

Performance Enhancements of Aromatic Polyurea Spray Coatings by the Use of Conventional Primer Systems

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Polyurea spray coatings have demonstrated a unique ability to rapidly form durable, high-performance coatings in adverse environmental conditions. These conditions, such as temperatures below 0°C and humidity levels above 90 percent, can often interfere with the cure times, surface properties and performance of other coating chemistries. Experienced polyurea systems houses and applicators continue to rapidly expand their portfolios of successful case histories as more polyurea application areas are identified. However, even the most experienced applicators can encounter challenges in the field due to substrate surface anomalies. Contaminants, bug holes, undesirable surface tensions and excessive moisture can cause problems ranging from defects on the polyurea coating surface, such as blisters and pin-holes, to more severe problems such as coating de-lamination. When problems such as these are anticipated or encountered, a suitable primer coat on the substrate surface, prior to application of the polyurea spray coating, can be employed to alleviate some of them. Several primer systems have been evaluated in the laboratory for use with polyurea spray coatings. This paper will present the results of testing that incorporated primer coats under an aromatic polyurea spray system. Commercial grade high-solids epoxy coating, isocyanate reacted separately with water and castor oil, and waterborne acrylic chemistries were evaluated. In addition, various cure times of the primers were evaluated to identify the optimum cure times of each primer system. The primers were applied onto concrete, wood, blasted steel and a fiber/cement wallboard. The benefits of enhanced adhesion and the prevention of blisters and pinholes pertaining to each primer are detailed.

INTRODUCTION

The spray polyurea elastomer market continues to enjoy rapid growth and development. This novel coating technology was first introduced by Dudley Primeaux of the Texaco Chemical Company¹. Spray polyurea elastomers continue to find utility in niche areas that pose considerable challenges to more traditional coating chemistries. Recently, engineers at large construction projects around the globe have approved and specified spray polyurea elastomers in application areas that previously favored traditional coating systems. It is evident that the unique physical properties and rapid cure characteristics of polyurea systems are winning the confidence and approval of architects, engineers, blenders, applicators and facility owners.

Even with a large and growing portfolio of successful case histories, spray polyurea elastomer coatings are governed by fundamental principles, shared by traditional coating chemistries, which must be followed to ensure a successful coating. Hare describes the three fundamental requirements necessary to achieve a successful coating, namely surface preparation, wetting, and adhesion². Early pioneers of spray polyurea elastomers

vehemently professed the necessity of proper substrate preparation. Early skepticism pertaining to the wetting abilities of two-second gel-time, spray polyurea coatings has been addressed. Studies revealed the adhesion strength of polyurea to concrete or wood, when properly prepared, was greater than the cohesive strength of these two common construction materials. Thus, substrate failure typically occurs before the polyurea bond to the substrate surface fails. The porosity of concrete and wood, coupled with a relatively rough and irregular surface, allows rapid setting polyurea coatings to permeate into the substrate surface, and to mechanically interlock in the microscopic surface ridges and valleys of the materials.

Adhesion to steel required a different approach. Studies revealed that the adhesion strength of polyurea to steel was greatly improved if the steel was first blasted to a 2-mil profile. The National Association of Corrosion Engineers (NACE) and the Society for Steel Protective Coatings (SSPC) specify this profile. Blasting ensures the removal of contaminants that could interfere with adhesion, increases the surface area of the substrate, ensures a uniform surface, and provides a large number of potential

sites that can react with an applied coating by chemical or physiochemical bonding. Perez and House illustrated a four-fold increase of the adhesion strength for an aliphatic polyurea system sprayed onto blasted steel, versus smooth steel.³ In addition to blasting of a metal surface, silane adhesion promoters have been found to provide significant improvements in the adhesion characteristics of polyurea systems to inorganic substrates. Specifically, addition of epoxy functional silane into the amine resin blend of a polyurea system has afforded an optimum enhancement of adhesion properties.

Following the prescribed guidelines for surface preparation, and proper formulation of a polyurea system help to ensure a strong bond of the elastomer to a substrate surface. Unfortunately, this does not always guarantee an adequate bond or defect-free coating. The potential for an improperly prepared surface, an undesirable substrate surface tension, or a substrate that can excessively out-gas is present at many job-sites. Any of these possibilities can lead to blisters or pinholes in the applied polyurea coating, leading to catastrophic delaminations of the entire coating in worst-case scenarios.

When dealing with difficult substrates or surfaces, the polyurea spray applicator can turn to a primer system that may avert such potential problems before they are encountered. Primer systems provide the benefits of enhanced adhesion via permeation into a porous substrate, leading to a reinforced substrate surface. In addition, the primer can form strong bonds with both the substrate and the polyurea coating being applied over it. Additionally, the primer can function as a sealer, preventing out-gassing of moisture in a substrate and eliminating some of the pin-holing problems that have been encountered.

This paper serves to illustrate the enhanced adhesion potentials of spray polyurea elastomers when primers are employed. Four different primers, cured at three different time intervals, on four different construction substrates are evaluated. In addition to the improvements in the adhesion strength of polyurea to the substrate, the sealing capabilities and pinhole elimination potentials of each primer system are examined.

EXPERIMENTAL

Four primer coating chemistries were evaluated on four common construction substrates. The primers, which are commercially available and widely used in the construction industry, were a high-solids, two-component epoxy; a one-component waterborne acrylic; a two-component isocyanate/water system, and a two-component isocyanate/castor oil combination. A detailed description of the four primer systems can be found in Table 1 below. Note that both urethane systems were prepared from the same RUBINATE® 9513 isocyanate product. This product offers unique reaction capabilities with water or with a hydroxyl-containing material such as Grade AA castor oil.

TABLE 1.

<u>Epoxy System</u>	<u>Chemical Makeup</u>
Resin Component	Epoxy resin Magnesium silicate TiO ₂ High flash naphtha Hydrocarbon resin Mica n-Butyl alcohol Methyl n-amyl ketone Plasticizer Crystalline Silica
Amine Component	Amine compound High flash naphtha n-Butyl Alcohol
<u>Waterborne Acrylic</u>	Water Acrylic resin emulsion TiO ₂ Calcium Carbonate Ethylene Glycol
<u>Emulsifiable MDI system</u>	(A) RUBINATE® 9513 (B) De-ionized water
<u>MDI / Castor Oil system</u>	(A) RUBINATE® 9513 (B) AA Grade castor oil

The four primer systems described above were brush applied onto four different test substrates, namely dry concrete, wet concrete (concrete soaked in water overnight), blasted steel, plywood and a fiber-cement board. All test substrates were obtained from a home improvement hardware store and therefore may not be representative of all construction surfaces in all applications. Due to the variation in concrete mixtures, wood, steel and fiber cement board, it is recommended that investigations be performed on actual job-site substrates to determine the degree of correlation to lab test substrates.

Cure times of 15 minutes, 2 hours and 24 hours of each primer system were examined on each test substrate prior to coating with an aromatic spray polyurea. An aromatic spray polyurea system, detailed in Table 2, was used for all adhesion strength and pinhole reduction evaluations. Additional information pertaining to this spray polyurea system can be found in a study by Perez, *et. al.*⁴

Table 2.

Isocyanate Component	RUBINATE® 9480	100 pbw
Resin Component	JEFFAMINE® D-2000 JEFFAMINE® T-5000 DETDA Silane A-187	59.6 pbw 11.1 pbw 28.3 pbw 0.67 pbw
Processing	Index Iso/Resin Volume Ratio Iso/Resin Weight Ratio	1.07 1.00 1.13
Physical Properties	Tensile Strength Tear Strength Elongation Shore D Hardness Modulus, 100% Modulus, 300%	2814 psi 624 pli 528% 49/41 1216 psi 1823 psi

Two main objectives were sought through the use of a primer coating for polyurea systems. The first was to enhance the adhesion of the polyurea coating to the substrate surface. The

second was to seal porous surfaces, such as concrete, in an attempt to reduce or eliminate blistering and pin holing caused when entrapped moisture flashes off as hot-reacting polyurea is coated over the substrate. Additionally, the primer can function to modify the surface tension of the substrate, which can also lead to a reduction of pinholes. In the case of adhesion enhancement, the primer can act as a penetrating coating that permeates well into the surface of the substrate. As the primer coat cures it can function to form a polymer/substrate matrix that can substantially increase the surface strength of the substrate, leading to increased overall bond strength. Additionally, the reactants of the primer can potentially react with the reactants of the polyurea system, thus forming strong covalent bonds within the polyurea/primer/substrate interfaces.

Functioning as a sealer, a successful primer can reduce flash evaporation of moisture entrapped in a porous substrate such as concrete or wood. This can effectively reduce or eliminate pin holes and blister defects that have been encountered in the field.

RESULTS AND DISCUSSION

The physical properties and performance characteristics of each primer system were first evaluated as stand alone coatings. High solids epoxy coatings have been previously discussed for polyurea primer applications.⁵ Iurilli and Perez have highlighted the use of high performance acrylic polymers for concrete protection.⁶ Primeaux described the successful use of isocyanates as primers for polyurea applications.⁷ Table 3 presents the performance of the individual primer coatings on smooth steel test panels.

During this phase of testing it was found that the RUBINATE® 9513 / water combination flash rusted the smooth steel test panels. Re-evaluation of the RUBINATE® 9513 / water combination on a blasted test panel showed a dramatic difference. The corrosion that occurred on the smooth steel test panel was eliminated when the test panel was blasted prior to the application of the primer coat. It is believed that the blast process removes an oxide layer that could catalyze the flash rust formation. Further surface analysis could verify this hypothesis.

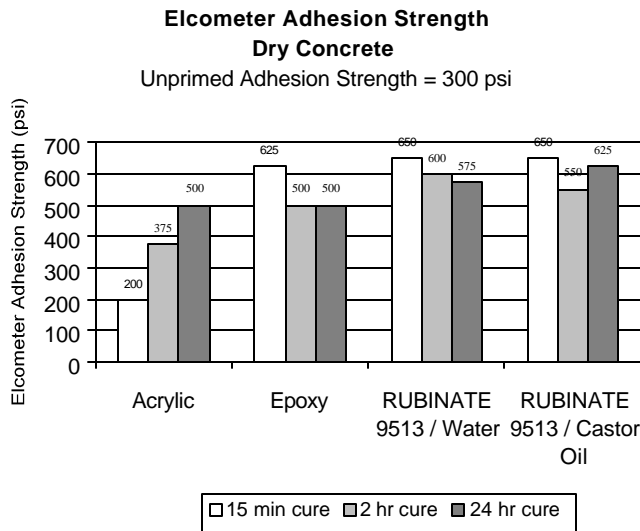
Table 3. Physical Properties and Performance Characteristics of the primer coatings.

	Waterborne Acrylic	High Solids, Two-Component Epoxy	RUBINATE® 9513 / Water (50/50 wt) *(Blasted Panel)*	RUBINATE® 9513 / Castor Oil (50/50 wt)
Appearance	White coating, low gloss, semi-smooth.	Tan color, medium gloss, semi-smooth	*** Opaque, low gloss, semi-smooth. ***	Clear amber coating, high gloss, very smooth, trace orange peel beneath coating surface
Dry Time, 6-mil draw down coat. a) Set To Touch b) Surface Dry c) Through Dry	a) 1.5 hour b) 3.0 hour c) 3.5 hour	a) 4.0 hour b) 4.25 hour c) 4.5 hour	* a) 7.0 hr b) 11.0 hr c) 14.0 hr *	a) 2.5 hour b) 3.5 hour c) 6.5 hour
Gloss (20° / 60°)	1.6 / 3.5	3.5 / 13.6	*12 / 50	136 / 141
Impact Resistance, Inch/pounds (Direct/Indirect)	80 / 60	20 / <10	>160 * >160 *	>160 >160
ASTM D-3359 Crosscut Adhesion	2 / 0	5 / 5	5 / 5 *	5 / 5
ASTM 4366-95 BYK-Gardner Pendulum Hardness (1.4 sec/oscillation)	11 12 11	44 45 42	107 * 112 * 114 *	24 25 25
Conical Mandrel Bend	Pass	Crack	Pass *	Pass
ASTM E96-80 Moisture Vapor Transmission Testing (Primer Cured Over Polyurea)	0.090 perms	0.015 perms	0.038 perms	0.032 perms

The data in Table 3 reveals distinct characteristics for each primer coating. The RUBINATE® 9513 / castor oil system produced a coating with overall high performance properties. The epoxy system was the hardest coating tested, but exhibited poor impact resistance. While the waterborne acrylic system proved to be the most rapid drying, it offered no enhancement to the moisture vapor transmission properties *versus* a non-coated polyurea standard (0.090 perm value). The acrylic was the softest coating, had the lowest gloss and exhibited the poorest adhesion to the smooth steel test panels. The one-component waterborne acrylic is believed to be the most fragile in cold climates due to its high water content. The RUBINATE® 9513 / water system is expected to be more stable because it is mixed with water just prior to coating application.

Testing also focused on the possible adhesion enhancement of each primer system. Figures 1 through 4 illustrate the Elcometer adhesion strength obtained for each system. Note that an unprimed sample of each substrate, coated only with the aromatic polyurea system, was used as a reference.

Figure 1.

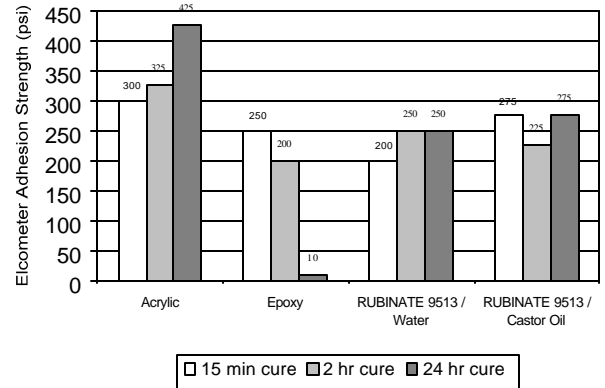


From Figure 1 it is observed that the adhesion strength of the polyurea to unprimed concrete is approximately 300 psi. Substrate failure resulted in the baseline, indicating the surface cohesive strength of the concrete to be approximately 300 psi. The waterborne acrylic primer test series

exhibited approximately 80% cohesive separation of the primer itself, with approximately 20% cohesive separation of the concrete. Immediate application of the spray polyurea over the waterborne acrylic resulted in the lowest adhesion for the series. Twenty-four-hour cure of the acrylic primer revealed an increase in the adhesive properties of the composite. Analysis of the epoxy system revealed that the best results are obtained after the polyurea coating is applied shortly after the epoxy has been applied to the substrate surface. The RUBINATE® 9513 / water system performed very well at all three primer cure times. The RUBINATE® 9513 / castor oil system also exhibited very good properties at all three cure time intervals of the primer.

Figure 2 depicts the Elcometer adhesion properties of the various polyurea/primer composite coatings on wet concrete. Note that in Figure 2 the unprimed adhesion strength is 580 psi with a 100% cohesive separation of the concrete, indicating an increase in the cohesive strength of the wet concrete *versus* dry concrete. The waterborne acrylic showed the highest adhesion strength of the

Figure 2. Elcometer Adhesion Strength Wet Concrete
Unprimed Adhesion Strength = 580 psi

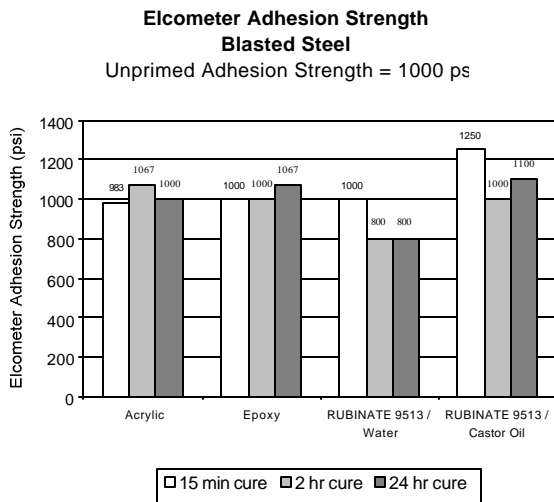


tested primers on wet concrete, but was still below the value of unprimed wet concrete. In all four cases, the primer/polyurea composite exhibited reduced adhesion properties. For this particular test, the epoxy system showed a dramatic decrease in the performance after 24

hours of primer cure time. It is suspected that after 24 hours, the epoxy was close to full cure and was no longer active on its surface.

Figure 3 examines the adhesion strength of polyurea and primer systems on blasted steel. An unprimed test sample coated only with the aromatic polyurea exhibited an Elcometer adhesion strength value of 1000 psi, with the "J.B. Weld®" epoxy adhesive, used to adhere the Elcometer test dollies to the coating surface, failing before the bond of the polyurea to the steel failed. It is therefore difficult to determine the true adhesion strength of polyurea to blasted steel. However, the bond strength for this particular polyurea coating is well in excess of 1000 psi.

Figure 3.



The acrylic primer adhesively separated from the polyurea coating in the 24-hour and 2 hour cure test periods. The 15 minute cure of the acrylic primer yielded an 80% cohesive separation of the polyurea during the testing. It is hypothesized that this decrease is a result of the moisture in the acrylic reacting with the isocyanate portion of the polyurea, causing micro foaming and, ultimately, decreasing the cohesive strength of the polyurea. Note that the same phenomenon is not observed in the case of the RUBINATE® 9513 / water combination. In a thin film, the water used in this system may be reacting at a greater rate than the water evaporating out of the waterborne acrylic. Thus, it is suspected that the water used in this system

may not be reacting with the isocyanate component of the polyurea system. The RUBINATE® 9513 / castor oil system shows best results after 2-hour and 24-hour cure schedules of the primer, prior to coating with polyurea. From this series of testing it appears that there may be no enhancement of the adhesion properties of properly formulated spray polyurea systems. Buried underground metal pipes may in fact require a suitable zinc-rich primer to provide cathodic disbondment protection that the polyurea coating alone may not offer.

Figure 4.

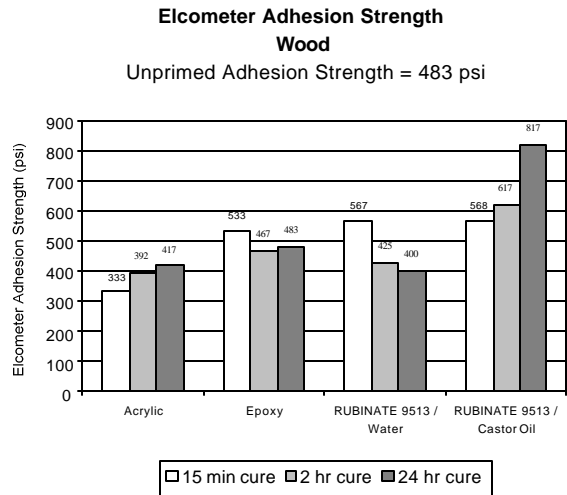
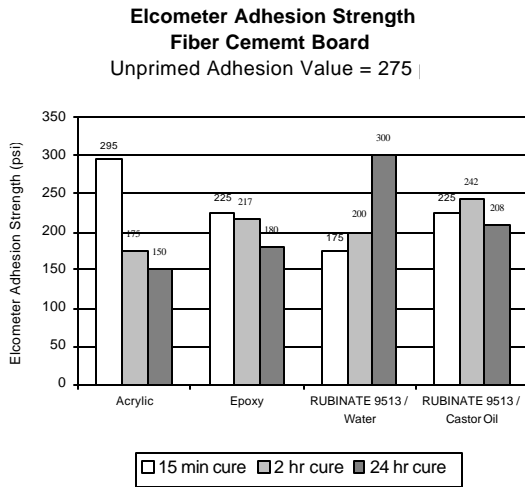


Figure 4 depicts the adhesion properties of the polyurea/primer systems on a plywood substrate. The unprimed adhesion value of the polyurea coating to wood was measured to be 483 psi, with 100% cohesive separation of the wood substrate. As shown above, a sequential increase in the adhesion strength of the waterborne acrylic system was observed, but all three were below the adhesion strength when no primer was used. The epoxy system displayed adhesion values similar to the unprimed test standard following all three epoxy primer cure times. The RUBINATE® 9513 / water combination, after a 15-minute cure, showed a substantial increase in the adhesion strength of the polyurea to the wood substrate. The RUBINATE® 9513 / castor oil combination showed substantial increases in the adhesion strength after 2-hour and 24-hour cure schedules, while the 15-minute cure of this

system did not show an increase in the adhesion strength of the polyurea coating to wood.

Figure 5 illustrates the Elcometer adhesion profiles of the polyurea/primer systems on a fiber cement board substrate. Testing of an unprimed board revealed a 300 psi adhesion value with 100% cohesive separation of the test substrate.

Figure 5.



Note that a decrease in the adhesion strength was observed with all primer systems tested, with the exception of the RUBINATE® 9513 / water combination after a 15-minute cure schedule.

The real benefit that can be realized by primer systems on this particular test substrate is the reduction or elimination of blisters and pinholes that this material has a tendency to cause in polyurea spray coatings. A section of unprimed fiber cement board was coated with the standard polyurea spray elastomer. Blisters and pinholes rapidly formed within the coating and were visible on the coating surface. A three square inch section of the highest surface defect density was isolated. A visual count of the surface defects within the area revealed 6 surface blisters and 10 pinholes. Table 4 lists the results of this defect counting for both the unprimed and primed fiber cement substrate.

Table 4. Surface defect count, 15 minute cure of primer.

System	Defect Count
Standard (No Primer)	6 blisters 10 pinholes
Waterborne Acrylic	1 blister 0 pinholes
Epoxy	4 blisters 0 pinholes
RUBINATE® 9513 / water	0 blisters 0 pinholes
RUBINATE® 9513 / AA Castor Oil	5 blisters 0 pinholes

The greatest amount of defect reduction is obtained from the RUBINATE 9513 / water system. In addition, good improvements were observed with the waterborne acrylic system.

Table 5 lists the results obtained when the primers were cured for a two hour time period prior to coating with polyurea. Notice that after this cure schedule, blisters and pinholes did not form on the polyurea coating surface.

Table 5. Surface defects count, 2-hour cure of primer coatings.

System	Defect Count
Standard (No Primer)	6 blisters 10 pinholes
Waterborne Acrylic	0 blister 0 pinholes
Epoxy	0 blisters 0 pinholes
RUBINATE® 9513 / water	0 blisters 0 pinholes
RUBINATE® 9513 / AA Castor Oil	0 blisters 0 pinholes

Table 6 lists the visible defect count on the test substrate after the primer coats were allowed to cure for 24 hours (prior to polyurea coating application). The data appears almost identical to the two hour primer cure schedule, with the exception of two blisters apparent on the RUBINATE 9513 / water combination.

Table 6. Surface defects count, 24-hour cure of primer coatings.

System	Defect Count
Standard (No Primer)	6 blisters 10 pinholes
Waterborne Acrylic	0 blister 0 pinholes
Epoxy	0 blisters 0 pinholes
RUBINATE® 9513 / water	2 blisters 0 pinholes
RUBINATE® 9513 / AA Castor Oil	0 blisters 0 pinholes

CONCLUSIONS

Primer systems used in conjunction with spray polyurea elastomer coatings have found utility in application areas where substrate preparation or conditions may not be optimal. As the polyurea industry continues to mature, new application areas, new surface substrates and new challenges will arise. The employment of primer coats may offer enhancements to the adhesion of the polyurea coating. Additionally, the primer may function as a sealer and/or modifier of the substrate surface tension, preventing undesired defects in the polyurea coating.

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