Feasibility study: The evaluation of polymer coatings to prevent weathering of weak rocks

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Feasibility Study:
The Evaluation of Polymer Coatings
to Prevent Weathering of Weak Rocks

_______________________________________

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the Faculty of the Undergraduate
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James Madison University

by Lauren Nicole Distler

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Abstract

The weathering and erosion of weak rocks along roadways can cause dangerous and potentially fatal rockfalls. Various slope stabilization methods exist, but each presents a set of challenges and trade-offs. The focus of the project is to understand the feasibility of utilizing a polymer-based slope stabilization technique. Rock samples were collected along US Route 33 in Virginia and West Virginia, and preliminary tests were conducted to evaluate the absorption of water (% mass) and durability. The study evaluates three polymer options in regard to the following criteria: adhesion to rock, layer thickness, semi-permeability, insolubility, and non-toxicity. The polymer selection process yielded that a water-based polyurethane would present the benefits of creating a waterproof and lightweight coating when applied to the rock analyzed as part of this study. Polymer coated rock samples were tested in same manner as the uncoated rock samples from the preliminary tests; where the results indicate a slight decrease in water absorption and an increase in erosion durability. Intended future work will investigate the impact of application technique on the durability and absorptive properties of coated rock samples.
Literature Review

Weathering and Undercutting

The construction of roads in mountainous regions often involves the creation of artificial slopes. This process alters the natural slope angles, leading to possible roadside hazards. Slope failures are especially prevalent in the Appalachian region of the Eastern United States. Among the different types of cut slope failures affecting the Appalachian region, undercutting-induced rock falls are among the most problematic. Rapid weathering and the subsequent erosion of weak rock layers cause these failures. Undercutting is a process by which weak layers of shale erode away, exposing large overhanging blocks of stronger rocks such as limestone and sandstone. Exposed blocks of stronger rock can end up as rock falls along highways, presenting a hazard to motorists and damage to the roadway [1]. Lanes and sometimes the entire roadway must be shut down in order to clear the rock hazard. An example of an undercutting-induced rock fall is shown below in Figure 1.

Figure 1: Diagram of undercutting-induced rockfall (left); example of rockfall, showing weak and strong rock layers (right)
Existing Slope Stabilization Techniques

At present, there are various existing slope stabilization technologies. First, slopes can be designed with benches to separate the undercut layer and weak underlying layer to slow the undercutting process. This method requires additional excavation and hauling away of material [5]. Another method is shotcrete, a spray-on concrete layer applied to the weak undercutting layer. However shotcrete adds a heavy layer (25-300lb/ft²; depending on thickness), which may itself get undercut over time and fail. Shotcrete also presents drainage issues, as it dams seepage from slopes [5]. Finally, the undercut unit can be stabilized with rock bolts that anchor rock blocks to the slope. Rock bolts generally work if the joint spacing is wide enough (3-6ft). Closely joined rocks require too many bolts, making the process impossible [5]. The Appalachian region could benefit from a different method of undercutting prevention and slope stabilization.

Polyurethane Coating

In the development of a new slope stabilization technique, the feasibility of a thin polymer coating on weak undercutting rocks will be assessed. Polymers are capable of displaying a wide range of mechanical, chemical, and thermal properties [4]. Desirable properties for such an application include insolubility in water, semi-permeability (allow moisture to escape from rock structure), and non-toxicity. Polyurethanes are usually thermosetting polymers, meaning they will not melt again when reheated [4]. Polyurethane foam liners have been used as a stabilization technique in mines and tunnels internationally [12]. The performance of these thin spray liners (TSLs) has been compared to shotcrete, a previously mentioned existing slope stabilization method. This analysis was done to assess the relative strength and flexibility of a polymer coating. [9,10] A clear difference in strength has not been empirically determined, but polymer liners weigh significantly less per ft² and have greater estimated ductility and tensile
strength than shotcrete [10]. These numbers are shown below in Table 1, and indicate greater flexibility and pull-apart strength for polyurethane TSLs.

Table 1: Comparison of relevant material properties for different liners [10]

<table>
<thead>
<tr>
<th>Support liner type</th>
<th>Estimated tensile strength (MPa)</th>
<th>Percent elongation (%)</th>
<th>Set time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shotcrete</td>
<td>6.9</td>
<td>0</td>
<td>45-60</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>18.5</td>
<td>125</td>
<td>10 sec</td>
</tr>
</tbody>
</table>

1 Strength in 28 days  
2 Initial set time

Figure 2 below shows the typical application process for most TSLs in a mining environment.

With the right equipment, polyurethane coatings with the desired properties could be used to stabilize slopes along highways. It is important to note that while this specific polyurethane liner requires a spray system, there are coating options in which a dip or brush coating application process is appropriate (Appendix A.)

Figure 2: Application of thin polyurethane layer to rock
Self-Polymerized Dopamine Thin Film

As previously stated polymers can take many forms and display a wide range of properties. Dopamine is a commonly known neurotransmitter, but it is also a key component of the sea mussel fibers used to attach sea mussels to virtually any surface or material [16,18].

![Mussels attached to rock (left) and teflon (right):](http://www.sciencedaily.com/releases/2007/10/071018142509.htm)

Under alkaline conditions, dopamine solutions can self-polymerize to form thin films on various surfaces [8,18]. Dopamine/polydopamine films have proven to have promising adhesive qualities, and have the ability to support a range of secondary treatment processes [15]. The process by which dopamine films are formed and applied is shown on the next page, Figure 4.
Figure 4: Dopamine self-polymerizes in pH 8.5 and coats surface, this surface is then a reactive platform for a wide range of applications [15]

Research focused on the material properties of dopamine thin films is limited. However, dopamine coatings are known to be insoluble in water and its adhesive qualities prove extremely effective in wet environments [15,17,18] This suggests that a dopamine coating may prove effective in weathering prevention.

**Thermoplastic Polyolefin Coating**

Another polymeric coating typically exposed to aqueous conditions are thermoplastic polyolefins, commonly used in pool coatings [11]. Looking closer, polyolefin coatings are composed of both a thermoplastic polymer, and a resin to enhance performance and flexibility. They display excellent adhesive properties to metal and concrete, and have excellent wear and UV resistance [11]. These characteristics make Polyolefin coatings a decent candidate for weathering and erosion protection of rocks. However these coatings require a thermal spray application technique, shown below in Figure 5. This method may not be possible to replicate in the laboratory due to the required equipment.
Polymer Evaluation and Discussion

Each of the polymers discussed in the sections above present unique tradeoffs. Table 2 on the next page is a summary of the project criteria and how each polymer qualifies. The data in this table will be used to select an appropriate polymer for feasibility testing in a laboratory environment. A specific product example of each polymer was selected for the completion of the table (listed below), and data sheets for each product are included in Appendix A of this document.

- Polyurethane: *WATERBASED ACROLON 100, Sherwin Williams*
- Self-Polymerized Dopamine: *Dopamine Hydrochloride, Sigma Aldrich*
- Thermoplastic polyolefin: *ResoCoat 301 Concrete and Fiberglass Pool and Spa Surface Coating, Resodyn Corporation*
### Table 2: Ranking and evaluation of polymer coating concepts

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Common Uses</th>
<th>Insoluble in Water (Y/N)</th>
<th>Low VOC (g/L)*</th>
<th>Cost Rating (Relative)</th>
<th>Adheres to Rock/Ceramic (Y/N)</th>
<th>Dip Coating Application (Y/N)</th>
<th>Appropriate Coating Thickness (microns)</th>
<th>Semi-permeable to allow for moisture escape (Y/N)</th>
<th>Feasibility Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyurethane</td>
<td>Mine/rock liner, Marine paints and coatings</td>
<td>Y</td>
<td>&lt;100</td>
<td>Moderate</td>
<td>Y</td>
<td>Y</td>
<td>75</td>
<td>N</td>
<td>✔</td>
</tr>
<tr>
<td>Self-Polymerized Dopamine</td>
<td>Thin-film adhesive coating</td>
<td>Y</td>
<td>0</td>
<td>High</td>
<td>Y</td>
<td>Y</td>
<td>0.01-0.05</td>
<td>N</td>
<td>✗</td>
</tr>
<tr>
<td>Thermoplastic Polyolefin</td>
<td>Swimming pool coating</td>
<td>Y</td>
<td>0</td>
<td>Moderate</td>
<td>N</td>
<td>251-381</td>
<td></td>
<td>N</td>
<td>✔**</td>
</tr>
</tbody>
</table>

* "Low VOC" limit set by EPA Standard: 250g/L
** Given lab availability of thermal spray coater

The criteria in Table 2 were developed from project requirements and the material property values provided for each product. For most coatings, the level of Volatile Organic Compounds (VOCs) per liter is a good indicator of toxicity. VOCs are harmful and can cause long-term health effects in humans and can impact the environment [14]. Therefore, minimizing VOCs released during application is an important selection factor. The thickness of the coating is important to ensure that the slope is stabilized as a result of application. A coating too thin may not adequately protect the rock from weathering over time.

The polyurethane coating was determined to be most feasible due to the suitability of dip coating as a laboratory application method and its low cost relative to dopamine. The inherent issues with the other polymer options and justification for their elimination are discussed below.
Elimination of Polymer Options

Self-Polymerized Dopamine

- Dopamine polymerizes to form an extremely thin film. This film is only 10-15 nm thick, and would not be significant enough to stabilize the slope.

- Dopamine hydrochloride is a neurotransmitter, and is extremely expensive. As of March 2015, 100g of Dopamine hydrochloride costs ~$320.00. Although its adhesive properties are significant, the cost is too high to conduct a laboratory feasibility study.

Thermoplastic Polyolefin

- As shown in the feasibility column of Table 2, the thermoplastic polyolefin is labeled conditionally feasible. For application in a laboratory setting, high-output polymer thermal spray equipment would be necessary for application of the polyolefin coating. The use of specific equipment does not allow for the modification of the polymer being applied.

Permeability of Polymer Coating

One of the main requirements for the polymer coating is permeability to liquid water. Water naturally infiltrates through and seeps out of rock layers. The application of shotcrete involves the installation of drainage holes to avoid water pressure buildup. This pressure buildup occurs when water becomes trapped in rock structures due to natural infiltration and the location of the water table. The pore size necessary for liquid water flow will depend on the level of pressure buildup in the rock structure. This issue must be taken into account in the development of a polymer solution as well. With the selection of polyurethane for the first feasibility test, two concepts to create a permeable layer were researched and evaluated. The first concept involves the creation of polyurethane foam.
Foams can be created either mechanically by agitation or mixing, or chemically by adding a surfactant solution [7]. Sometimes, both are necessary to sustain a stable foam. It is unknown how the water-based polyurethane will react to the addition of a surfactant. A simple and inexpensive (10 USD/100g) surfactant was investigated for use in this project: Sodium dodecyl sulfate (SDS.) SDS was selected on the basis of price and availability. Since it is not known how the surfactant will perform, an inexpensive option (SDS) will first be assessed. Experimentation is needed to determine the proper concentration of SDS solution to be added to the polymer. If the bubbles are stable within the solution, it is predicted that they will be stable once the coating has dried. Integration of the foaming process is outside the scope of this project, and will be reserved for future work and investigation.

The second concept to create a permeable coating layer is by punching holes in the layer to allow for drainage once the polymer has been applied. This concept stemmed from a US patent issued in 1980, describing a protective plastic coating with one-way valve like perforations [13.] The perforations are sized so that moisture within the underlying material can escape, but rainwater cannot pass through to rot the material. The concept of perforations will be considered as permeability of the polymer layer is considered. This research project proposes the investigation of the properties of polyurethane coatings on clayey silicate rocks in order to test the feasibility of such a solution in the realm of slope stabilization and weathering prevention. The permeability of the polymer coating will be considered after initial testing of the polyurethane has been completed and results verified feasible.
Laboratory Testing and Methods

Rock Sampling

Weak rock samples were collected from two different locations along Route 33 in Virginia and West Virginia. These locations are shown in Figure 6 below.

The locations for sampling were selected on the basis that the rocks were identified as shales and mudstones, for RT33-002 and -003 respectively. Shales and mudstones are two notoriously weak rocks types. Also, these locations were selected because they are representative of a layered cutslope with both strong and weak rock layers. It was hypothesized that samples from these locations would provide weak rocks similar to those involved with undercutting induced rockfalls. Images of the two sampling locations with GPS coordinates, geologic formation, and lithology information are on the next page, Figure 7 and 8.
Site ID: RT33-002

GPS Location: 38.6341670, -79.2308330

Geologic Formation: Millboro

Lithology: Shale

Site ID: RT33-003

GPS Location: 38.5883330, -79.1677780

Geologic Formation: Hampshire

Lithology: Mudstone
Rock Characterization and Behavioral Observation

X-Ray Diffraction (XRD)

Next, each of the samples were characterized by x-ray diffraction. This was done in order to determine the mineral composition of each sample and confirm that these rocks are in fact weak shales and mudstones. X-rays are just below the visible light spectrum and range from .01-10 nm, meaning x-rays are high energy, high frequency, and short wavelength. Minerals have unique atomic crystal lattices or arrangements, which can diffract x-rays in order to determine the chemical composition of the mineral. Each mineral has characteristic d-spacing, but in order to determine the true composition there must be enough d-spacings or peaks to form a fingerprint of the mineral present. The fingerprint is used by a match search database that can correctly identify the phase identity, phase purity, or percent phase composition of the sample. The computer returns a graph, showing peaks that indicate a miller index matched to a known mineral by the computer. The following methods were used for sample preparation and the XRD analysis.

Sample Preparation

1. Acquire samples
2. If samples are too large to grind, use mill to get to a grindable state
3. Grind sample with pestle and mortar until a very fine powder
4. Place metal sample holder face down on glass plate.
5. Pile ground sample in the hole of sample holder until packed tightly
6. Place metal backing plate clip on sample holder
7. Rotate at least at a 45 degree angle to make sure sample is compact
8. Log in XRD book to keep track of when this trial occurred

9. Place in XRD and analyze

10. Clean equipment

**XRD Analysis**

1. Set up computer program

2. Open shutters

3. Set sample angle range and run time

4. Run sample

5. Transfer data to auto search chemical composition with the International Center for Diffraction Database (ICDD) and Joint Committee on Powder Diffraction Standards (JCPDS.)

**Jar Slake Test**

A jar slake durability test was conducted for each sample type. The purpose of this test was to observe the effect of a 24-hour water submersion on rock samples. The results indicate the relative strength of the rock in an aqueous environment. This is important in understanding how the rock might break down naturally, and provides a good baseline of the durability of the samples. [6]

The samples used were approximately 50g each, completely submerged by at least 1 inch of water. Specimens were observed at frequent intervals for the first 30 minutes, and after 24 hours the final observations were made. The following scale (Table 3) was used to categorize the behavior of the samples, once submerged [6.]
Table 3: Jar Slake Durability scale for categorizing behavior of shales [6]

<table>
<thead>
<tr>
<th>Category</th>
<th>Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Degrades to pile of flakes or mud</td>
</tr>
<tr>
<td>2</td>
<td>Breaks rapidly and/or forms many chips</td>
</tr>
<tr>
<td>3</td>
<td>Breaks slowly and/or forms many chips</td>
</tr>
<tr>
<td>4</td>
<td>Breaks rapidly and/or develops few fractures</td>
</tr>
<tr>
<td>5</td>
<td>Breaks slowly and/or develops few fractures</td>
</tr>
<tr>
<td>6</td>
<td>No changes</td>
</tr>
</tbody>
</table>

Initial (Uncoated) and Polyurethane Coated Rock Testing

24 Hour Absorption: ASTM §D6473 - 10

The purpose of absorption testing is to determine the susceptibility of rock samples to water influx, resulting in increased mass. Ideally, the polyurethane coating will result in reduced absorption and mass increase. This will be achieved by first completing a set of baseline absorption tests of uncoated rock samples. These values will then be compared to the results of a set of comparison tests in which the rock samples have been coated with polyurethane.

Rock samples were cut to a minimum of 1kg (2.2lb) in mass. These values were recorded as initial masses for each trial. Each specimen was air-dried and placed in water between 20 and 30°C for 24± 4hr. After 24 hours elapsed, the specimens were removed from the water and toweled dry to remove any visible films of water. The specimens were weighed again to obtain a
final mass value for each trial. [3] These recorded mass values were then used to calculate the % absorption of the samples, using Equation 1.

\[
\text{absorption, } \% = \frac{B - A}{A} \times 100
\]

Eq. 1

Where \( A \) = mass of air-dried test specimen, g,

\( B \) = mass of saturated-surface dry test specimen, g

As previously stated, this experiment was replicated for the polyurethane-coated samples for comparison. A similar process was also applied to the next experiment, the slake durability test.

*Slake Durability Index (SDI): ASTM §D4644 - 08*

The purpose of the slake durability test described in this section is to determine how weak the rock samples are and how well they are able to resist erosion. In this test, erosion is simulated by two wetting cycles and abrasion. This test requires the use of a slake durability device. This device was made available through the James Madison University Department of Geology and Environmental Science. A schematic of the durability device is shown below, Figure 9.

*Figure 9: Slake durability device, showing critical dimensions [2]*
Each trial required ten intact and roughly equidimensional shale fragments that weigh between 40 and 60 g each. The total test specimen for each trial weighed between 450 and 550 g. The specimens were oven-dried at 110°C for 24 hours before the first slake cycle. The trough was filled with room temperature distilled water to a level 20mm below the drum axis (see Figure 9.) The specimens were loaded into the drum and were rotated at 20 rpm for 10 minutes. The specimens were removed and again oven-dried for 24 hours. An oven-dried mass was obtained for the first cycle, and the process was repeated for a second slake cycle. [2] Photographs were taken at each stage to show deterioration, as the slake durability index is not always representative of the true durability of the specimen. The mass values recorded throughout the trial were then used to calculate the slake durability index (second cycle), using Equation 2.

\[ I_d(2) = \left[ \frac{W_F}{B} \right] \times 100 \quad Eq. 2 \]

Where \( I_d(2) \) = slake durability index (second cycle),

\( B \) = mass of oven-dried specimen before the first cycle, g

\( W_F \) = mass of oven-dried specimen retained after the second cycle, g

The SDI values range from 0 to 100, as they are representations of the percentage of material/rock retained after two tumbling cycles. In addition to the calculation of SDI values for each trial, a description of the rock fragments after the second cycle was recorded. As previously stated this method was conducted first as a baseline test, and again after the samples had been coated with polyurethane. The same procedure was used in both instances.
Results

Rock Characterization and Behavioral Observation

X-Ray Diffraction (XRD)

The results for the RT33-002 samples are below, Figure 10.

![XRD Results for RT33-002](image)

The results show a dramatic spike in quartz, SiO$_2$, indicating the main mineral composition of the sample. Additional peaks of muscovite, KAl$_2$(AlSi$_3$O$_{10}$(F,OH)$_2$, and Illite, which is the breakdown of muscovite. Feldspar and its breakdown, Kaolinite, are very common clay minerals and were also present in this sample to some extent.
XRD results for RT33-003 are below, Figure 11. The results again indicate that the sample is composed mainly of SiO₂, silicon dioxide and muscovite, KAl₂(AlSi₃O₁₀)(F,OH)₂.

The XRD results determined the mineral composition of both samples. The fingerprints represented by large spikes in the graph indicate a silicate base for each rock type. These results confirm that adhesion of the polymer coating to the samples can be completed successfully.
Jar Slake Durability

Three trials were conducted for each sample type. When subjected to the jar slake durability test, each rock type behaved similarly overall. The results for RT33-002 are below in Table 4.

Table 4: Uncoated RT33-002 Results of Jar Slake Durability

<table>
<thead>
<tr>
<th>Trial</th>
<th>Behavior (24 Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6- No changes</td>
</tr>
<tr>
<td>2</td>
<td>6- No changes</td>
</tr>
<tr>
<td>3</td>
<td>6- No changes</td>
</tr>
</tbody>
</table>

The RT33-002 samples displayed no deterioration, cracking or changes whatsoever. These results indicate that the samples collected from site RT33-002 are inherently strong shales. This could also be due in part to the mainly silicate composition. The results for site RT33-003 are below in Table 5.

Table 5: Uncoated RT33-003 Results of Jar Slake Durability

<table>
<thead>
<tr>
<th>Trial</th>
<th>Behavior (24 Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6- No changes</td>
</tr>
<tr>
<td>2</td>
<td>5- Breaks slowly and/or develops few fractures</td>
</tr>
<tr>
<td>3</td>
<td>5- Breaks slowly and/or develops few fractures</td>
</tr>
</tbody>
</table>

The results indicate that the samples collected from site RT33-003 are slightly stronger than those collected from RT33-002. Small fractures developed throughout the 24-hour period. This makes RT33-003 samples more desirable for this feasibility study, due to their slightly weaker nature.
Initial (Uncoated) Rock Testing

24 Hour Absorption

This section investigates results from the uncoated rock testing. At the conclusion of the 24 hour time period, the samples were removed and weighed. It should be noted that only 1 trial was conducted for the RT33-002 rock samples. This decision will be discussed in greater detail in the next section of this report (*Slake Durability Index (SDI)*.) The result is below in Table 6.

*Table 6: Absorption results for uncoated RT33-002 sample*

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Initial Mass- air dried (g)</th>
<th>Final Mass (g)</th>
<th>Absorption, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1226.07</td>
<td>1239.91</td>
<td>1.129%</td>
</tr>
</tbody>
</table>

Table 7 below shows the results for the uncoated RT33-003 samples. The mean absorption was 0.85%, with a standard deviation of 0.70%. The uncertainty due to measurement error was calculated to be ±0.012%, as calculated in Appendix B of this report.

*Table 7: Absorption results for uncoated RT33-003 samples*

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Initial Mass- air dried (g)</th>
<th>Final Mass (g)</th>
<th>Absorption, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1392.24</td>
<td>1415.29</td>
<td>1.656%</td>
</tr>
<tr>
<td>2</td>
<td>1055.5</td>
<td>1061.09</td>
<td>0.530%</td>
</tr>
<tr>
<td>3</td>
<td>1037.16</td>
<td>1040.96</td>
<td>0.366%</td>
</tr>
</tbody>
</table>

\[ \mu = 0.851\% \]
\[ \sigma = 0.702\% \]

Uncertainty, ± = 0.012%
Slake Durability Index (SDI)

After the second slake cycle and oven dry, the samples were weighed a final time. The SDI results for uncoated RT33-002 samples are shown below in Table 8.

Table 8: SDI results for uncoated RT33-002 samples

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Initial Mass After Oven Dry #1 (g)</th>
<th>First Slake Cycle</th>
<th>Mass After First Cycle (g)</th>
<th>Second Slake Cycle</th>
<th>Mass After Second Cycle (g)</th>
<th>Slake Durability Index (SDI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>434.53</td>
<td></td>
<td>431.27</td>
<td></td>
<td>429.89</td>
<td>98.93</td>
</tr>
<tr>
<td>2</td>
<td>502.67</td>
<td></td>
<td>499.98</td>
<td></td>
<td>498.05</td>
<td>99.08</td>
</tr>
<tr>
<td>3</td>
<td>511.97</td>
<td></td>
<td>508.25</td>
<td></td>
<td>505.52</td>
<td>98.74</td>
</tr>
</tbody>
</table>

µ = 98.92
σ = 0.17
Uncertainty, ± = 0.029

The results for the RT33-002 samples validate the jar slake durability result from the previous section. The shale samples collected at this location are extremely strong, as they returned SDI values of 98.92 ± 0.03, with a standard deviation of 0.17. The strength of the RT33-002 samples makes them less applicable to this project. Their durability also presented challenges in the sample preparation process. The collected samples proved extremely difficult to cut with the rock saw. Due to the sheer number of samples necessary for testing and the viability of the RT33-003 rocks, continuing to use RT33-002 is unnecessary for the completion of this project.

Table 9 is populated with the SDI results for the uncoated RT33-003 samples.
Table 9: SDI results for uncoated RT33-003 samples

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Initial Mass After Oven Dry #1 (g)</th>
<th>First Slake Cycle</th>
<th>Mass After First Cycle (g)</th>
<th>Second Slake Cycle</th>
<th>Mass After Second Cycle (g)</th>
<th>Slake Durability Index (SDI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>538.94</td>
<td>517.58</td>
<td></td>
<td>495.66</td>
<td>91.97</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>459.51</td>
<td>449.25</td>
<td></td>
<td>439.22</td>
<td>95.58</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>449.93</td>
<td>441.92</td>
<td></td>
<td>432.71</td>
<td>96.17</td>
<td></td>
</tr>
</tbody>
</table>

\[ \mu = 94.58 \]
\[ \sigma = 2.28 \]

Uncertainty, ± = 0.029

The average SDI value was 94.58 ± 0.03, with a standard deviation of 2.28. These results show that the RT33-003 samples are weaker than RT33-002, and prove to be a better representative of a weak shale. It should be noted that although the SDI results were lower than RT33-002 samples, the average SDI value of 94.58 still indicates a strong rock. As previously stated, photos were taken at various stages throughout the SDI testing process. A large SDI value is not necessarily indicative of a strong rock, as the mass retained does not describe the fractured state of the sample. For example, Figure 12 on the next page shows uncoated RT33-003 samples before and after SDI testing.
As seen in Figure 12, the samples have been eroded and weathered, but the SDI value is over 90. For this reason, observation of the samples is essential to determining the true impact of simulated weathering and erosion. The photos for each trial are provided in Appendix C of this report. These photos are provided to comply with the ASTM standard used in durability testing.

**Polyurethane Coated Rock Testing**

The same procedures were repeated for rocks dip-coated in the polyurethane. The results for 24 Hour Absorption and SDI are discussed below.

**24 Hour Absorption**

At the conclusion of the 24-hour time period, the samples were removed and weighed. Table 10 is populated with the absorption results for coated RT33-003 samples.
Table 10: Absorption results for coated RT33-003 samples

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Initial Mass- air dried (g)</th>
<th>Final Mass (g)</th>
<th>Absorption, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>982.77</td>
<td>984.29</td>
<td>0.155%</td>
</tr>
<tr>
<td>2</td>
<td>1072.2</td>
<td>1073.78</td>
<td>0.147%</td>
</tr>
<tr>
<td>3</td>
<td>1023.45</td>
<td>1025.66</td>
<td>0.216%</td>
</tr>
</tbody>
</table>

\[ \mu = 0.151\% \\
\sigma = 0.005\% \\
\text{Uncertainty, } \pm = 0.014\% \\

The average absorption value for the coated samples was 0.151± 0.014%, with a standard deviation of 0.005%.

Slake Durability Index (SDI)

The SDI results for the coated RT33-003 samples are below in Table 11.

Table 11: SDI results for coated RT33-003 samples

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Initial Mass After Oven Dry #1 (g)</th>
<th>First Slake Cycle</th>
<th>Mass After First Cycle (g)</th>
<th>Second Slake Cycle</th>
<th>Mass After Second Cycle (g)</th>
<th>Slake Durability Index (SDI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>472.84</td>
<td></td>
<td>472.84</td>
<td></td>
<td>472.48</td>
<td>99.92</td>
</tr>
<tr>
<td>2</td>
<td>430.04</td>
<td></td>
<td>429.90</td>
<td></td>
<td>429.49</td>
<td>99.87</td>
</tr>
<tr>
<td>3</td>
<td>456.53</td>
<td></td>
<td>456.36</td>
<td></td>
<td>455.95</td>
<td>99.87</td>
</tr>
</tbody>
</table>

\[ \mu = 99.89 \\
\sigma = 0.03 \\
\text{Uncertainty, } \pm = 0.031 \\

28
The average SDI value was 99.89 ± 0.03, with a standard deviation of 0.03. These values indicate that the polymer coating strengthened the samples. Images of the samples before and after SDI testing show that there was significantly less deterioration, and hardly any loss of mass during the experiment. This is shown below, Figure 13.

Figure 13: Coated RT33-003 samples before and after SDI testing
Discussion

This section discusses the differences between the results of the uncoated and coated samples for both absorption and SDI testing. Absorption values for each trial are plotted on Figure 14, below. The large standard deviation in the uncoated samples causes a dramatic effect on the graph, but there is still a slight difference in the smallest %mass value for uncoated samples and the largest value for the coated samples.

![RT33-003 Absorption Trials 1-3 (Coated and Uncoated)](image)

*Figure 14: Absorption result comparison: RT33-003 uncoated and coated samples*

The SDI results are a little less variable, with standard deviations of 2.28 and 0.03 for the uncoated and coated trials respectively. Figure 15 shows a comparison between the uncoated and coated samples.
As previously stated, differences in the samples are also assessed by observation. The more significant difference in deterioration is concluded from these photographs.

Figure 15: SDI result comparison: RT33-003 uncoated and coated samples
Conclusions

The purpose of this feasibility study was to compare the weathering and erosive properties of both uncoated weak rock samples, and rock samples coated with a weather-resistant thermoset polymer: polyurethane. It was hypothesized that a thin coating of the polyurethane polymer would result in changes to the properties of absorption and erosion/weathering resistance of silicate-based rock samples. Data was obtained through 24-hour water absorption tests and slake durability testing to measure % mass increase and slake durability index (SDI) values. Uncoated samples absorbed an average of 0.850±0.012%, and coated samples an average of 0.151±0.014%. The average SDI value for uncoated rocks samples was 94.58 ± 0.03, and the average SDI for the coated samples was 99.89 ± 0.03. These results indicate a slight decrease in absorption (%mass) and an increase in SDI values of the samples. The polyurethane coating has passed initial feasibility tests. Intended future work will consider the permeability of the polymer coating to liquid water.
Future Work

As previously discussed, the next phase of this project will deal directly with the permeability of the polyurethane coating. There are several methods by which this can be achieved. The most promising method to investigate is the addition of a surfactant, Sodium dodecyl sulfate (SDS), to create polyurethane foam. The Critical Micelle Concentration (CMC) of SDS in pure water is about 8.2mM. The CMC is the concentration above which micelles are formed and continue to form. Micelles are essential to the stability of the foam. It is unknown how the surfactant will react with polyurethane, so experimentation will be necessary to determine the best ratio of surfactant to solution. Experiments with 2x, 4x, 8x, and 16x the CMC concentration will be attempted to ensure proper foamability with the presence of the urethane.

Additional work may also include the acquisition of different rock samples that are more representative of weak and highly erodible shale. Investigating the impact of the polymer coating on rocks with lower SDI values will be more indicative of its potential to slow weathering and erosion.
Acknowledgements

This project was sponsored in part by a Madison Trust Innovation Grant, awarded in Fall 2014. I would like to thank my advisor, Dr. Kyle Gipson of the Department of Engineering, my readers; Dr. Yonathan Admassu of the Department of Geology and Environmental Science, and Dr. Elise Barrella of the Department of Engineering for their support and guidance throughout the completion of this project. Thank you to JMU geology student Caryn Martin ('16), and JMU engineering student Garret Brown ('16) for their unwavering interest and laboratory assistance. Thank you to Dr. Klebert Feitosa of the Department of Physics and Astronomy for his useful and constructive recommendations on the continuation of this project. And a very special thanks to Ron Phillips, Lab Manager within the Department of Geology and Environmental Science, for his laboratory expertise, understanding, and feedback throughout this project.
References


**WATERBASED ACRYOLON 100**

### PRODUCT INFORMATION

**PRODUCT DESCRIPTION**

Water-based urethane. Provides performance properties comparable to or superior to solvent-based urethanes. Contains a high gloss, abrasion resistant urethane that has excellent weathering properties. Retains its appearance over a wide range of chemical, weather, and mechanical conditions. Can be applied directly to water-based and solvent-based organic zinc-rich primers. Low odour. Non-flammable. <100 g/L VDC. Can be used as primer. Resists film attack by mildew. (MR Extra White Base only)

**PRODUCT CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Finish</th>
<th>High Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Water-resistant color available, Clear Coat (B657724)</td>
</tr>
<tr>
<td>Volume Solids</td>
<td>48.5% ± 2%, catalyzed, unaccelerated</td>
</tr>
<tr>
<td>Weight Solids</td>
<td>25% ± 2%, catalyzed, unaccelerated</td>
</tr>
<tr>
<td>VOC (EPA Method 24)</td>
<td>Unreduced: 100 g/L; 0.83 lb/gal Reduced: 100 g/L; 0.63 lb/gal</td>
</tr>
</tbody>
</table>

Mix Ratio: 4:1 by volume

**Recommended Spreading Rate per coat:**

<table>
<thead>
<tr>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet mls (microns)</td>
<td>4.0 (100)</td>
</tr>
<tr>
<td>Dry mls (microns)</td>
<td>2.0 (50)</td>
</tr>
<tr>
<td>Coverage kq/fgal</td>
<td>195 (4.8)</td>
</tr>
</tbody>
</table>

Theoretical coverage fg/gal (m³/L) @ 1 mil = 25 microns/dt

### PERFORMANCE CHARACTERISTICS

- For use on prepped substrates in industrial and marine environments, such as:
  - Offshore platforms
  - Exterior surfaces of steel tanks
  - Structural steel
  - Rail cars and locomotives
  - Paper mills
  - Power plants
  - Bridges
  - Conveyors
  - Nuclear power facilities
  - Marine applications
  - Floors

- Chemical processing equipment
- Industrial machinery and equipment
- Suitable for use in USDA inspected facilities
- Acceptable for use in Canadian Food Processing facilities, category D2, D3, E8
- Acceptable for use in high performance architectural applications
- Recommended for use in Airframe and Appliances, Class II (NS-308), 4000 lb/m² (90 kg/m²)
- Resists film attack by mildew (MR Extra White Base only)

**TEST RESULTS**

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrasion Resistance</td>
<td>ASTM D4080, CS17 wheel, 1000 cycles, 1 kg load</td>
<td>25 mg loss</td>
</tr>
<tr>
<td>Accelerated Weathering - QUV</td>
<td>ASTM D5269, 10,000 hours, 1500 hours</td>
<td>Passes</td>
</tr>
<tr>
<td>Adhesion</td>
<td>ASTM D4541</td>
<td>1.000 psi</td>
</tr>
<tr>
<td>Corrosion Resistance</td>
<td>ASTM D5964, 10 cycles, 3000 hours</td>
<td>Rating 10 at ASTM D610 for rusting, no more than 10° rust coverage at scrape</td>
</tr>
<tr>
<td>Direct Impact Resistance</td>
<td>ASTM D2794</td>
<td>&gt;150 lb</td>
</tr>
<tr>
<td>Dry Heat Resistance</td>
<td>ASTM D2415</td>
<td>200°F (93°C) constant, 250°F (121°C) intermittent</td>
</tr>
<tr>
<td>Flexibility</td>
<td>ASTM D522, 180° bend, 1/8” mandrel</td>
<td>Passes</td>
</tr>
<tr>
<td>Pencil Hardness</td>
<td>ASTM D3363</td>
<td>3H</td>
</tr>
<tr>
<td>Salt Fog Resistance (Zinc Chloride IV, 2 coats of Water-based Acryolon 100)</td>
<td>ASTM B117, 4,000 hours</td>
<td>Rating 9 at ASTM D610 for rusting</td>
</tr>
<tr>
<td>Scrub Resistance</td>
<td>ASTM D2246</td>
<td>5000+ cycles, no visible wear</td>
</tr>
<tr>
<td>Thermal Shock</td>
<td>ASTM D2246, 10 cycles</td>
<td>Passes</td>
</tr>
</tbody>
</table>

Meets the requirements of SSPC Point No. 36, Level 3 for white and light colors. Dark colors may require a clear coat.
# Protective & Marine Coatings

## WATERBASED ACROLON 100

### WATERBASED URETHANE

**PART A: B65724**
- CLEAR BASE
- BLACK

**PART A: B655720**
- EXTRA WHITE BASE
- SAFETY RED

**PART A: B659720**
- MR, EXTRA WHITE BASE
- SAFETY YELLOW

**PART B: B65720**
- HARDENER

### PRODUCT INFORMATION

#### RECOMMENDED SYSTEMS

<table>
<thead>
<tr>
<th>Steel</th>
<th>Dry Film Thickness / ct. Milis (Microns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ct. Procry Universal Primer</td>
<td>2.0-4.0 (50-100)</td>
</tr>
<tr>
<td>1-2 cts. Waterbased Acrolon100</td>
<td>2.0-4.0 (50-100)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Steel</th>
<th>Dry Film Thickness / ct. Milis (Microns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ct. Zinc Clad III HS-100</td>
<td>3.0-5.0 (75-125)</td>
</tr>
<tr>
<td>1 ct. Macropoxy Q40-100</td>
<td>4.0-6.0 (100-150)</td>
</tr>
<tr>
<td>1-2 cts. Waterbased Acrolon100</td>
<td>2.0-4.0 (50-100)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Steel</th>
<th>Dry Film Thickness / ct. Milis (Microns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ct. Zinc-Clad IV Primer</td>
<td>3.0-4.0 (75-100)</td>
</tr>
<tr>
<td>1-2 cts. Waterbased Acrolon100</td>
<td>2.0-4.0 (50-100)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Steel</th>
<th>Dry Film Thickness / ct. Milis (Microns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ct. Eoelon II Rust-Inhibiting Primer</td>
<td>2.0-4.0 (50-100)</td>
</tr>
<tr>
<td>1-2 cts. Waterbased Acrolon100</td>
<td>2.0-4.0 (50-100)</td>
</tr>
</tbody>
</table>

### SURFACE PREPARATION

Surface must be clean, dry, and in sound condition. Remove all oil, dust, grease, dirt, loose rust, and other foreign material to ensure adequate adhesion.

Refer to product Application Bulletin for detailed surface preparation information.

#### Minimum recommended surface preparation:

- **Iron & Steel:** SSPC-SP6/NACE 3
- **Aluminum:** SSPC-SP1
- **Galvanizing:** SSPC-SP1
- **Concrete & Masonry:** SSPC-SP13/NACE 8, or ICRI No. 310.22, CSR-03
- **Requires primer:**

### Do not used hydrocarbon solvents for cleaning

#### Surface Preparation Standards

<table>
<thead>
<tr>
<th>ISO 8501-1</th>
<th>Swedish Std.</th>
<th>NACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>A1</td>
<td>A1</td>
</tr>
<tr>
<td>B1</td>
<td>B1</td>
<td>B1</td>
</tr>
<tr>
<td>C1</td>
<td>C1</td>
<td>C1</td>
</tr>
<tr>
<td>D2</td>
<td>D2</td>
<td>D2</td>
</tr>
<tr>
<td>E3</td>
<td>E3</td>
<td>E3</td>
</tr>
<tr>
<td>F3</td>
<td>F3</td>
<td>F3</td>
</tr>
<tr>
<td>G3</td>
<td>G3</td>
<td>G3</td>
</tr>
</tbody>
</table>

### TINTING

Tint Part A with CCE or Envirotone Colorants. Use the 100% tint strength formula pages. Five minutes minimum mixing on a mechanical shaker is required for complete mixing of color.

### APPLICATION CONDITIONS

- **Temperature:** 55°F (13°C) minimum, 120°F (49°C) maximum
- **Relative humidity:** At least 5°F (2.8°C) above dew point, 85% maximum

Refer to product Application Bulletin for detailed application information.

### ORDERING INFORMATION

<table>
<thead>
<tr>
<th>Packaging</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part A:</td>
<td>1 gallon (3.78L)</td>
</tr>
<tr>
<td>Part B:</td>
<td>5 gallon (18.9L)</td>
</tr>
</tbody>
</table>

**Weight:** 10.3 ± 0.2 lb/gal ; 1.24 Kgl, catalyzed

### SAFETY PRECAUTIONS

Refer to the MSDS sheet before use.

Published technical data and instructions are subject to change without notice. Contact your Sherwin-Williams representative for additional technical data and instructions.

### DISCLAIMER

The information and recommendations set forth in this Product Data Sheet are based upon tests conducted by or on behalf of The Sherwin-Williams Company. Such information and recommendations set forth herein are subject to change and pertain to the product offered at the time of publication. Consult your Sherwin-Williams representative to obtain the most recent Product Data Information and Application Bulletin.

### WARRANTY

The Sherwin-Williams Company warrants its products to be free of manufacturing defects in accord with applicable Sherwin-Williams quality control procedures. Liability for products proven defective, if any, is limited to replacement of the defective product or, at the option of the purchaser, refund of the purchase price paid for the defective product as determined by Sherwin-Williams. NO OTHER WARRANTY OR GUARANTEE OF ANY KIND IS MADE BY SHERWIN-WILLIAMS, EXPRESSED OR IMPLIED, STATUTORY, OR OTHER, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

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www.sherwin-williams.com/protective
WATERBASED ACROTON 100
WATERBASED URETHANE

APPLICATION BULLETIN

SURFACE PREPARATIONS

Surface must be clean, dry, and in sound condition. Remove all oil, dust, grease, dirt, loose rust, and other foreign material to ensure adequate adhesion.

Do not use hydrocarbon solvents for cleaning.

Iron & Steel

Remove all oil and grease from surface by Solvent Cleaning per SSPC-SP1. Minimum surface preparation is Commercial Blast Cleaning per SSPC-SP1/NACE 2. For better performance, use Near White Blast Cleaning per SSPC-SP1/NACE 2. Blast clean all surfaces using a sharp, angular abrasive for optimum surface profile (2 mils / 50 microns). Prime any bare steel the same day as it is cleaned or before flash rusting occurs.

Aluminum

Remove all oil, grease, dirt, oxide and other foreign material by Solvent Cleaning per SSPC-SP1. Primer required.

Galvanized Steel

Allow to weather a minimum of six months prior to coating. Solvent Clean per SSPC-SP1. When weathering is not possible, or the surface has been treated with chromates or silicates, first Solvent Clean per SSPC-SP1 and apply a test patch. Allow paint to dry at least one week before testing adhesion. If adhesion is poor, brush blasting per SSPC-SP7 is necessary to remove these treatments. Rusty galvanizing requires a minimum of Hand Tool Cleaning per SSPC-SP2, prime the area the same day as cleaned. Primer required.

Concrete and Masonry

For surface preparation, refer to SSPC-SP13/NACE 6, or ICRI No. 310.2R, CSP 1-3. Surfaces should be thoroughly clean and dry. Concrete and mortar must be cured at least 28 days @ 75°F (24°C). Remove all loose mortar and foreign material. Surface must be free of laitance, concrete dust, dirt, form release agents, moisture curing membranes, loose cement and hardeners. Fill bug holes, air pockets and other voids with Steel-Seam FT910. Primer required.

Pre-Finished Siding:
(Non-carbon, Silicone Polyester, and Polyester Polymers)

Remove oil, grease, dirt, oxides, and other contaminants from the surface by cleaning per SSPC-SP1 or water blasting per NACE Standard RP-01-72 (caution: excessive blasting pressure may cause warping, use caution). Always check for compatibility of the previously painted surface with the new coating by applying a test patch of 2 - 3 square feet. Allow to dry thoroughly for 1 week before checking adhesion.

SURFACE PREPARATION STANDARDS

<table>
<thead>
<tr>
<th>Surface Preparation Standards</th>
<th>SSPC-SP1</th>
<th>SSPC-SP2</th>
<th>NACE</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Primer</td>
<td>A - 4.0</td>
<td>A - 6.5</td>
<td>SPC 1</td>
<td></td>
</tr>
<tr>
<td>Near White Primer</td>
<td>S - 6.1</td>
<td>D - 8.3</td>
<td>SPC 2</td>
<td></td>
</tr>
<tr>
<td>Industrial Black</td>
<td>S - 6.1</td>
<td>S - 6.1</td>
<td>SPC 3</td>
<td></td>
</tr>
<tr>
<td>Brush-Off Blast</td>
<td>S - 6.1</td>
<td>S - 6.1</td>
<td>SPC 4</td>
<td></td>
</tr>
<tr>
<td>Hand Tool Cleaning</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Power Tool Cleaning</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

APPLICATION CONDITIONS

Temperature: 55°F (13°C) minimum, 120°F (49°C) maximum.
Relative humidity: 55% maximum

APPLICATION EQUIPMENT

The following is a guide. Changes in pressures and tip sizes may be necessary for proper spray characteristics. Always purge spray equipment before use with listed reducer. Any reduction must be compliant with existing VOC regulations and compatible with the existing environmental and application conditions.

Reducer: Water, 5-15% minimum reduction required for brush and roll
Clean Up: Water
Airless Spray: Unit: 30:1 Pump Pressure: 2700-3000 psi Hose: 1/4" ID Tip: .013" - .015" Filter: 60 mesh Reduction: As needed, up to 15% by volume
Conventional Spray: Gun: DeVille's JGA Fluid Tip: E Air Nozzle: 765 Atomization Pressure: 45-55 psi Fluid Pressure: 10-20 psi Reduction: As needed, up to 15% by volume
Brush: Brush: Nylon/ Polyester Reduction: As needed, up to 15% by volume
Roller: Cover: 3/8" woven with solvent resistant core Reduction: As needed, up to 15% by volume

If specific application equipment is not listed above, equivalent equipment may be substituted.
WATERBASED ACROLON 100
WATERBASED URETHANE

APPLICATION PROCEDURES

Surface preparation must be completed as indicated.
Mix Components thoroughly with low speed agitation before use. Make certain no pigment remains on the bottom of the can. Then combine 4 parts by volume of Part A with 1 part by volume of Part B. Mix thoroughly with low speed agitation. Reduce 5% - 15% by volume with water for brush and roll application.
Apply paint at the recommended film thickness and spreading rate as indicated below:

**Recommended Spreading Rate per coat:**

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet mils (microns)</td>
<td>4.0 (100)</td>
<td>5.0 (200)</td>
</tr>
<tr>
<td>Dry mils (microns)</td>
<td>2.0 (50)</td>
<td>4.0 (100)</td>
</tr>
<tr>
<td>Coverage sq ft/gal (m²/L)</td>
<td>196 (4.8)</td>
<td>390 (9.5)</td>
</tr>
<tr>
<td>Theoretical coverage sq ft/gal (m²/L)</td>
<td>776 (19.0)</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: Brush or roll application may require multiple coats to achieve maximum film thickness and uniformity of appearance.

**Drying Schedule @ 5.0 mils wet (126 microns):**

<table>
<thead>
<tr>
<th>Condition</th>
<th>55°F/13°C</th>
<th>77°F/25°C</th>
<th>90°F/32°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>RH</td>
<td>50%</td>
<td>50%</td>
<td>70%</td>
</tr>
<tr>
<td>To touch</td>
<td>3 hours</td>
<td>1.5 hours</td>
<td>45 minutes</td>
</tr>
<tr>
<td>To handle</td>
<td>12 hours</td>
<td>6 hours</td>
<td>2 hours</td>
</tr>
<tr>
<td>To recoat:</td>
<td>16 hours</td>
<td>8 hours</td>
<td>2-4 hours</td>
</tr>
<tr>
<td>maximum:</td>
<td>3 months</td>
<td>3 months</td>
<td>3 months</td>
</tr>
<tr>
<td>To cure:</td>
<td>14 days</td>
<td>10 days</td>
<td>2 days</td>
</tr>
<tr>
<td>Pot Life:</td>
<td>2.5 hours</td>
<td>2 hours</td>
<td>45 minutes</td>
</tr>
<tr>
<td>Sweep-in-Time:</td>
<td>None</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Application of coating above maximum or below minimum recommended spreading rate may adversely affect coating performance.

**CLEAN UP INSTRUCTIONS:**

Clean spills and spatters immediately with water. Clean tools immediately after use with water. Follow manufacturer’s safety recommendations when using any solvent.

**DISCLAIMER:**

The information and recommendations set forth in this Product Data Sheet are based upon tests conducted by or on behalf of the Sherwin-Williams Company. Such information and recommendations set forth herein are subject to change and pertain to the product offered at the time of publication. Consult your Sherwin-Williams representative to obtain the most recent Product Data Information and Application Bulletin.

**SAFETY PRECAUTIONS:**

Refer to the MSDS sheet before use.
Published technical data and instructions are subject to change without notice. Contact your Sherwin-Williams representative for additional technical data and instructions.

**WARRANTY:**

The Sherwin-Williams Company warrants our products to be free of manufacturing defects in accord with applicable Sherwin-Williams quality control procedures. Liability for products proven defective, if any, is limited to replacement of the defective product or the refund of the purchase price paid for the defective product as determined by Sherwin-Williams. NO OTHER WARRANTY OR GUARANTEE OF ANY KIND IS MADE BY SHERWIN WILLIAMS, EXPRESSED OR IMPLIED, STATUTORY, BY OPERATION OF LAW OR OTHERWISE, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

www.sherwin-williams.com/protective
Dopamine hydrochloride

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product identifiers
   Product name : Dopamine hydrochloride
   Product Number : H8502
   Brand : Sigma
   CAS-No. : 62-31-7

1.2 Relevant identified uses of the substance or mixture and uses advised against
   Identified uses : Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet
   Company : Sigma-Aldrich
   3050 Spruce Street
   SAINT LOUIS MO 63103
   USA
   Telephone : +1 800-325-5832
   Fax : +1 800-325-5052

1.4 Emergency telephone number
   Emergency Phone # : (314) 776-6555

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture
   GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)
   Acute toxicity, Oral (Category 4), H302
   Acute aquatic toxicity (Category 1), H400
   Chronic aquatic toxicity (Category 1), H410

   For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 GHS Label elements, including precautionary statements
   Pictogram
   Signal word : Warning
   Hazard statement(s)
   H302 : Harmful if swallowed.
   H410 : Very toxic to aquatic life with long lasting effects.
   Precautionary statement(s)
   P264 : Wash skin thoroughly after handling.
   P270 : Do not eat, drink or smoke when using this product.
   P273 : Avoid release to the environment.
   P301 + P312 + P330 : IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell. Rinse mouth.
   P391 : Collect spillage.
   P501 : Dispose of contents/container to an approved waste disposal plant.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none
3. COMPOSITION/INFORMATION ON INGREDIENTS

3.1 Substances

<table>
<thead>
<tr>
<th>Synonyms</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,4-Dihydroxyphenethylaminehydrochloride</td>
</tr>
<tr>
<td>4-([2-Aminoethyl]-1,2-benzenedial)hydrochloride</td>
</tr>
<tr>
<td>2-([3,4-Dihydroxyphenyl]ethyl)aminehydrochloride</td>
</tr>
<tr>
<td>3-Hydroxytyramine hydrochloride</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Formula</th>
<th>C₈H₁₁NO₂ · HCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>189.94 g/mol</td>
</tr>
<tr>
<td>CAS-No.</td>
<td>62-31-7</td>
</tr>
<tr>
<td>EC-No.</td>
<td>200-527-8</td>
</tr>
</tbody>
</table>

Hazardous components

<table>
<thead>
<tr>
<th>Component</th>
<th>Classification</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dopamine hydrochloride</td>
<td>Acute Tox. 4; Aquatic Acute 1; Aquatic Chronic 1; H302, H410</td>
<td>&lt;= 100 %</td>
</tr>
</tbody>
</table>

For the full text of the H-Statements mentioned in this Section, see Section 16.

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Wash off with soap and plenty of water. Consult a physician.

In case of eye contact
Flush eyes with water as a precaution.

If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11.

4.3 Indication of any immediate medical attention and special treatment needed
No data available

5. FIREFIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture
Carbon oxides, Nitrogen oxides (NOx), Hydrogen chloride gas

5.3 Advice for firefighters
Wear self-contained breathing apparatus for firefighting if necessary.

5.4 Further information
No data available
6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures
Use personal protective equipment. Avoid dust formation. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Avoid breathing dust.
For personal protection see section 8.

6.2 Environmental precautions
Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

6.3 Methods and materials for containment and cleaning up
Pick up and arrange disposal without creating dust. Sweep up and shovel. Keep in suitable, closed containers for disposal.

6.4 Reference to other sections
For disposal see section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling
Avoid contact with skin and eyes. Avoid formation of dust and aerosols. Further processing of solid materials may result in the formation of combustible dusts. The potential for combustible dust formation should be taken into consideration before additional processing occurs. Provide appropriate exhaust ventilation at places where dust is formed.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities
Protect against light. Keep container tightly closed in a dry and well-ventilated place.
Recommended storage temperature 2 - 8 °C
Keep in a dry place. Keep in a dry place.
Storage class (TRGS 510): Non Combustible Solids

7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

8.1 Control parameters
Components with workplace control parameters
Contains no substances with occupational exposure limit values.

8.2 Exposure controls
Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166 Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove’s outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested: DermaTest® (KCL 740 / Aldrich Z077272, Size M)
Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Breakthrough time: 480 min
Material tested: Dermatrix® (KCL 740 / Aldrich 2877272, Size M)
data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Body Protection
Complete suit protecting against chemicals. The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
For nuisance exposures use type P95 (US) or type P1 (EU EN 143) particulate respirator. For higher level protection use type OV/AG/P99 (US) or type ABEK-P2 (EU EN 143) respirator cartridges. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties
a) Appearance
   Form: powder
   Colour: white
b) Odour
   No data available
c) Odour Threshold
   No data available
d) pH
   3.0 - 5.5 at 40.0 g/l at 20 °C (68 °F)
e) Melting point/freezing point
   Melting point/range: 248 - 250 °C (478 - 482 °F)
f) Initial boiling point and boiling range
   No data available
g) Flash point
   No data available
h) Evaporation rate
   No data available
i) Flammability (solid, gas)
   No data available
j) Upper/lower flammability or explosive limits
   No data available
k) Vapour pressure
   No data available
l) Vapour density
   No data available
m) Relative density
   No data available
n) Water solubility
   No data available
.o) Partition coefficient: n-octanol/water
   log Pow: -2.58 at 25 °C (77 °F)
p) Auto-ignition temperature
   No data available
q) Decomposition temperature
   No data available
r) Viscosity
   No data available
9.2 Other safety information
No data available

10. STABILITY AND REACTIVITY

10.1 Reactivity
No data available

10.2 Chemical stability
Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions
No data available

10.4 Conditions to avoid
Light.

10.5 Incompatible materials
Strong oxidizing agents

10.6 Hazardous decomposition products
Other decomposition products - No data available
In the event of fire: see section 5

11. TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity
LD50 Oral - Rat - 1,870 mg/kg
LC50 Inhalation - Rat - 4 h - > 5.0 mg/l
(OECD Test Guideline 403)

Dermal: No data available

LD50 Intravenous - Rat - 4.8 mg/kg

Skin corrosion/irritation
Skin - Rabbit
Result: No skin irritation
(OECD Test Guideline 404)

Serious eye damage/eye irritation
Eyes - Rabbit
Result: No eye irritation
(OECD Test Guideline 405)

Respiratory or skin sensitisation
No data available

Germ cell mutagenicity
No data available

Carcinogenicity
IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity
No data available

Specific target organ toxicity - single exposure
No data available

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

Additional information
RTECS: UX1092000

Nausea, Headache, Vomiting. To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

Liver - Irregularities - Based on Human Evidence
Liver - Irregularities - Based on Human Evidence

12. ECOLOGICAL INFORMATION

12.1 Toxicity
Toxicity to fish static test LC50 - Leuciscus idus (Golden orfe) - 2.200.0 - 4.800.0 mg/l - 96 h (DIN 38412)
Toxicity to daphnia and other aquatic invertebrates static test EC50 - Daphnia magna (Water flea) - 24.5 mg/l - 48 h (OECD Test Guideline 202)
Toxicity to algae static test EC50 - Algae - < 1 mg/l - 72 h (OECD Test Guideline 201)

12.2 Persistence and degradability
Biodegrability Biode/Aerobic Result: 60 - 70 % - According to the results of tests of biodegradability this product is not readily biodegradable. (Directive 67/548/EEC Annex V, C.4.C.)

12.3 Bioaccumulative potential
Bioaccumulation is unlikely.

12.4 Mobility in soil
No data available

12.5 Results of PBT and vPvB assessment
PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

12.6 Other adverse effects
An environmental hazard cannot be excluded in the event of unprofessional handling or disposal. Very toxic to aquatic life with long lasting effects.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods
Product
Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material.

Contaminated packaging
Dispose of as unused product.
14. TRANSPORT INFORMATION

DOT (US)
UN number: 3077 Class: 9 Packing group: III
Proper shipping name: Environmentally hazardous substances, solid, n.o.s. (Dopamine hydrochloride)
Reportable Quantity (RQ):
Marine pollutant: yes
Poison Inhalation Hazard: No

IMDG
UN number: 3077 Class: 9 Packing group: III
Proper shipping name: ENVIRONMENTALLY HAZARDOUS SUBSTANCE, SOLID, N.O.S. (Dopamine hydrochloride)
Marine pollutant: yes

IATA
UN number: 3077 Class: 9 Packing group: III
Proper shipping name: Environmentally hazardous substance, solid, n.o.s. (Dopamine hydrochloride)

15. REGULATORY INFORMATION

SARA 302 Components
No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
Acute Health Hazard, Chronic Health Hazard

Massachusetts Right To Know Components
No components are subject to the Massachusetts Right to Know Act.

Pennsylvania Right To Know Components
<table>
<thead>
<tr>
<th>Component</th>
<th>CAS-No.</th>
<th>Revision Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dopamine hydrochloride</td>
<td>62-31-7</td>
<td></td>
</tr>
</tbody>
</table>

New Jersey Right To Know Components
<table>
<thead>
<tr>
<th>Component</th>
<th>CAS-No.</th>
<th>Revision Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dopamine hydrochloride</td>
<td>62-31-7</td>
<td></td>
</tr>
</tbody>
</table>

California Prop. 65 Components
This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

16. OTHER INFORMATION

Full text of H-Statements referred to under sections 2 and 3.
Acute Tox: Acute toxicity
Aquatic Acute: Acute aquatic toxicity
Aquatic Chronic: Chronic aquatic toxicity
H202: Harmful if swallowed.
H400: Very toxic to aquatic life.
H410: Very toxic to aquatic life with long lasting effects.

HMIS Rating
Health hazard: 2
Chronic Health Hazard: *
Flammability: 0
Physical Hazard: 0

NFPA Rating
Health hazard: 2
Fire Hazard: 0
Reactivity Hazard: 0

Further information
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Preparation Information
Sigma-Aldrich Corporation
Product Safety – Americas Region
1-800-521-8956

Version: 3.11 Revision Date: 01/14/2015 Print Date: 03/22/2015
ResoCoat 301 Concrete and Fiberglass Pool and Spa Surface Coating

PHYSICAL PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond strength of ResoCoat 301 coating over ResoSeal 800 and ResoBond 805 on concrete (ASTM D-4541) Concrete failure Bond strength of ResoCoat 301 coating over ResoBond 805 on fiberglass (ASTM D-4541)</td>
<td>&gt;500 psi</td>
</tr>
<tr>
<td>Finish appearance</td>
<td>Smooth surface with semi-gloss finish</td>
</tr>
<tr>
<td>Type</td>
<td>Ready to use Polymer Thermal Spray dry powder 490 micron (40 mesh) None</td>
</tr>
<tr>
<td>Coatings VOC (g/L)</td>
<td>Minimum of one year when stored at 70° F in unopened original sealed container</td>
</tr>
<tr>
<td>Shelf life</td>
<td>70 to 100 square feet per hour</td>
</tr>
<tr>
<td>Thickness (1 coat)</td>
<td>10-15 mils</td>
</tr>
<tr>
<td>Coverage</td>
<td>20 ft² at 10 mils thickness (See Coverage section below)</td>
</tr>
</tbody>
</table>

Physical properties were determined on specimens prepared under laboratory conditions using applicable ASTM procedures. Actual field conditions may vary and yield different results; therefore, data are subject to reasonable deviation.

ResoCoat 301 Concrete and Fiberglass Pool and Spa Surface Coating is a zero VOC, Thermal Spray applied polymeric pool coating finish that is engineered to flow out quickly into a complete, pinhole free polymer surface. The coating is formulated for superior adhesion to the substrate, and provides outstanding resistance to ultra-violet light, color fade, water treatment chemicals, extreme temperatures, and physical damage. The coating is ready for immediate use following application.

ResoCoat 301 Pool and Spa finish materials may be applied directly to properly prepared fiberglass surfaces. Concrete and other cementitious surfaces must be prepared for PTS coating with the application of ResoSeal 800 Concrete Sealer and ResoBond 805 Tel-Coat to prevent the formation of pinholes and other defects due to outgassing of air and moisture from the concrete. ResoSeal 800 is specifically formulated to provide a non-permeable barrier, even at the elevated temperatures of the thermal spray process, and yield a pinhole free topcoat surface.

ResoCoat 301 is applied with the Resodyn PTS-30 Polymer Thermal Spray (PTS) system to thickness of 10-15 mils. A single layer provides a complete, non-porous, continuous surface with all the desired properties for a beautiful long-lasting pool and spa finish. ResoCoat 301 Pool and Spa Surface coating finish is available in a variety of solid and blended colors. Resodyn also offers custom color matching services for special projects.

CHARACTERISTICS

- Creates a complete flowed-out, pinhole free surface
- Variety of color options
- Zero VOCs
- Excellent adhesion
- Easy repair and touch-up

APPLICATION WORKING ENVIRONMENT

ResoCoat 301 may be applied to dry substrates at temperatures above 40° F. Polymer Thermal Spray application rates will decrease at lower ambient temperatures due to the time and thermal energy required to preheat and maintain the substrate surface at the proper temperature for good adhesion and material flow-out.

Substrates that readily absorb heat at a fast rate such as concrete require more preheating before beginning the coating material application than a composite surface such as fiberglass. Concrete coated with ResoSeal 800 and ResoBond 805 sealers will provide noticeably reduced time to preheat and much improved flow characteristics over unsealed concrete, with application rates approaching that of fiberglass or other composite substrates.

Surface Preparation and Cleaning

All substrate structures must have the necessary strength to withstand imposed loads during normal use and operation. If a smooth finish is desired, the surface should be floored free of ridges or depressions and all voids and surface imperfections should be filled. Cure new concrete for 28 days prior to application.

Prior to the application of any coating or over-coating, surfaces must be free of dirt, dust, oil, grease, water, and other contaminants that may inhibit bonding. New concrete must be dry, firm and have achieved full 28 day cure prior to coating. When preparing old concrete, mechanical methods should be utilized to remove laitance, old paints, protective coatings, and attacked or deteriorated concrete. All structural cracks, bug holes, and major imperfections should be repaired prior
to application of pool and spa coating products.

Concrete surfaces must be sealed with ResoSeal 500 Concrete Sealer and coated with ResoBond 808 Tie-Coat to prevent outgassing from the concrete during Thermal Spray application and provide good adhesion of the ResoCoat 301 finish. Read and follow all instructions for these sealer materials to ensure a pinhole free, well-adhered surface for top coating.

Fiberglass and other resin composite surfaces must be prepared by lightly sanding the surface with 100 grit sandpaper to remove any contaminates, wax, or oxidation. Clean the surface with compressed air or vacuum after sanding, and then wipe the surface with a residue free solvent such as acetone, alcohol, or MEK.

APPLICATION

Installation
ResoCoat 301 Concrete and Fiberglass Pool and Spa Surface Coating is ready to use as supplied, and requires no mixing. Pour material directly from the container into the fluidized bed powder feed hopper to approximately one-half full.

Apply using the Resodyn PTS-30 Polymer Thermal Spray system. System operational parameters and powder feed rates will vary based on substrate type, ambient temperature, and other process variables. Refer to the Resodyn PTS-30 Users Guide for information regarding setting and adjusting process parameters specific to your equipment and application. The process of PTS coating application utilizes methods and skills similar to that of spray painting. Practice of the application process using the PTS-30 system on a non-vital, similar substrate may be required prior to actual job-site use of the system to achieve a satisfactory coating deposition.

Initial PTS-30 Parameter Settings

**Applicator:** Level 5 Powder Setting
**Powder Fluidizer:** 3-8 psi as required
**Powder Transport:** 3-7 psi
**Powder Feed:** 8-20 psi. Adjust as required.

**Note:** The above general system parameters are suggested beginning parameters only. Final applicator power level and material feed settings must be determined by the operator during spray application. Adjustments will be required to optimize the application rate, coating thickness, and material flow-out based on environmental and substrate variations, and other processing conditions. Refer to the PTS-30 Users Guide section ‘Applying a Coating with the PTS-30 System’ for a detailed discussion on system operation and coating application.

Process Parameters

**Pre-heat temperature:** 203-212°F (95-100° C)

**In-process target temperature range:** 385-500°F (140-150° C)

**Maximum process temperature:** 350°F (175° C) for seconds only

**Applicator stand-off distance:** 18-24" as required for temperature control and spray pattern.

**Note:** Accurate determinations of the substrate preheat temperature and in-process coating surface temperature is mandatory to ensure a well adhered coating. Use of an Infrared (IR) Thermometer is highly recommended to easily and accurately read the surface temperatures throughout the entire process. Resodyn offers an optional hands free IR thermometer accessory handle for the PTS-30 applicator. See the PTS-30 User Guide or Resodyn website for details.

The listed pre-heat temperature is specific to the coating material, and must be reached before beginning the material deposition to achieve proper wetting and adhesion. Pre-heat is also required to achieve proper flow-out of the material during continued application. Exceeding the maximum temperature during the application process may degrade the physical properties of the coating material causing discoloration and reduced performance over the life of the coating.

The applicator gun to substrate stand-off distance must be varied by the operator to control the amount of heat input into the substrate and coating. Holding the applicator at a distance closer to the substrate increases the amount of heat available for the coating process. Moving the applicator farther away from the substrate reduces the thermal energy input to the process and should be used when required to avoid exceeding the materials maximum temperature.

Apply the material to a uniform thickness of 8-10 mils (0.008" - 0.010") over the entire surface. Ensure complete coverage and overlap of spray passes. Achieving the optimum application rate will require adjustment of the feed rate and power level settings to allow for a steady application of material in a continuous, smooth, back and forth application pattern, with previously applied material flowing out from residual substrate/coating heat combined with current processing heat as each subsequent pass is deposited. Excessive material feed rates and/or inadequate power settings will result in the need to stop material feed and return to post-heat previously deposited material to continue the melt and flow-out process to achieve a smooth continuous coating surface. Inadequate feed rate and/or excessive power level selection will result in the rapid overheating of the coating material, sealers, or substrate.

The optimized process will be a balance of the correct power level, feed rate, applicator stand-off distance, and applicator traverse speed to yield a high application rate of a fully processed coating.

www.resodync coatings.com  Resodyn Engineered Polymeric Systems  1-406-497-5268
COATING REPAIR & TOUCH-UP

Damage and physical wear to the coating surface can be easily repaired by simply reheating the surface to remelt and flow the materials at the area of damage. If required, additional matching coating material may be applied to the heated area to completely fill and cover the damage. All materials should flow together to produce a coating repair that is not readily detectable, and will continue to provide outstanding performance.

COVERAGE

1 pound = 20 ft² at 10 mils thickness

Coverage will vary depending upon surface conditions, porosity, application techniques, and project specifics.

CURING/ RETURN TO SERVICE

ResoCoat 301 Concrete and Fiberglass Pool and Spa Surface Coating is fully cured after 4 hours. Upon reaching ambient temperature, the coating is ready for immediate service, and the pool/spa may be filled with water. Allow the coating to cool undisturbed by fans, water spray, water fill, or any other means of accelerated rate cooling.

ResoCoat 301 Concrete and Fiberglass Pool and Spa Surface Coating applied over fully cured ResoSeal concrete sealer is pictured below. The coating is pinhole free, well adhered, and has a flowed-out smooth finish.

PACKAGING

25 and 50 pound bag lined cartons with desiccant packet.

CLEAN-UP

Follow the User Guide instructions for powder hopper removal from the PTS-30 control cart. Pour the remaining unused powder back into its original bag lined container. Ensure the desiccant packet remains with the powder inside the bag liner and reseal the bag. Vacuum the remaining powder residue from the hopper canister and from inside and around the powder feed pump. Engage the “purge” button on the control panel for 10 seconds to blow any remaining powder through the umbilical feed hose and from the applicator feed tube. The system is now ready for the next use.

SHELF LIFE

ResoCoat 301 Concrete and Fiberglass Pool and Spa Surface Coating has a shelf life of at least one (1) year when stored in the original, unopened, tightly sealed containers in a dry location at 70°F.

Return all unused material to the original container immediately after use. Remove as much air from the bag liner as possible and reseal tightly ensuring the desiccant packet remains inside the sealed bag. Agglomeration of the powder particles may occur when exposed to humidity and moisture for extended periods, causing poor fluidization and powder flow.

CAUTION and SAFETY

Consult Material Safety Data Sheets and container label. Caution Statements for detailed explanations of the hazards and personal protection required in handling these materials.

WARNING! May cause eye, skin and respiratory tract irritation.

INHALATION: Inhalation of dusts may cause respiratory irritation.

INGESTION: May cause irritation to the mouth, throat, and abdomen. May also cause nausea or vomiting.

SKIN CONTACT: Prolonged contact may cause irritation.

EYE CONTACT: Contact with eyes may cause irritation.

CHRONIC EXPOSURE: No known chronic health effects.

AGGRAVATION OF PRE-EXISTING CONDITIONS: None known.

PERSONAL PROTECTION

VENTILATION SYSTEM: A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits. Please refer to the ACGIH document, Industrial Ventilation, A Manual of Recommended Practices, most recent edition, for details.

PERSONAL RESPIRATORS (NIOSH APPROVED): Not expected to require personal respirator. If the exposure limit is exceeded a respirator may be required. Where respirators are required, you must have a written program covering the basic requirements in the OSHA respirator standard. These include training, fit testing, medical approval, cleaning, maintenance, cartridge change schedules, etc. See 29CFR1910.134 for details.

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An example of an OSHA approved air purifying cartridge respirator is pictured for reference below.

**SKIN PROTECTION:** Wear protective clothing as appropriate.

**EYE PROTECTION:** Use safety glasses and/or goggles, as appropriate where dusting or contact is possible.

**GOOD HYGIENE CONDITIONS:** Wash with soap and water before eating any food.

**FIRST AID MEASURES**

**INHALATION FIRST AID:** If individual develops breathing difficulties, remove to fresh air and seek medical attention if breathing difficulties continue.

**SKIN CONTACT FIRST AID:** Use good hygiene practices and wash skin with soap and water after handling.

**EYE CONTACT FIRST AID:** Remove contact lens if present. Hold eyelids apart, initiate and maintain gentle and continuous irrigation for 15 minutes lifting upper and lower eyelids occasionally. Get medical attention immediately.

**INGESTION FIRST AID:** Induce vomiting ONLY as directed by medical personnel. Never give anything by mouth to an unconscious person. Get medical advice immediately.

---

**NOTE TO PHYSICIANS:** Treat symptoms.

**WARRANTY**

We warrant that our goods will conform to the description contained in the order, and that we have good title to all goods sold. **WE GIVE NO WARRANTY, WHETHER OF MERCHANTABILITY, FITNESS FOR PURPOSE OR OTHERWISE, EXPRESS OR IMPLIED, OTHER THAN AS EXPRESSLY SET FORTH HEREIN.** We are glad to offer suggestions or to refer you to customers using Resodyn materials for a similar application. Users shall determine the suitability of the product for intended application before using, and users assume all risk and liability whatsoever in connection therewith regardless of any suggestions as to application or construction. In no event shall we be liable hereunder or otherwise for incidental or consequential damages. Our liability and your exclusive remedy hereunder or otherwise, in law or in equity, shall be expressly limited to our replacement of nonconforming goods at our factory or, at our sole option, to repayment of the purchase price of nonconforming goods.

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Information concerning government safety regulations available upon request. Visit our Website at www.resodyn.com for downloadable versions of MSDS and Technical Data Sheet.

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Appendix B: Uncertainty Calculations for Absorption and SDI Results

The method used to calculate uncertainty is the Root Sum Squared (RSS) uncertainty formula. This method takes into account the uncertainty of each variable in the equation of concern. This is done by taking the partial derivative of the entire equation with respect to each variable and multiplying each by its own uncertainty. Each term is then squared and summed, before taking the square root to obtain the uncertainty for the entire equation. This process is shown below for both the absorption and SDI test results discussed in this report.

Absorption

The main equation of concern is Equation B1, calculation of absorption % by mass.

\[
\text{absorption, } \% = \left[ \frac{(B - A)}{A} \right] \times 100 \quad \text{Eq. B1}
\]

Where $A =$ mass of air-dried test specimen, g,

$B =$ mass of saturated-surface dry test specimen, g

The RSS method involves the taking the partial derivative of Equation B1 with respect to each variable. The derivatives are below, Equation B2 and B3.

\[
\frac{\delta \text{Absorption, } \%}{\delta B} = \frac{1}{A} \quad \text{Eq. B2}
\]

\[
\frac{\delta \text{Absorption, } \%}{\delta A} = -\frac{B}{A^2} \quad \text{Eq. B3}
\]
As previously discussed, the derivatives are multiplied by the individual uncertainty of each variable, squared, and summed. The square root of this value is the uncertainty for the equation of concern, Equation B1. Equation B4, below, shows this process.

\[
\omega_{\text{Absorption,\%}} = \sqrt{\left( \frac{\delta_{\text{Absorption,\%}}}{\delta B} \right)^2 + \left( \frac{\delta_{\text{Absorption,\%}}}{\delta A} \right)^2}
\]

Eq. B4

The values in Table B1 and B2 show the uncertainty for absorption testing based on the uncertainty of the scale used to mass the samples. The scale was Sartorius CPA 6202S, and from observation there was a fluctuation of about 0.1g while massing the samples. These values were used throughout the uncertainty calculations for both absorption and SDI.

**Table B1: Uncertainty calculation for absorption test of RT33-003, Uncoated**

<table>
<thead>
<tr>
<th>Trial</th>
<th>$\delta/\delta B$</th>
<th>$\delta/\delta A$</th>
<th>$\omega_B$</th>
<th>$\omega_A$</th>
<th>$\omega_{\text{Absorp.}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00072</td>
<td>-0.00073</td>
<td>0.1</td>
<td>0.1</td>
<td>0.010%</td>
</tr>
<tr>
<td>2</td>
<td>0.00095</td>
<td>-0.00095</td>
<td>0.1</td>
<td>0.1</td>
<td>0.013%</td>
</tr>
<tr>
<td>3</td>
<td>0.00096</td>
<td>-0.00097</td>
<td>0.1</td>
<td>0.1</td>
<td>0.014%</td>
</tr>
<tr>
<td>Average Uncertainty</td>
<td>±</td>
<td></td>
<td></td>
<td></td>
<td>0.012%</td>
</tr>
</tbody>
</table>

**Table B2: Uncertainty calculation for absorption test of RT33-003, Coated**

<table>
<thead>
<tr>
<th>Trial</th>
<th>$\delta/\delta B$</th>
<th>$\delta/\delta A$</th>
<th>$\omega_B$</th>
<th>$\omega_A$</th>
<th>$\omega_{\text{Absorp.}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00102</td>
<td>-0.00102</td>
<td>0.1</td>
<td>0.1</td>
<td>0.014%</td>
</tr>
<tr>
<td>2</td>
<td>0.00093</td>
<td>-0.00093</td>
<td>0.1</td>
<td>0.1</td>
<td>0.013%</td>
</tr>
<tr>
<td>3</td>
<td>0.00098</td>
<td>-0.00098</td>
<td>0.1</td>
<td>0.1</td>
<td>0.014%</td>
</tr>
<tr>
<td>Average Uncertainty</td>
<td>±</td>
<td></td>
<td></td>
<td></td>
<td>0.014%</td>
</tr>
</tbody>
</table>
SDI

The exact method was used to calculate the uncertainty for the SDI results. Equation B5 is now the equation of concern:

\[ I_d(2) = \left[ \frac{W_F}{B} \right] \times 100 \quad Eq. B5 \]

Where \( I_d(2) \) = slake durability index (second cycle),

\( B = \) mass of oven-dried specimen before the first cycle, g

\( W_F = \) mass of oven-dried specimen retained after the second cycle, g

The partial derivatives calculated for each variable, Equation B6 and B7:

\[ \frac{\delta I_d(2)}{\delta W_F} = \frac{1}{B} \quad Eq. B6 \]

\[ \frac{\delta I_d(2)}{\delta B} = -\frac{W_F}{B^2} \quad Eq. B7 \]

The format of the RSS formula for the SDI results, Equation B8:

\[ \omega_{I_d(2)} = \sqrt{\left( \omega_{\frac{\delta I_d(2)}{\delta W_F}} \right)^2 + \left( \omega_{\frac{\delta I_d(2)}{\delta B}} \right)^2} \quad Eq. B8 \]

The values in Table B3, B4, and B5 show the uncertainty for SDI testing based on the uncertainty of the scale used to mass the samples.
Table B3: Uncertainty calculation for SDI test of RT33-002, Uncoated

<table>
<thead>
<tr>
<th>Trial</th>
<th>$\delta/\delta W_F$</th>
<th>$\delta/\delta B$</th>
<th>$\omega W_F$</th>
<th>$\omega B$</th>
<th>$\omega I_d(2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00230</td>
<td>-0.00228</td>
<td>0.1</td>
<td>0.1</td>
<td>0.032</td>
</tr>
<tr>
<td>2</td>
<td>0.00199</td>
<td>-0.00197</td>
<td>0.1</td>
<td>0.1</td>
<td>0.028</td>
</tr>
<tr>
<td>3</td>
<td>0.00195</td>
<td>-0.00193</td>
<td>0.1</td>
<td>0.1</td>
<td>0.027</td>
</tr>
</tbody>
</table>

Average Uncertainty $\pm$ 0.029

Table B4: Uncertainty calculation for SDI test of RT33-003, Uncoated

<table>
<thead>
<tr>
<th>Trial</th>
<th>$\delta/\delta W_F$</th>
<th>$\delta/\delta B$</th>
<th>$\omega W_F$</th>
<th>$\omega B$</th>
<th>$\omega I_d(2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00186</td>
<td>-0.00171</td>
<td>0.1</td>
<td>0.1</td>
<td>0.025</td>
</tr>
<tr>
<td>2</td>
<td>0.00218</td>
<td>-0.00208</td>
<td>0.1</td>
<td>0.1</td>
<td>0.030</td>
</tr>
<tr>
<td>3</td>
<td>0.00222</td>
<td>-0.00214</td>
<td>0.1</td>
<td>0.1</td>
<td>0.031</td>
</tr>
</tbody>
</table>

Average Uncertainty $\pm$ 0.029

Table B5: Uncertainty calculation for SDI test of RT33-003, Coated

<table>
<thead>
<tr>
<th>Trial</th>
<th>$\delta/\delta W_F$</th>
<th>$\delta/\delta B$</th>
<th>$\omega W_F$</th>
<th>$\omega B$</th>
<th>$\omega I_d(2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00211</td>
<td>-0.00211</td>
<td>0.1</td>
<td>0.1</td>
<td>0.030</td>
</tr>
<tr>
<td>2</td>
<td>0.00233</td>
<td>-0.00232</td>
<td>0.1</td>
<td>0.1</td>
<td>0.033</td>
</tr>
<tr>
<td>3</td>
<td>0.00219</td>
<td>-0.00219</td>
<td>0.1</td>
<td>0.1</td>
<td>0.031</td>
</tr>
</tbody>
</table>

Average Uncertainty $\pm$ 0.031
Appendix C: Data Sheets and SDI Photos

Standard Test Method For Specific Gravity and Absorption of Rock for Erosion Control

D6473 -10

RT33-02 (Uncoated)

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Soak Date/ Time (Start)</th>
<th>Soak Date/ Time (Finish)</th>
<th>Initial Mass-air dried (g)</th>
<th>Final Mass (g)</th>
<th>Absorption, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2/7/15, 4:30 PM</td>
<td>2/8/15, 5:30 PM</td>
<td>1226.07</td>
<td>1239.91</td>
<td>1.129%</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

RT33-03 (Uncoated)

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Soak Date/ Time (Start)</th>
<th>Soak Date/ Time (Finish)</th>
<th>Initial Mass-air dried (g)</th>
<th>Final Mass (g)</th>
<th>Absorption, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2/7/15, 4:30 PM</td>
<td>2/8/15, 5:30 PM</td>
<td>1392.24</td>
<td>1415.29</td>
<td>1.656%</td>
</tr>
<tr>
<td>2</td>
<td>3/22/15, 11:00 AM</td>
<td>3/23/15, 11:05 AM</td>
<td>1055.50</td>
<td>1061.09</td>
<td>0.530%</td>
</tr>
<tr>
<td>3</td>
<td>3/22/15, 11:00 AM</td>
<td>3/23/15, 11:05 AM</td>
<td>1037.16</td>
<td>1040.96</td>
<td>0.366%</td>
</tr>
</tbody>
</table>

RT33-03 (Coated)

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Soak Date/ Time (Start)</th>
<th>Soak Date/ Time (Finish)</th>
<th>Initial Mass-air dried (g)</th>
<th>Final Mass (g)</th>
<th>Absorption, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3/27/2015, 2:20 PM</td>
<td>3/28/2015, 2:25 PM</td>
<td>982.77</td>
<td>984.29</td>
<td>0.155%</td>
</tr>
<tr>
<td>2</td>
<td>3/27/2015, 2:20 PM</td>
<td>3/28/2015, 2:25 PM</td>
<td>1072.2</td>
<td>1073.78</td>
<td>0.147%</td>
</tr>
<tr>
<td>3</td>
<td>3/27/2015, 2:20 PM</td>
<td>3/28/2015, 2:25 PM</td>
<td>1023.45</td>
<td>1025.66</td>
<td>0.216%</td>
</tr>
</tbody>
</table>
Standard Test Method for Slake Durability of Shales and Similar Weak Rocks

D4644 - 08

Photos were taken for each trial (one after each oven dry.) The following ID system was used:
Rock Type_ Trial #_ Photo #. Labeled images have been provided in this Appendix, following the results below.

RT33-02 (Uncoated)

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Oven Dry #1 @ 75°C</th>
<th>Initial Mass After Oven Dry #1 (g)</th>
<th>Oven Dry #2 @ 75°C</th>
<th>Mass After First Cycle (g)</th>
<th>Oven Dry #3 @ 75°C</th>
<th>Mass After Second Cycle (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Start Date/Time</td>
<td>Finish Date/Time</td>
<td>Start Date/Time</td>
<td>Finish Date/Time</td>
<td>Start Date/Time</td>
<td>Finish Date/Time</td>
</tr>
<tr>
<td>1</td>
<td>2/6/15, 3:30PM</td>
<td>2/7/15, 3:30PM</td>
<td>2/7/15, 4:15PM</td>
<td>2/8/15, 4:30PM</td>
<td>2/8/15, 5:10PM</td>
<td>2/9/15, 5:10PM</td>
</tr>
<tr>
<td>2</td>
<td>2/7/15, 6:00PM</td>
<td>2/8/15, 5:00PM</td>
<td>2/8/15, 5:30PM</td>
<td>2/9/15, 5:30PM</td>
<td>2/9/15, 5:55PM</td>
<td>2/10/15, 5:55PM</td>
</tr>
<tr>
<td>3</td>
<td>2/7/15, 6:00PM</td>
<td>2/8/15, 5:00PM</td>
<td>2/8/15, 5:45PM</td>
<td>2/9/15, 5:45PM</td>
<td>2/9/15, 6:15PM</td>
<td>2/10/15, 6:15PM</td>
</tr>
</tbody>
</table>
### RT33-03 (Uncoated)

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Oven Dry #1 @75°C</th>
<th>Initial Mass After Oven Dry #1 (g)</th>
<th>Oven Dry #2 @75°C</th>
<th>Mass After First Cycle (g)</th>
<th>Oven Dry #3 @75°C</th>
<th>Mass After Second Cycle (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Start Date/Time</td>
<td>Finish Date/Time</td>
<td>Start Date/Time</td>
<td>Finish Date/Time</td>
<td>Start Date/Time</td>
<td>Finish Date/Time</td>
</tr>
<tr>
<td>1</td>
<td>2/6/15, 3:30PM</td>
<td>2/7/15, 3:30PM</td>
<td>2/7/15, 4:15PM</td>
<td>2/8/15, 4:30PM</td>
<td>2/8/15, 5:10PM</td>
<td>2/9/15, 5:10PM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2/7/15, 6:00PM</td>
<td>2/8/15, 5:00PM</td>
<td>2/8/15, 5:30PM</td>
<td>2/9/15, 5:30PM</td>
<td>2/9/15, 5:55PM</td>
<td>2/10/15, 5:55PM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2/7/15, 6:00PM</td>
<td>2/8/15, 5:00PM</td>
<td>2/8/15, 5:45PM</td>
<td>2/9/15, 5:45PM</td>
<td>2/9/15, 6:15PM</td>
<td>2/10/15, 6:15PM</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

### RT33-03 (Coated)

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Oven Dry #1 @75°C</th>
<th>Initial Mass After Oven Dry #1 (g)</th>
<th>Oven Dry #2 @75°C</th>
<th>Mass After First Cycle (g)</th>
<th>Oven Dry #3 @75°C</th>
<th>Mass After Second Cycle (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Start Date/Time</td>
<td>Finish Date/Time</td>
<td>Start Date/Time</td>
<td>Finish Date/Time</td>
<td>Start Date/Time</td>
<td>Finish Date/Time</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SDI Images

These images are included to comply with ASTM standard D4644 -08, used to test the durability of the samples.

RT33-02 (Uncoated)

RT33-02_01_01
RT33-02_01_02

![Image of a scale weighing a sample of black material. The scale reads 43.127 g.]
RT33-02_02_01

![Image of a scale with a container holding coal samples, displaying a weight of 502.67 grams.](image_url)
RT33-03 (Uncoated)

RT33-03_01_01
RT33-03_02_01

459.52 g
RT33-03 (Coated)

RT33-03DC_01_01