PROCEEDINGS

Effective Use of Roof Coatings

Matthew M. Copeland, Gregory R. Doelp, and Paul C. Scheiner

Simpson Gumpertz and Heger

41 Seyon Street, Building 1, Suite 500, Waltham, MA 02453

Phone: 781-907-9000 • Fax: 781-907-9009 • E-mail: mmcopeland@sgh.com and grdoelp@sgh.com

Addressing the Building Envelope

ABSTRACT

Roof coating manufacturers attribute many benefits to their roof coating systems, including protection of underlying roofing from damaging ultraviolet rays, reduced thermal cycling of the roof, improved waterproofing performance, and, with reflective coatings, reduced energy costs. This paper summarizes the major coating types available including acrylics, polyurethanes, and specialty products such as soy-based coatings, and discusses the applications that each type is best suited for. The authors explain the importance of identification of suitable roofs and suitable coating products for those roofs, coating characteristics important for successful coating performance, and appropriate performance and maintenance expectations for coating systems.

SPEAKERS

Matthew M. Copeland — Simpson Gumpertz and Heger - Waltham, MA

MATTHEW M. COPELAND joined Simpson Gumpertz & Heger Inc. (SGH) in 2005 after receiving a BS in civil engineering from Northeastern University. He is a project engineer specializing in historic building investigation and repair projects, with a focus on materials science issues. He has experience with a variety of building envelope issues including implementation of innovative technologies, such as building-integrated photovoltaics and custom terra cotta rain screen systems. Mr. Copeland is a registered professional engineer in the Commonwealth of Massachusetts.

Gregory R. Doelp — Simpson Gumpertz and Heger - Waltham, MA

GREGORY R. DOELP joined Simpson Gumpertz & Heger Inc. (SGH) in 1984 with a BS in civil engineering from the University of Delaware and a MS in Civil Engineering from Cornell University. He specializes in investigating and designing roofing, plaza waterproofing, and below-grade waterproofing systems. His projects have also included analyzing building moisture problems and leakage problems, as well as repairing and renovating structures. Mr. Doelp is a member of the American Society of Civil Engineers and several honor societies. Mr. Doelp is a registered professional engineer in the Commonwealth of Massachusetts and seven other states.

Effective Use of Roof Coatings

INTRODUCTION

Roof coating manufacturers attribute many benefits to their liquid-applied roof coating systems, including prolonging the service life of the existing roof system, protecting the underlying roofing system from damaging ultraviolet rays, reducing thermal cycling of the roof, repairing minor leaks and cracks to restore waterproofing performance, reducing building energy costs, and improving building aesthetics. Some manufacturers offer watertightness warranties for their coating systems.

With so many advertised benefits, many building owners are eager to embrace the promises of roof coatings as an inexpensive way to address their roofing problems. For example, simply coating over an existing aging built-up roof sounds like an attractive alternative when presented to a building owner previously faced with a choice of either an ongoing maintenance regimen of leak chasing and patching or a wholesale roof replacement. A coating project is relatively inexpensive and noninvasive, which can be particularly important for occupied buildings. The finished product often looks like a new roof when first installed, but a deeper look is necessary to see if a roof coating will live up to its claims.

When it comes to real-world performance, roof coatings certainly have their place in the roofing industry and have been used successfully on many buildings, but they are not a cure-all for every old roof approaching the end of its service life. Many factors must be taken into account by the building owner and the designer when determining whether a roof coating is appropriate for a particular building. The capabilities and limitations of the roof coating must be consistent with the owner's expectations for the performance of the roof coating. Once it is determined that a particular roof is appropriate for a roof coating application, the correct coating for that particular application must be selected in order for a project to be successful.

Many roofing systems are candidates for roof coatings, including metal roofs, built-up roofs, single-ply membranes (PVC, EPDM, etc.), and modified bitumen. Some roofs are better suited for coating application than others, and the condition of both the exposed roof surface and the underlying materials is key to a successful application of a liquid-applied coating.

COATING BASICS

Roof coatings, like other coating systems, are made up of several constituents, including a solvent (sometimes also known as the carrier), a binder (sometimes also known as resin), pigments, and other additives. Coatings are often classified or referred to by the type of solvent or binder used in the formulation. These components play an important role in determining a coating's physical characteristics and performance, so it is helpful to have at least a rudimentary understanding of coating composition when discussing coating performance.

(

The most critical coating component is the binder, also known as the resin, which is the film-forming component of the coating. The binder is the component that has the most influence on the coating's physical characteristics such as elongation, water absorption, tensile strength, and the coating's adhesion properties. Coatings are manufactured with a wide variety of binders; some common binders include acrylics, polyurethanes, alkyds, silicones, and polyvinyl acetates. The type of binder is often combined with the type of solvent (discussed below) when referring to a particular coating, i.e., "water-based acrylic."

Acrylic binders are common in water-based roof coatings. These water-based acrylic coatings make up a large portion of the systems marketed as white "cool roof" coatings. These water-based formulations are generally designed to meet local volatile organic compound (VOC) regulations; though organic, solvent-based acrylics also exist. Coatings based on acrylic binders are often less expensive than coatings based on other binders.

Though polyurethane-based coatings are generally more expensive than acrylics, they often offer better long-term performance, particularly when exposed to ponding water conditions. Polyurethane can be a one- or two-component product, with two-component products typically curing more rapidly but requiring greater applicator skill to install correctly. Aliphatic polyurethanes are more stable than aromatic compounds when exposed to ultraviolet light, are therefore less prone to yellowing, and are typically used in topcoats of polyurethane roof-coating systems.

There are now many specialty coatings currently on the market, purporting to provide performance similar to more traditional coating products while using alternative materials. Such coatings are being introduced in part because of various green and sustainability initiatives. Among the most popular of these products are coatings containing soy products. The soy components

The terms ***drying*** and ***curing*** refer to different processes, but if they are used interchangeably, some confusion can result. Drying simply refers to the evaporation of the coating solvent, leaving the binder and other components behind. Curing describes the actual chemical process by which the binder forms a film over the substrate. In some cases, the film is formed simply by evaporation (drying) of the solvent; however, most often, the film is formed by a chemical reaction within the binder. Various mechanisms of reaction exist, and the curing mechanism must be considered when evaluating a coating for a particular use.

Figure 1

	Percentage Increase After Water Absorption (ASTM D471)		
Coating Sample	Average Linear Dimension in Plane	Mass	Thickness
Water-based acrylic 1	3.1	10.4	10.0
Water-based acrylic 1 (reinforced)	1.6	3.2	3.1
Water-based acrylic 2	2.1	12.5	10.5
Water-based acrylic 3	0.0	3.2	6.3
Water-based acrylic 4	2.6	11.1	12.6
Solvent-based soy alkyd 1	4.2	13.5	11.7
Solvent-based soy alkyd 2	1.8	6.6	NA*
Solvent-based aromatic polyurethane	1.5	3.5	1.2

*Data not available.

Figure 2 – Water absorption properties of selected coatings after one year of outside exposure.

of these coatings are implemented in a variety of ways, such as modified-polyurethane and alkyd binders, but the coatings are generally marketed as "soy-based" regardless of the underlying chemistry, simply because a portion of their polymers are derived from soybeans.

We performed laboratory testing on several roof-coating products. We generally found that some soy-based coatings provide physical properties within the same range as their nonsoy counterparts (*Figure 2*). However, simply selecting a soy-based coating is not an assurance of similar performance; the principles described below must still be followed.

(

The solvent (also sometimes known as the carrier) in a liquid coating makes the application of the coating possible and is not a part of the final cured coating film. The other components of the coating are suspended in the solvent, which typically is water or a VOC such as xylene or toluene. For this reason, coatings are commonly referred to as "water-based" or "solvent-based." Some coating formulations are designed without a solvent to avoid the issues of VOCs and loss of solvent during curing. These are referred to as "high solids coatings" or "100% solids coatings."

Water-based coatings dry by evaporation of the water. However, water-based coatings cure by coalescence of the emulsion particles in the binder into a uniform film (the difference between curing and drying is discussed in the sidebar, *Figure 1*). Coalescence is a process involving controlled evaporation of water and cosolvents, which allows emulsion particles to come into close contact with one another and react, forming the cross-linked coating. Water-based roof coatings are less sensitive to application over damp substrates than are solvent-based coatings because small amounts of water can diffuse through the coating surface. Although the substrate water may not affect the curing of the liquid-applied coating, the substrate water may inhibit bond of the coating to the substrate.

Application of water-based coatings is typically limited to ambient and substrate temperatures greater than approximately 40 to 45°F because of concern that condensation may occur on the substrate and inhibit bond or that condensation may form on the freshly applied coating, slowing the cure and washing out the binder. Rain shortly after application of water-based coatings can also cause similar problems. In addition, high ambient humidity can be detrimental to proper coating curing as the high humidity slows the rate of water evaporation. Despite these limitations, water-based coatings are popular because they are easy to apply, and the equipment can be cleaned with water alone.

After application, solvent evaporates out of solvent-based coatings during the drying process and initiates the curing. The loss of solvent concentrates the binder molecules so they can react to form the coating film. The rate of evaporation is influenced by temperature; solvent evaporates more quickly in warmer temperatures. If the solvent evaporates too quickly or too slowly, the polymerization reactions of the resin may not occur effectively, and the resin may not form an effective film. If the substrate is damp, the binder may not adhere properly to the substrate. Moisture may interfere with the bond of the coating, and moisture vapor trying to escape from the substrate may break the adhesion of the new coating while it is still weak, so that an adequate bond never develops. A general rule of thumb is that solvent-based coatings should be applied only when the temperature is 5°F above the dewpoint and rising, but less than approximately 95°F. Similar

The terms ***latex*** and ***elastomeric*** are often used when describing coating systems. Sometimes these terms are used in a manner similar to terms like "acrylic" or "polyurethane," and if so, they may create some confusion because they are thought to describe some type of coating binder. Technically speaking, ***latex*** refers to an emulsion, but it is also used to refer to a rubber compound that can be naturally occurring or synthetic. In the context of roof coatings, the term ***latex*** does not describe a specific binder polymer but instead refers simply to a water-based coating that can contain a variety of different binder polymers.

Likewise, the term ***elastomeric*** does not refer to a specific type of coating at all, but rather a property of a coating. Many different coatings have elastomeric properties that are defined by the coating's ability to stretch considerably and then return to its original shape.

Figure 3

to water-based coatings, if the freshly applied coating surface becomes damp with condensate or rain, portions of the resin may wash out or become diluted, resulting in an incompletely cured coating. Solvent-based coatings generally are less permeable and develop better adhesion to a given substrate than water-based coatings.

The use of solvents is often limited by VOC regulations imposed by federal, state, and local jurisdictions. A desire to limit VOC content is often the cause of product formulation changes from solvent-based to water-based or to high-solids formulations. Issues with solvent-based coatings include flammability of the solvent and the potential for the vapors to enter the building ventilation system; odors from the coating affecting building occupants, even if the building ventilation system is isolated; and health concerns from exposure to the vapors and the coating itself. Solvent-based coatings may be incompatible with other roof-system components in contact with the coating, such as the existing roof membrane, flashings, or sealants, which may be soluble in the solvent. Solvent-based coatings typically require the use of solvents to clean tools. See *Figure 3*.



Figure 4 – Coating failure at locations of ponding water.

PRINCIPLES FOR SUCCESSFUL ROOF COATING APPLICATION

Successful roof coating applications depend on a specific process, beginning with evaluating whether a particular roof is suitable for coating and then identifying an appropriate type of coating for the application. The general process is outlined below.

Roofs that are at the end of their service life and are deteriorated can rarely have their service life extended by application of a roof coating. Problems often arise with the performance of the applied coating when it is applied to a very old roof because of inadequate attachment of the underlying roofing materials to the roof deck, moisture trapped within the existing roofing materials, cracks and gaps in the underlying roofing membrane that cannot be bridged by the roof coating, and other issues.

Roofs suitable for coating application should have the following characteristics:

- The existing roofing materials must be attached to the roof structure sufficiently to meet local code requirements. A roof's uplift resistance is only as strong as its weakest plane. Applying a coating on top of poorly attached materials will not improve the insufficient attachment of the underlying roofing.
- The roof substrate should be sound and free from large cracks, split seams, and gaps. Roof coatings are generally able to bridge small cracks and gaps in the underlying membrane and may be able to fill small pinholes. However, the coatings generally are not intended to repair major defects in the underlying roofing, and their ability to bridge cracks is dependent upon the degree of movement that the crack experiences. Coatings should not be expected to bridge all cracks.
- Major existing leakage problems must be addressed before application of the roof coating, including removal of existing wet roofing materials. As noted above, roof coatings may be able to repair small pinholes and cracks in existing roofing materials, but the root cause of major leaks should be addressed before coating application. For example, a leak due to a split seam in an EPDM membrane roof should first be repaired by patching the split seam with an EPDM membrane patch before any coating application.
- Existing moisture in the roof system must be removed as part of any roofcoating project. The importance of removing moisture from existing roofing systems to be recovered or coated is well understood by the industry and is discussed in industry standards. When evaluating a roof as a candidate for roof coating application, the designer must be confident that the existing moisture in the roof can be removed. The new roof coating should be applied to a clean, dry substrate.
- Adequate slope-to-drain is a factor in the success or failure of roof systems in general, and it is especially critical with roof coatings. Roof coatings tend to deteriorate more severely in areas of ponding water than in areas that drain well (*Figure 4*). If cracks develop in the coating, water can pass through the cracks, get under the coating, and contribute to delamination (*Figure 5*). If the ponding problems are severe enough, the roof should not be considered a can-



Figure 5 – Cracks in roof coating. Water passes through cracks in the coating and contributes to delamination of the coating from the roof membrane.

didate for a coating, or a coating that can perform in immersion conditions should be selected.

Once the design team has determined that a roof is suitable to receive a coating, the next task is to choose a specific coating system for that particular roof. There are a wide variety of different coating systems on the market that range from relatively thin, unreinforced coatings (that are more like a paint) to relatively thick, reinforced coatings (that act like a continuous membrane). When considering which coating to use, several factors should be evaluated, including the following:

- Choose a coating system that has previously been successfully installed and has performed well on the same type of roof. Designers should confirm that the coating has been successfully installed on similar roofs by visiting the sites of other installations, contacting building owners with similar installations, and reviewing photographs of similar projects. Visiting the sites of other installations generally provides the best opportunity to evaluate performance. Reviewing manufacturers' published values for various physical properties of their roof coatings alone will not guarantee adequate performance.
- Roof coatings perform differently on different substrates, so designers must be certain to select a coating that is intended for the type of roof at hand. For example, some roofs move more than others in response to temperature changes and structural loads, so a coating must be selected that can accommodate the expected movement. If a coating is too brittle to accommodate the movement in the roof substrate, it may crack and delaminate (*Figure 6*).
- As noted above, if the roof has severe and pervasive ponding, it should not be a candi-



Figure 6 – Cracking and coating delamination. Brittle coating cannot accommodate movement in substrate.

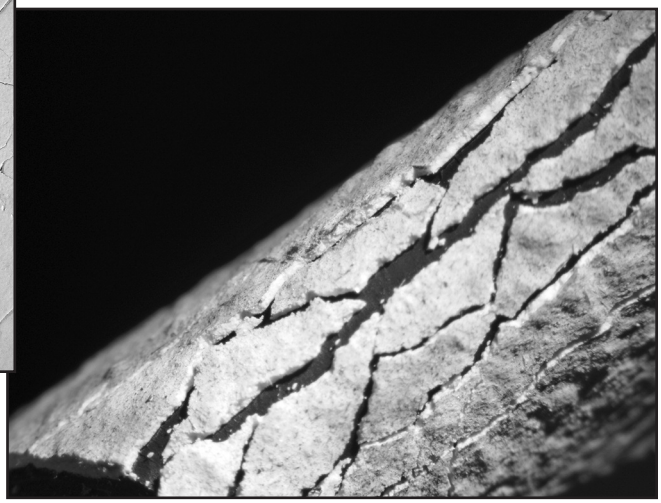


Figure 7 – Water-based acrylic coating performing well on steeply sloped roof, colored green to match historic patinated copper. Note: Copper roof in lower right, shown covered with EPDM (for emergency repairs) in lower left, and then coated in top of photo.



Figure 8 – Cracks in roof coating. Water gets underneath the coating at cracks and contributes to delamination.

Figure 9 – Cracks in a brittle coating.



date for coating. However, if the roof has only small, short-term puddles, relatively good drainage overall, and the designer wants to pursue a coating, then the coating selected should have good properties in ponded water (such as low water-absorption). The options for coatings that will provide long-term durable performance under ponded water conditions are limited, but polyurethane or silicone coatings generally perform better than acrylic coatings under these conditions. Water-based acrylic coatings are typically more susceptible to degradation under ponded-water conditions than other coatings and therefore are most suited for installation on roofs with good slope-to-drain throughout the roof (*Figure 7*).

As noted above, reviewing physical properties of coatings alone cannot guarantee coating performance in service; however, comparing physical properties is a good way to compare different coatings and evaluate them relative to one another. Designers should focus on certain key physical properties of coatings; these properties include the following:

- Roofing systems can experience temperature cycles of 150°F or more (from winter cold to midsummer heat), and they must be able to withstand the stresses imposed by movement as a result of these temperature swings. When a roof coating is applied as part of the roof system, it must be able to move with the underlying roofing without cracking (*Figure 8*). Since most roof membranes are highly elastic and exhibit significant elongation capabilities, roof coatings must match or exceed this performance. Coatings with higher elongation and tensile strength properties will generally perform better than otherwise similar coatings with lower elongation and tensile strength values.
- As is the case with most roofing materials, water absorption leads to premature degradation of roof coatings. Depending on the components of a particular coating, water absorption may lead to chemical breakdown of the coating. Absorbed water can also lead to mechanical stresses within the coating due to freeze-thaw cycling. Cracks in the coating can exacerbate the degradation from freeze-thaw cycling by allowing additional water into the coating, resulting in larger cracks and more water intrusion.

The water absorption characteristics of a coating are not included on some coating manufacturers' product data sheets, though they can be easily determined by laboratory testing. Water absorption characteristics can also change over time, particularly in a coating exposed to the elements in service. We tested several water-based acrylic coating samples in our laboratory both before and after approximately one year of exposure to the weather and found that the water absorption characteristics did not remain constant. Additional research is needed to identify an appropriate threshold for water absorption in roof coatings; but in relative terms, lower water absorption will result in better coating performance.

- The glass transition temperature (Tg) of a coating is the temperature above which the coating remains flexible. Below the glass transition temperature, a coating can become brittle and prone to fracture (*Figure 9*). Because a roof coating must be able to accommodate the movement of the underlying roofing without fracturing, it is important that the ambient temperature where the roof coating is in service remain well above the coating's Tg throughout its service life. This point becomes especially important in cold-weather climates where wintertime temperatures may approach the Tg of many coatings. To provide the best performance, the ambient temperature should not be lower than a coating's Tg.

The Tg is typically not included among the physical properties listed on a coating's product data sheet. The data can be obtained through laboratory analysis of coating samples, though a coating's manufacturer may also be able to provide the Tg for its coatings on a case-by-case basis.

- The adhesion between the coating and the underlying roofing is critical to the successful performance of the roof system. However, the adhesion is a function of many factors, including the substrate condition, substrate preparation procedures, environmental conditions during application and immediately after, and application methods. Therefore, while strong adhesion is important and should be evaluated during application, it is not exclusively a physical characteristic of an individual coating.

Once a roof has been identified as a good candidate for coating application and an appropriate coating product has been selected, the following procedures should be followed to give the coating application the best chance of success:

- Roof coating specifications should include requirements for a thorough in-place mock-up process. The mock-ups should include review and approval by the designer of the substrate preparation procedures prior to application of the coating, as well as review and approval of the coating application itself. Unique mock-ups should be performed for each substrate type and each coating type on the job. While a review of the coating mock-up for aesthetics should be included, it should not be the primary focus. The mock-up should demonstrate that the coating, as applied to the specific roof substrate, will meet all technical performance requirements set for the project. The mock-ups should include testing and involvement of the manufacturer as described below. However, a mock-up cannot be used to evaluate the long-term performance of the coating system. Hence, it is important to use coatings with a successful track record on the same substrate, and use the mock-up to evaluate constructability, initial performance, and aesthetics.
- Designers typically rely on manufacturers with a long-term track record of reliable performance, but if the performance history is not complete or long enough, or if there are questions in the performance history, third-party testing of the physical properties of coatings may be appropriate to confirm that they are meeting the required performance standards. If possible, testing should be performed during the mock-up process to show that the new coating has the properties specified. Depending on the size of the project, it may also be appropriate to test periodically during the construction (similar to periodic weld inspections in a PVC roof); however, it will take some time to perform the tests, which may make it difficult to take corrective action in time if necessary. Some of the coating properties that could be tested include elongation, tensile strength, water absorption, and adhesion. Testing the Tg may also be appropriate, especially in cold climates.
- Throughout the specification, mock-up, and application process, the designer and installer should maintain a close relationship with the manufacturer of the roof coating being used. Because of the complex chemistry involved in making the coatings, the manufacturer is in the best position to understand nuances about how the coating will perform in certain situations and can make informed recommendations about how best to approach a unique application. Following manufacturers' recommendations alone will not ensure a successful roof coating application, but manufacturers' unique knowledge of their products can prove especially valuable when applied in conjunction with mock-ups and thorough performance testing.

Finally, after a roof and coating have been selected and all possible steps have been taken to provide a quality installation, the last factor in coating application success is maintenance. All coatings, whether they are roof coatings or other types, require periodic maintenance to keep up performance. Regular maintenance of roofs and any applied coatings is particularly important given the harsh environment where the coatings are installed. Roofs and their coatings should be closely inspected at least annually. The inspection should include walking all areas of the roof and performing an up-close, hands-on inspection of any areas exhibiting signs of deterioration (cracking, staining, peeling, blistering, etc.). An up-close, hands-on inspection should also be performed in areas prone to premature deterioration, such as valleys, low points where water ponds, high-traffic areas, and beneath mechanical equipment. Any areas of deterioration should be repaired promptly, including repairing any damage to underlying roofing materials and replacing any wet roofing materials. At some point, the coating system (i.e., original coating with additional maintenance applications) may become so thick that the coating material will not perform as intended.

There is a wide range of reasonable expected service lives for roof coatings due to the variety of coatings available and the variety of roofs to which they are applied. A five-year lifespan is a reasonable expectation for a roof coating when the preceding guidelines are followed. At the other end of the spectrum, some roof coatings may last 15 years or longer with proper maintenance and ideal roof and environmental conditions. It is important that the designer, owner, and manufacturer make an honest assessment of what is reasonable to expect before embarking on a coating application.

SUMMARY

Roof coatings can extend the service life of an existing roofing system and might provide additional benefits such as improved aesthetics or energy performance, but these benefits will only be achieved if the existing roof is a suitable candidate for coating and an appropriate coating system is selected. The roof coating must also be properly applied and maintained to realize these benefits.