration the more particles come in contact with the coated surface and are then eliminated. Because the initial concentration was double in the 60ppm case twice as many particles came in contact with the surface yielding a higher ppm reduction of NO particles.

Those trials that altered the initial concentration of NO2 gas show a similar percent reduction for an initial concentration of 30ppm and 60ppm. In almost every setup the percent reduction was over 95% and over half the trials had a
percent reduction of 100%. It is interesting to note that even though the initial concentration was doubled for half the trials it still took approximately 45 minutes to complete the tests. It occurred in only a small number of cases that the concentration of nitrogen dioxide was reduced to zero within a 25-30 minute period though it did happen even during a 60ppm test. It can be seen that the indoor trials that contained an initial concentration of about 40ppm were not able to completely reduce all of the NO₂ to zero over the 45-minute period. The graphs trends are very similar for the 30ppm and 60ppm tests.
## Appendix A

### Nitric Oxide

#### Indoor Trials

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#### Outdoor

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### Nitrogen Dioxide

#### Indoor Trials

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<td>93%</td>
</tr>
<tr>
<td>35.8-.4=35.7</td>
<td>99%</td>
<td>14.9-0=14.9</td>
<td>100%</td>
</tr>
<tr>
<td>(w/out)</td>
<td></td>
<td>30ppm</td>
<td></td>
</tr>
<tr>
<td>42-.8=41.2</td>
<td>98%</td>
<td>11.6-0=11.6</td>
<td>100%</td>
</tr>
<tr>
<td>38.1-.4=37.7</td>
<td>99%</td>
<td>17.2-.8=16.4</td>
<td>95%</td>
</tr>
<tr>
<td>41.2-.6=40.6</td>
<td>99%</td>
<td>14-0=14</td>
<td>100%</td>
</tr>
</tbody>
</table>

#### Outdoor

<table>
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<tr>
<th>ppm</th>
<th>% reduction</th>
<th>ppm</th>
<th>% reduction</th>
</tr>
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<tbody>
<tr>
<td>51.8-.2=51.6</td>
<td>99.6%</td>
<td>14.9</td>
<td>100%</td>
</tr>
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<td>45</td>
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<td>100%</td>
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<tr>
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<td>(w/out)</td>
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<td>30ppm</td>
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<tr>
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<td>39.2</td>
<td>100%</td>
<td>17.4</td>
</tr>
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<td>2</td>
<td>46</td>
<td>100%</td>
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<tr>
<td>3</td>
<td>38.9</td>
<td>100%</td>
<td>16.4</td>
</tr>
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</table>
References


Note: Additional references in the form of web addresses can be found in the document.