Surface preparation, choice of coating chemistry, and attention to application guidelines hold key to success of restoration projects

Maximizing roof-coating performance in the emerging era of the cool roof

All participants in a field-applied reflective roof coating project would like to make certain the project is successful. Success will usually be gauged by several measures:

- The rejuvenation, protection, and restoration of the original roof surface to extend its useful service life and reduce maintenance costs;
- The roof surface reflectivity and emissivity, which contribute to a cooler roof surface and result in lower cooling-energy costs for the building the roof protects;
- The length of time the coating continues to provide these desired benefits, and how much maintenance of the coating is required over time; and
- The level of efficiency and effectiveness of the project management and execution.

These measures of the success of a roof-coating project can lead to the following questions.

- Is there a key to maximizing roof coating performance?
- Is the "quality" of a coating the key to long-term performance, or are all coatings basically similar?
- Do application method and technique determine the performance of the installation?
- Is the selection of the product, the manufacturer, the contractor, or the specifier the key to achieving a high-quality installation?

Early field-applied roof coatings were typically composed of asphalt or coal tar, and were designed for application to BUR (built-up roof) systems of similar composition. These coatings were designed with one function in mind: to rejuvenate and protect the single surface to which the coating is applied, the BUR membrane.

Today, a wide variety of materials are used in roofing and in preparing the surface to which a coating is applied. Along with asphalt BUR and modified-bitumen surfaces, the range of materials includes EPDM and Hypalon thermoset membranes, PVC and TPO thermoplastic membranes, SPF (spray polyurethane

foam), and metal surfaces finished with a wide array of factory-applied paints or coatings.

Accordingly, the field-applied coating segment of the roofing industry has evolved in complexity to keep pace with the varied chemistries of roof substrates. If a single "key" exists to maximizing the performance of every roof coating-application, it centers on the concept of maximizing the adhesion of the coating to the roof substrate. Simply put, if the coating does not adhere to the roof substrate, it cannot meet any of the other intended performance functions.

Maximizing adhesion of a coating to the variety of roofing substrates in use today, under a wide range of climatic conditions, requires a general appreciation of the principles of adhesion and how the manufacturer, the contractor, the specifier, and the building owner all may play a role in a successful roof-coating application.

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Power washing of a PVC single-ply roof membrane prior to application of coating. All photos courtesy of ERSystems Inc.

Backgrounder: Adhesion and cohesion

Adhesion is the bonding/joining/sticking of two materials to each other. Adhesion can be described as primarily a surface phenomenon in which the coating must interact with the surface of the roof substrate (Fig. 1). The strength of the interaction is defined by the following factors.

- The area of surface contact between the coating and the roof substrate impacts the bond strength. Coating formulations are designed to "wet" and spread over the roof surface to maximize contact with the substrate and then cure at a controlled rate (Fig. 2). Surface texture, porosity, coating viscosity, and application technique may all impact surface interaction at the contact area. Some texture and porosity may be beneficial in providing additional sites for the coating to physically "grab" onto the substrate. On the other hand, air pockets can be formed between the coating and an irregular roof surface, reducing coating-to-substrate contact and potentially providing a site for a coating defect. Roll application of a coating may be a recommended application technique to eliminate air pockets (Fig. 3). Finally, surface contaminants may interfere with good contact between the coating and the roof substrate. Surface treatments to improve coating-to-substrate contact will be discussed later in this article.
- The chemistry of the coating and the chemistry of the roof substrate figure prominently in the strength of the adhesive bond formed at curing. Dissimilar materials may exhibit difficulty in forming a strong interaction with each other, and therefore produce a weak adhesive bond. Manufacturers may recommend specific coatings for particular roof substrates to match chemistries for maximum adhesion. Coatings described as "all-purpose" may, in reality, be limited in their ability to provide maximum performance over a wide variety of substrates in a wide variety of environments.

Cohesion is the inner strength or bonding force holding together the cured coating itself (Fig. 1), and it is also important in roof-coating performance. Cohesive forces in a specific

coating may be maximized by curing under optimal conditions, and by applying the coating at the proper thickness to enhance the curing process. Recommendations by manufacturers regarding thickness and conditions of application are important, and should be followed.

Techniques for improving bonding properties

Surface treatment of a substrate is carried out to improve the contact zone between the coating and the roof substrate. Washing at pressures of 2,500 to 3,000 psi is a typical method used for removing dirt, loose debris, and any material interfering with coating contact with the roof substrate. To avoid damage to the substrate, the condition of the roof must be considered when cleaning it in this way. Cleaning agents and chemicals may be used to help remove greases and oils that are difficult to remove with water; however, power washing alone is satisfactory for most roof surfaces. It is important to rinse the roof with sufficient amounts of water to remove the loose dirt and cleaners (if used) and flush the rinse water and debris to the drains. Finally, good environmental practice should be followed in collecting rinse water and disposing of it appropriately.

Other surface pretreatments such as scarifying or grinding may be required to prepare a roof substrate for coating.

Finally, primers may be used to improve the adhesion of the coating to a roof substrate. The chemistry of the primer is characterized by its ability to improve the bond to the well-prepared roof substrate and interact with the subsequent topcoating—i.e., the primer acts as a "bonding bridge" between the substrate and topcoat. Primers are quite specific for each roof substrate, and manufacturer recommendations should

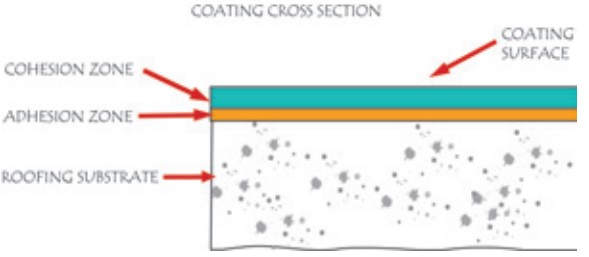


Fig. 1: Coating adhered to substrate

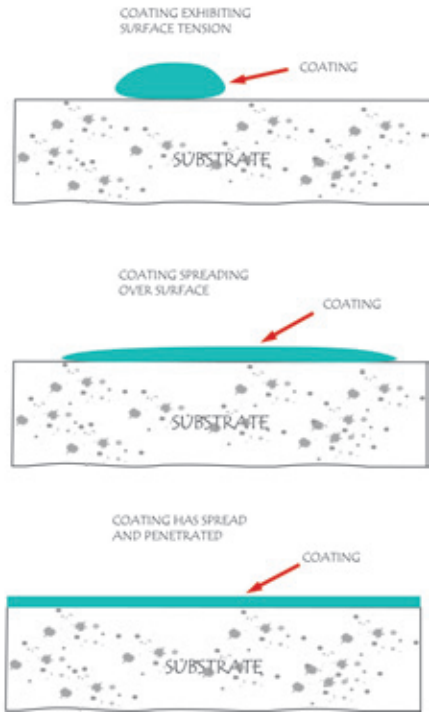


Fig. 2a, 2b, 2c: Coating spreading, sticking to substrate.

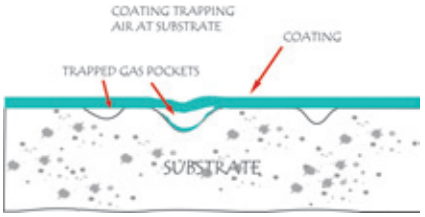


Fig.3: Air entrapped by coating at substrate surface

be followed accordingly. Primers are especially important in improving adhesive performance of all-purpose coatings to the wide variety of roof substrates to which they may be applied. A note of caution: primers are *not* a substitute for good surface preparation and conscientious application; in fact, good surface preparation is essential to the satisfactory performance of the primer.

Field-test measurement of coating adhesion

The simplest and most widely used method of measuring adhesion in the field is to peel a thin layer of the coating away from the rigid roof substrate. To prepare a field-adhesion test, the applicator or inspector should:

- select a representative area of the roof, as small as 1 sq. ft.;
- clean and prepare the area in much the same way you would clean the roof, wipe, and let the surface dry; and
- apply a thin layer of the coating to be tested with a small brush and place a strip of fabric/cloth about 1 inch wide and 6 to 8 inches long into the coated area, leaving a couple of inches

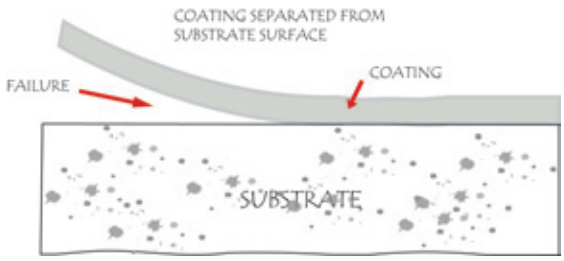


Fig. 4a: Adhesive failure

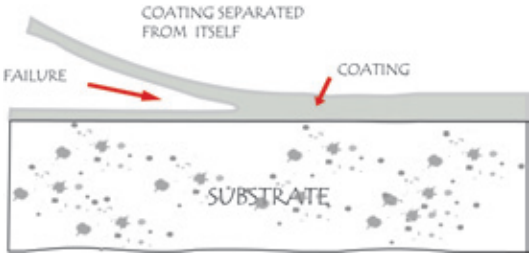


Fig. 4b: Cohesive Failure

of the fabric as a tail beyond the coated area.

Using the brush, make certain the fabric is placed smoothly into the coating so the coating can penetrate through the fabric weave. A second thin layer of thecoating can then be applied over the fabric and the original coated area.

Cleaning materials and techniques, primers, and coatings can be compared by preparing side-by-side applications on the roof being tested. For most coatings under ordinary curing conditions, a minimum of three to seven days of cure time should be allowed to make comparisons of adhesive strength.

To test adhesive strength, the fabric tail is pulled in a smooth, peeling motion at an angle of about 45 degrees with a consistent force (Fig. 4a); 2 to 5 pounds of force indicates sufficient adhesive strength to provide for excellent performance in most coating applications. Mastics and sealers used at metal-roof seams and areas of extreme roof movement will typically need to exhibit much higher forces of adhesion than a general field coating.

Modes of failure are described in Fig.

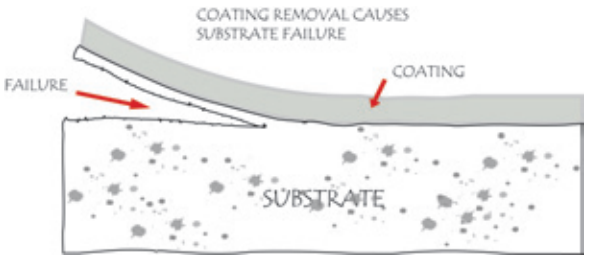


Fig. 4c: Substrate surface failure

4. Separation and failure begins at a defect, a weakness, or a region of high stress; like a chain, failure occurs at the weakest point. Failure may occur at the substrate interface with the coating (Fig. 4a, adhesive failure), within the coating (Fig. 4b, cohesive failure), or within the substrate (Fig. 4c).

These various modes of failure clearly underline the importance of selecting the coating for the specific substrate, preparing the surface, selecting a coating with sufficient cohesive strength, ensuring proper application to minimize defects and maximize surface area contact, and considering environmental conditions to effect a good cure of the coating.

Roof-substrate age and coating adhesion

Interestingly, adhesion of a coating to an existing roof substrate will improve as the roof surface ages, assuming precautions are taken to prepare the aged roof surface prior to coating, as described above. This occurs because, as roof surfaces weather, two developments may occur:

- process chemicals that are often slick and oily will weather away, leaving a surface that is more receptive to the coating, and
- the roof surface itself may weather, producing a surface that is microscopically rough and irregular, helping to facilitate physical adhesion of coating to substrate.

On the other hand, if highly reflective "cool-roof" coatings are specified as part of the original roof installation, special cleaning measures to remove process chemicals and oily or loose materials may be required to make certain that sufficient adhesion to recently installed roof membranes is achieved.

Field-applied coatings and roof restoration

A number of factors should be considered in applying highly reflective roof coatings to an existing roof to maximize coating performance and restoration-project satisfaction.

First, good roofing practice must be followed.

- The roof should drain properly. Most roofing materials, and especially coatings, are *not* designed to hold water for extended periods of time. Accordingly, most manufacturers' warranties require that water is able to drain from the roof surface. It is difficult to ensure dry conditions for proper curing of the coating on a roof that holds water. Showers and even heavy dew that may accumulate in low areas of the roof can interfere with the cure cycle and result in lower cohesive and adhesive strengths of the coating.
- Wet insulation should be removed and replaced, and the roof membrane repaired accordingly. Wet roofs do not perform well—they compromise coat-

ing performance, and they definitely impact energy performance of the roof system.

- Weaknesses or limitations of the original roof system must be corrected, and the roof should be made watertight prior to the application of the coating. Seams and fasteners on metal roofs may need attention, seams on single-ply membranes should be checked, etc.
- Weather conditions during the project installation must be monitored. Because coatings are applied in a liquid form and cure by either evaporation or chemical reaction, or both, weather conditions are critical to achieving maximum performance of the coating. Surface moisture may interfere with the coating cure process as described previously. Moisture in the air—humidity—will impact how quickly water may evaporate from a water-based coating, and humidity will determine how rapidly a moisture-cure coating will react and cure. Temperature will impact the rate of evaporation and the rate of a chemical-curing process; very high or very low temperatures may present issues. Wind may impact the uniformity of spray application. Manufacturer application recommendations must be followed to achieve maximum performance.
- Long-term performance of the roof system, including the protective coating, is enhanced with regular roof inspections and maintenance.

Roof-substrate considerations

The existing roof substrate figures prominently in roof-coating applications. Surface preparation and coating-material selection are crucial.

The selection of a coating must be based on criteria that include compatibility with the roof substrate, the performance level desired, the problem to be solved, and the weather and climate

Thermoset rubbers such as EPDM (ethylene propylene diene monomer) and Hypalon are common low-slope roof surfaces, and require cleaning to remove dirt and surface contaminants. Water-borne wash primers (sprayed on and then rinsed off) or film-forming primers are usually recommended to enhance adhesion. Weakness of adhesive bonding at seams and penetrations can be a common limitation of EPDM single-ply membranes. Prior to restoration, all seams must be checked and reinforced with EPDM cover tape.

Hypalon membranes can chalk excessively, requiring diligent cleaning along with the use of primers.

Thermoplastic single-ply membranes such as PVC (polyvinyl chloride) and TPO (thermoplastic olefin) are heat welded at the seams and penetrations. The welds need to be probed for any deficiencies before coating. PVC membranes may pick up excessive dirt due to the presence of UV-reactive plasticizers at the surface of the sheet, which can leave a sticky residue, so thorough cleaning and generous rinsing is important. TPO membranes are typically characterized by a very smooth, "low-energy" surface, requiring specific primers to accomplish satisfactory adhesion.

Metal roof surfaces present a myriad of issues for restoration projects, including the presence of rust and corrosion; expansion/contraction with temperature change, which can cause leaks at exposed fasteners, seams, and penetrations; and fading, chalking, and chipping of surface colors. All must be dealt with in the surface-preparation phase of restoration. Power washing and scraping or brushing may be necessary prior to priming. To seal gaps at high-stress areas such as fasteners, seams, and penetrations, it is important to use coatings characterized by excellent adhesion to metal, high viscosity, high solids, and high film build with excellent elongation and tensile strength.

Newer metal-paint formulations that are designed to be more colorfast present recoating-adhesion challenges. Kynar® and other fluoropolymer resin-based paints require a specific Kynar-based coating to achieve adequate field adhesion. Other metal paints, such as siliconized polyesters, may exhibit properties similar to the fluoropolymer finishes, but Kynar-based coatings may not adhere to these existing coatings. A field test using an iodine solution, available at the local drug store, can be used to indicate whether the existing finish is of a silicone type. Proper identification of the metal finish is essential to achieving satisfactory adhesion.

Roof surfaces composed of asphalt may require 90 days of exposure before coating to give the weather time to negate the effect of surface oils. The use of water-borne asphalt emulsion coatings can provide a good basecoat/primer that facilitates adhesion of a white fin-

Left: A metal roof is made watertight. Right: Coating-adhesion pull test in progress.

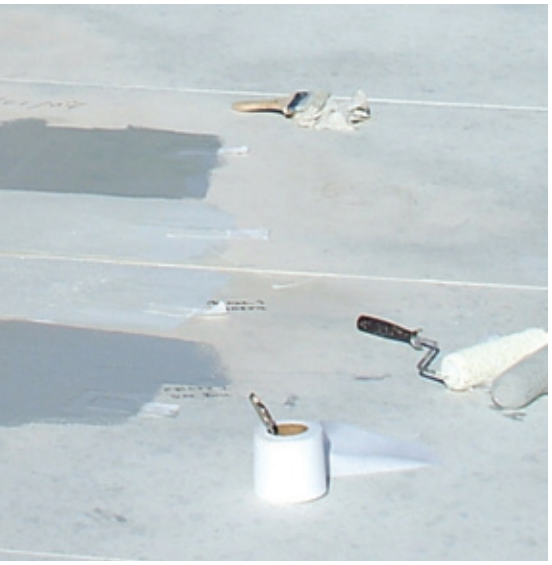
ish coat. An asphalt BUR with an aluminized asphalt coating may require significant washing to remove aluminum flake at the surface of the coating and to ensure proper adhesion.

Aged SPF roofs also may have been topcoated with silicone coatings, which dictates the use of a silicone restoration recoat. Field adhesion testing of the recoat application is needed.

Coatings chemistry: Getting the right match

Acrylic coatings are typically water based, easy to handle, moderately priced, and exhibit good performance in a wide variety of applications to nearly every one of the roof substrates described here. For those reasons, acrylics are the most commonly used highly reflective roof coatings. Acrylic coatings cure by water evaporation, exhibit a reasonable degree of cohesive strength (moderate elongation and tensile strength), and will provide good adhesion to most roof surfaces.

Because acrylic coatings are water based, performance and application limitations do come into play. Ambient weather conditions during application are very important. The roof surface must be dry at the time of application, and the coating must be exposed to favorable drying conditions to initiate cure prior to the onset of inclement weather. The coating must be kept at temperatures above 38 F until the water



carrier has an opportunity to evaporate.

Acrylic coatings should not be applied in areas where water will stand on the surface for over a day or two; the better the coating cure, the better its water resistance performance will be. The ASTM D-6083 standard defines the performance properties for an acrylic coating. If the coating is going to be used in any area that may be described as "cold," it is imperative that the coating meet the standard.

Polyurethane roof coatings are solvent based, typically exhibit much stronger physical properties such as elongation and tensile strength than an acrylic coating (3–10X or more), and also exhibit greater adhesion to most roof substrates than acrylic coatings. They are often used in areas of high roof stress and shear, such as sections where roof fasteners, seams, and penetrations are encountered, as is the case with metal roofs. They may be formulated to high solids levels, minimizing the amount of solvent used, and these coatings will typically meet federal and state VOC regulations.

Polyurethane coatings may be single-component moisture-cure or two-component reactive coatings. Most polyurethane coatings for roofing applications are single-component products, and utilize the moisture in the air to effect cure. Polyurethane coatings typically exhibit very good water resistance upon curing, may be functional in a wider temperature range than acrylics, and in general are not as weather sensitive during application as acrylic coatings. They are also more difficult to work with, however, due to solvent content, and are typically more expensive than acrylic coatings.

Silicone coatings are solvent based and are typically used in the coating of SPF roof surfaces. Silicone coatings weather very well and offer good adhesion to SPF, but are characterized by fairly weak cohesive strength, lower tensile strength, and modest elongation. They exhibit good resistance to water, but possess limited abrasion resistance. Their use is essential in recoating of existing silicone-coated SPF roof surfaces, however.

Rubber-based coatings may be based on materials such as SBS, EPDM, and even Hypalon in various solvents. Application to asphaltic substrates and membranes of similar chemistry is most common. Cured films of these coatings will approximate the characteristics of the original rubber surface, and adhesion to roof surfaces of the same type of chemistry will typically be quite good.

In closing, a word on the value of colaboration

The manufacturer, contractor, specifier, and building owner all play a role in maximizing the performance of a field-applied, high-performance reflective coating. The coating manufacturer must supply a product with the needed performance properties. The contractor is responsible to "get the most out of the coating" by means of proper application techniques and by following manufacturer recommendations. The specifier should recommend a coating system based on the problems that must be solved and the objectives of the building owner. Regular maintenance, as determined by the building owner and contractor, can help extend the life of any roof system, including field-applied coatings.

It is important to use manufacturer services to: help understand the coating options available that will best address the roof issues observed; conduct adhesion tests in the field; help train crews on proper application techniques; and understand data sheets and specifications and the need to follow them.

Proper surface-preparation methods are critical to maximizing adhesion of roof coatings; optimal adhesion goes a long way toward maximizing performance of all field-applied roof coatings.

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