ELASTOMERIC ACRYLIC COATINGS FOR USE ON COMMERCIAL STRUCTURES

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ABSTRACT

The protection of commercial buildings from the elements is a major function of the coatings used in new build and maintenance applications. Waterborne elastomeric acrylic coatings represent an important category of coatings used in both residential and commercial architectural painting. Based on acrylic latex binders with very low glass transition temperatures, elastomeric acrylic coatings are used on low slope roofing, masonry walls and structures, and are also utilized as components of exterior insulation and finishing systems (EIFS). Key properties imparted by the elastomeric acrylic binder to the coating systems include low VOC, dirt pickup resistance, excellent flexibility even at low temperatures, the bridging of small cracks in masonry, UV and water resistance, solar reflectivity for cool roofs, and the ability to be applied in thick films without mudcracking. This paper will explore the chemistry of elastomeric acrylics, techniques for their evaluation in the laboratory, a discussion of the various applications where they are utilized and expected performance, and results of accelerated and natural exposures and real world case studies.

INTRODUCTION

Commercial structures are comprised of complex assemblies of materials designed to withstand a variety of environmental and physical stresses, while maintaining their integrity and function as the office buildings, hospitals, retail stores, airports, concert halls, restaurants, churches, and other buildings and structures which we utilize every day. These structures are built from a variety of materials including wood, metal, concrete, cinderblock, brick, stucco, and drywall, many of which require the application of coatings at some point in their lifetime. Coatings used in commercial architecture range from interior wall coatings for drywall, such as those used in residential homes, to high performance coatings used for applications such as flooring, protection of roofing membranes, and fire protection. Within this wide gamut of coating types and the chemistries used to make them, waterborne acrylics have an important position. As one of the major generic types of coating chemistries, waterborne acrylic latex coatings represent a multi-billion dollar industry in the USA.[1] Within the confines of the commercial architectural coatings market, waterborne acrylics are certainly used for interior walls and ceilings and exterior walls, much as they are used in a residential architectural setting. However, there are many higher performance applications such as roofing, concrete stains and sealers, direct to metal coatings, and exterior insulation and finishing systems (EIFS) which rely on acrylic technology.

Waterborne acrylic latex coatings are a broad category which encompasses a wide variety of applications and performance requirements. Acrylic polymers can be tailored to meet these widely varying needs because of the many acrylic monomers available for their production. Acrylic latex polymers made via emulsion polymerization can be varied in hardness, chemical/solvent resistance, barrier properties, adhesion, flexibility, hydrophobicity, and other properties by manipulating the monomer composition and processing conditions. Elastomeric acrylics represent one specific class of acrylic latex polymers that are based on polymer compositions with very low glass transition temperatures (T_g), typically well below 0°C. Because they are normally used at temperatures above their T_g, they usually exist in a rubbery state. In the rubbery state, elastomeric acrylics can be deformed by applying a stress, but they will return to their original state once the stress is removed. The low polymer T_g results in soft coatings that have excellent flexibility, a unique balance of tensile strength and elongation, and crack-bridging properties. The low T_g also results in low minimum film formation temperatures, and therefore elastomeric acrylics have low coalescent demand and offer low volatile organic content (VOC).

The unique properties afforded by elastomeric acrylic coatings makes them excellent choices for applications where elongation and flexibility are key requirements. Some common applications within the scope of commercial architectural coatings include coatings for EIFS, low slope roofing, and masonry walls. This paper will explore the use of elastomeric acrylic coatings for each application, and discuss key targeted properties, expected performance, laboratory testing methods, examples of accelerated and natural exposures, and real world case studies.

THE CHEMISTRY OF ELASTOMERIC ACRYLICS

Acrylic latex polymers are prepared by a process called emulsion polymerization. There is a large body of technical literature dealing with the process[2], but a brief explanation is in order here. The medium for emulsion polymerization is water. Acrylic monomers typically have low solubility in water, but can be emulsified into monomer droplets by using surfactant. Excess surfactant forms micelles, and it is within the surfactant micelles where the free radical polymerization process is initiated by water soluble initiators. Because they have a low but finite water solubility, acrylic monomers can be transported from the monomer droplets, through the water phase, and into the micelles where they become part of the growing polymer chain. As the polymer chains grow, a colloidal particle forms, and is the ultimate product of the emulsion polymerization process. The resulting acrylic latex polymer is a stable dispersion of polymer particles in water. Each particle contains many polymer chains of typically high molecular weight (e.g., M_w of 500K to 1 million). Typical solids levels are 40 – 55% by weight. A key benefit of acrylic latex polymers is the ability to supply a ready to use, high molecular weight resin at high solids. Dissolving such a high molecular weight resin in solvent would yield excessively high viscosities, or very low solids, which prevent the supply of solventborne resins at those molecular weights. Another major benefit of latex polymers prepared via emulsion polymerization is the use of water as the dispersing medium, which allows formulation of low VOC coatings.

Acrylic latex polymers form cohesive films through a unique process in which the colloidal particles pack tightly together as water leaves the coating, and eventually the particles coalesce as the polymer chains diffuse across the particle boundaries and become entangled.[3] A diagram of the film formation process is shown in Figure 1. The ease with which the polymer chains diffuse depends on several factors, including their molecular weight and T_g, and the presence of coalescing solvents that increase their mobility. Polymers with lower T_g can form films with less coalescing solvents, and allow the production of coatings with lower VOC. Polymer T_g is dictated by the various acrylic monomers and their ratios in the final polymer composition. Each monomer has a T_g value associated with its homoploymer, and this T_g value dictates whether the monomer will increase or decrease the polymer T_g of a copolymer containing it. Table 1 lists the homopolymer T_g values for some of the most common acrylic monomers and other co-monomers used in emulsion polymerization. Elastomeric acrylics, which have low polymer T_g values well below 0°C, are thus prepared with high levels of "soft" monomers such as butylacrylate or 2-ethylhexylacrylate.

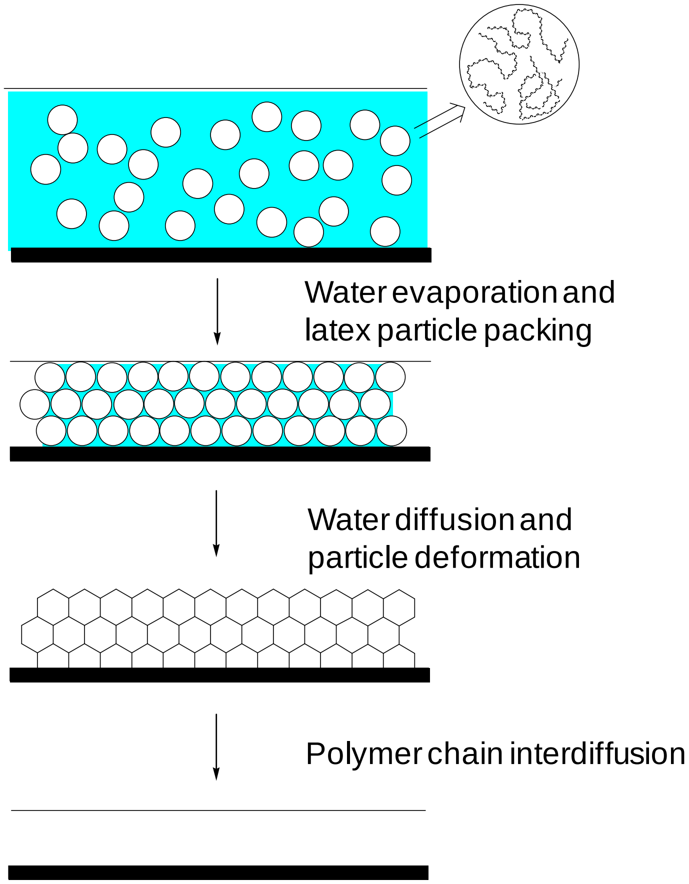

Figure 1. Film formation mechanism for a waterborne acrylic latex polymer. Inset shows that each latex particle consists of multiple high molecular weight polymer chains.

Table 1. Homoploymer T_g values for some common monomers used in acrylic latex polymers.

Monomer	T_g (°C)
methyl acrylate (MA)	+ 8
ethyl acrylate (EA)	-17
butyl acrylate (BA)	-48
2-ethylhexylacrylate (EHA)	-70
methyl methacrylate (MMA)	+ 100
butyl methacrylate (BMA)	+ 20
acrylonitrile (AN)	+ 145
styrene	+ 90
vinyl acetate (VA)	+ 33

The low T_g of elastomeric acrylics offers several benefits, including excellent flexibility, maintenance of the flexibility at low temperature, a good balance of tensile strength and elongation, excellent adhesion, and low coalescent demand which translates into low VOC of the formulated coating. The flexibility and tensile/elongation of elastomeric acrylics give them the ability to bridge small cracks in substrates such as concrete, and provide impact resistance to prevent damage to the coating, such as when hail strikes a roof. In addition, elastomeric acrylic coatings can be applied at high dry film thicknesses (DFT) without mudcracking. The low T_g polymer allows film stresses that develop during drying to be relieved more easily than a harder polymer, and elastomeric acrylic formulations are typically at higher volume solids content, which means that there is less shrinkage from water evaporation as the coating dries. Films are typically applied at 10 to 20 mils DFT in a single coat without mudcracking.

The low T_g of the polymer can also lead to several potential problems, such as surface tack leading to poor dirt pickup resistance. To prevent dirt pickup issues, many elastomeric acrylics contain self-crosslinking functionality which gives a low level of crosslinking on the surface of the coating to prevent tackiness and dirt particles sticking to the coating. Morphology of the acrylic polymer can also help this issue. The versatility of the emulsion polymerization process allows preparation of latex particles with domains of both soft and hard polymer phases, and the correct combination and structure can lead to a unique balance of film formation at low minimum film formation temperature (MFFT) with good hardness properties. The classic example is the “core-shell” morphology, where the core of the latex is a hard polymer, and the shell is based on a soft composition. The soft shell provides film formation at low VOC, and the hard phase reinforces the soft phase to provide better hardness properties. Other more complex morphologies, such as shown in Figure 2, are often employed and can similarly lead to the required balance of the film formation and hardness.

Elastomeric acrylic coatings can also be formulated using harder acrylic binders with high levels of non-volatile plasticizers. The approach will lead to greater flexibility of the harder binder, but

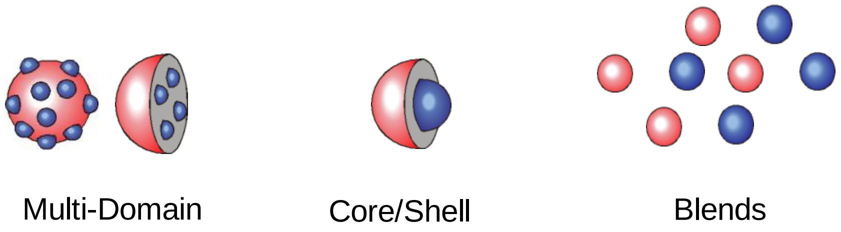

Figure 2. Various latex morphologies with polymer phases of more than one T_g. These morphologies can be used to balance hardness with a low minimum film formation temperature.

the result is usually only temporary. The plasticizer eventually will migrate from the film, which can then become brittle and more likely to crack, especially at low temperatures. Plasticizers will also often migrate to the film surface, where they can lead to dirt pickup and mildew growth problems. To avoid these issues, waterborne elastomeric acrylic coatings should only be formulated with low T_g binders which do not have to be formulated with plasticizers, and which will maintain their flexibility at low temperatures.

APPLICATIONS USING ELASTOMERIC ACRYLIC COATINGS

Elastomeric acrylic coatings are utilized for their ability to be applied in thick films, good dirt pickup resistance even though they are based on low T_g binders, their excellent flexibility especially at low temperatures, the ability to bridge small cracks that undergo movement, and good impact resistance. Coating applications within the commercial architectural market which exploit the benefits of elastomeric acrylics include roofing, exterior insulation and finishing systems (EIFS), and concrete and masonry walls. Elastomeric roof coatings rely on the good adhesion of the binder, as well as weatherability, resistance to ponding water, and impact resistance in order to withstand hail and foot traffic that may make contact with the roof. In addition, roof coatings based on elastomeric acrylics are typically colored white and designed to keep the roof and the structure cool by reflecting sunlight, and thus its ability to resist dirt pickup is also an important property as a dirty coating is less efficient at reflecting sunlight. Dirt pickup resistance is an important aesthetic property in coatings for concrete and masonry walls, but the bridging of small moving cracks is particularly vital for this application. Fluctuations in temperature can lead to expansion and contraction of small cracks in the masonry surface, and only coatings that have high elongation, particularly at low temperatures, can withstand cracking. Good flexibility, water resistance, and dirt pickup resistance are also needed in EIFS applications, where elastomeric acrylics are often used to prepare flexible textured finishes and water resistive barriers used in EIFS drainage systems. EIFS is a multi-layer system, including water resistive barriers, adhesive, insulation and various coating layers, and elastomeric acrylics are used in some of these layers. A further description of each application – roof coatings, EIFS and masonry wall coatings – is given in the sections below.

ELASTOMERIC ROOF COATINGS

Elastomeric acrylic roof coatings are used mostly for the maintenance of low slope roofing, and are applied over a variety of roofing substrates including built-up asphalt, spray polyurethane foam, EPDM (ethylene propylene diene monomer) rubber, modified bitumen, TPO (thermoplastic polyolefin), metal and concrete. Two important purposes of an acrylic roof coating are protection of the underlying roof substrate from further degradation by the weather and thus prolonging the roof life via maintenance, and creation of a "cool roof" by nature of its white color and its ability to reflect sunlight and keep the roof and the underlying building from excessive heat buildup.

Over the past 30 years, the concept of cool roofs has gained increasing momentum in the marketplace. Urban areas, which contain large areas of asphalt paving and dark roofing, are subject to what has been termed the urban heat island effect.[4] The urban area is hotter than nearby rural areas, and for large cities the difference in annual mean air temperature is estimated to be from 1 to 3°C. Roofs and pavement areas can be from 27 - 50°C hotter than air temperatures on hot summer days, and are one source of the heat islands. Because urban surfaces release heat more slowly than surfaces in rural areas, the urban area can have an air temperature as much as 12°C higher than the rural area at night. The heat island effect results in higher energy usage to cool buildings and elevated levels of pollutants and greenhouse gas emissions. In 1991, the Committee on Science, Engineering and Public Policy of the National Academy of Sciences, National Academy of Engineering and the Institute of Medicine published a report titled "Policy Implications of Greenhouse Warming".[5] One mitigation option in their report was the use of "white surfaces" in order to "…reduce air conditioning use and the urban heat island effect by 25% through planting vegetation and painting roofs white at 50% of U.S. residences."

Research into the use of white elastomeric acrylic roof coatings to reduce energy demand has been going on for over 30 years. Early "birdhouse" experiments demonstrated that white coatings could significantly reduce the internal temperature of uninsulated and poorly ventilated buildings. Figure 3 shows an example of such a test, where white model buildings with asphalt shingle roofs were exposed in the sun to compare heat development. One of the models was coated with a reflective white elastomeric acrylic coating. On a sunny day with an outside temperature of 87°F, the inside of the building with the black roof was 128°F, while the building with the white roof had an internal temperature of only 97°F. The surface temperature of the roof was 135°F for the black roof, and the white roof surface was only 110°F. Thus, the white coating was found to reduce both the exterior surface temperature, as well as the interior temperature.

Based on the results of these rather simplistic experiments, the effects of white reflective acrylic roof coatings were studied on full-scale roofs in a cooperative research project between Rohm and Haas Company, the University of Southern Mississippi, and Mississippi Power Company in the 1980's.[6] Three similar buildings were built in the Hattiesburg campus of the University of Southern Mississippi. Two buildings were of similar design using construction techniques and insulation guidelines prevalent in the 1970's. One was the control building, made with minimal insulation and a smooth surface black asphalt built-up roof. The second was similar except that

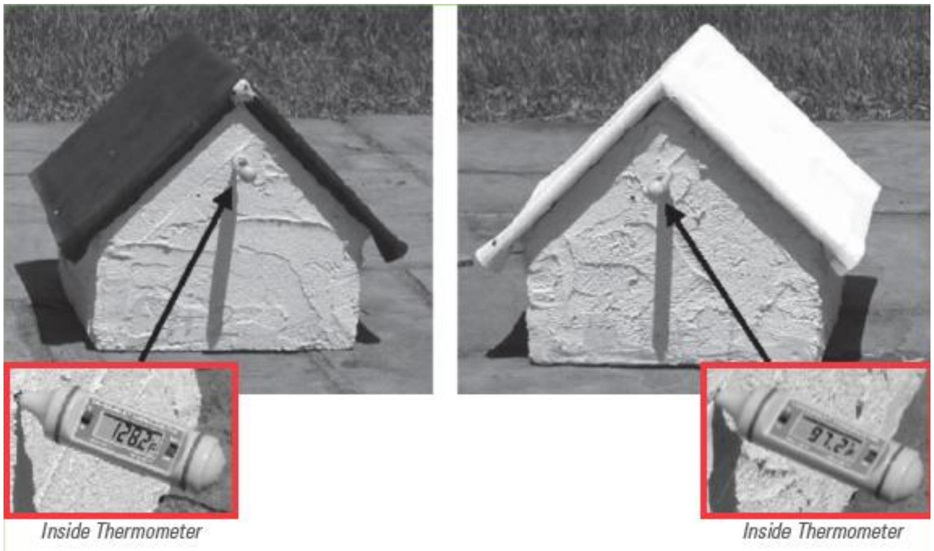

Figure 3. Model buildings with either a black or white roof, were exposed on a sunny day with a temperature of 87°F. The insets show the internal temperature of the black roofed building was 128°F, while the white roof building was only 97°F.

the roof was coated with a white elastomeric acrylic coating. The third building was constructed using revised insulation guidelines from the 1980's, consistent with the "Good Cents" program espoused by the Mississippi Power Company, which encouraged increased insulation usage in the foundation, walls and ceiling, and installation of double pane windows and airtight weatherstripping. The buildings are described further in Table 2. Each building was individually heated and cooled using a heat pump, and telemetry data was gathered for exterior and interior air temperature and relative humidity, solar radiation, time, wind velocity and watt-hours of energy consumed. Inside air temperature was kept constant at 24°C, and data were recorded every 15 minutes for one year. After one year on monitoring, the building coated with the white elastomeric acrylic roof coating had 21.9% lower energy consumption in the summer compared to the control building. The white roof coating also reduced the energy demand by 4% in the winter. Although it was originally theorized that black roofs would absorb heat in the winter and an energy penalty would be incurred by a roof coated with a reflective material, this study demonstrated that it is not true. The hypothesis for this result was that because black bodies are more ideal energy radiators, heat absorbed during the winter daylight would be more easily emitted during the nighttime. The more heavily insulated "Good Cents" house had 29.8% lower energy demand in the summer, and 42.1% lower demand in the winter. A serious limitation of the insulation option is that it can only be incorporated during construction or major renovation, whereas the roof coating can be applied at any time during the life of the building. A number of other studies have been carried out since the 1980's which show the advantage of applying reflective white roofs for energy consumption and their positive effect on the urban heat island phenomenon.[7]

The reduction of energy consumption when using white elastomeric acrylic roof coatings is based on their high solar reflectivity and low emissivity compared to dark roofs. Much of the energy in sunlight, particularly infrared and near infrared radiation, is reflected by the white

Table 2. Description of the three buildings built for the cooperative research study on the campus of the University of Southern Mississippi.[6]

Construction Material	Building 1: Control	Building 2: White ERC	Building 3: "Good Cents"
Ceiling	R11 4" Batt Fiberglass	R11 4" Batt Fiberglass	R30 10" Batt Fiberglass
Walls (Concrete block)	No Insulation	No Insulation	Perlite R2.85 Urethane R11.7
Windows	Single Glass Standard	Single Glass Standard	Double Glass Tight Fit
Doors	Wood Door Standard	Wood Door Standard	Metal w/ Insulation and Weatherstrip
Foundation	No Insulation	No Insulation	1.5" Insulation R11.7, Perimeter
Roof System	Built-up	Built-up w/ white acrylic coating	Built-up

surface. However, if the coating quickly becomes dirty, it loses the benefit of high solar reflectivity. Dirt pickup resistance is tested in the lab by applying a "dirt" substitute, such as a dispersion of brown iron oxide pigment, to a coated panel, allowing it to dry under various conditions, and then removing the "dirt" under running water with only gentle abrasion. A comparison of the Y-reflectance before dirt application and after removal is made to determine the dirt pickup resistance. No standard method exists for this test, but it can be a good predictor of field exposures. There are several standards which dictate the performance of elastomeric acrylic roof coatings, including ASTM D6083,[8] the California Energy Commission Title 24,[9] several regional standards such as for Miami-Dade County in Florida, and the Energy Star program. Some of these specify initial solar reflectivity, and the Energy Star program specifies a solar reflectivity of at least 50% after 3 years exposure. The ability of the elastomeric acrylic to maintain the high degree of whiteness needed for solar reflectivity is due to self-crosslinking functionality built into the acrylic polymer. As the coating ages and is exposed to UV light, a light crosslinking of the polymer at the surface occurs, which allows the coating to better resist having the dirt stick and embed into the surface.

The most common test used to analyze the performance of elastomeric acrylic roof coatings is measuring the tensile and elongation of free films according to ASTM D2370. The balance of tensile strength and percent elongation separates elastomeric acrylics from harder acrylics used in, for example, typical house paint. ASTM D6083 specifies that an elastomeric roof coating have greater than 100% elongation at break and 200 psi tensile strength at room temperature. California Title 24 requires greater than 200% elongation and 100 psi tensile strength at room temperature, and greater than 60% elongation and 100 psi tensile strength at low temperature (0°F). These properties are critical because one wants good toughness (tensile) and flexibility (elongation) across a broad range of service temperatures. The flexibility is important because roofs tend to expand and contract with building movement, changes in temperature, and thermal shocks caused by severe weather. The plot in Figure 4 shows the relationship between tensile

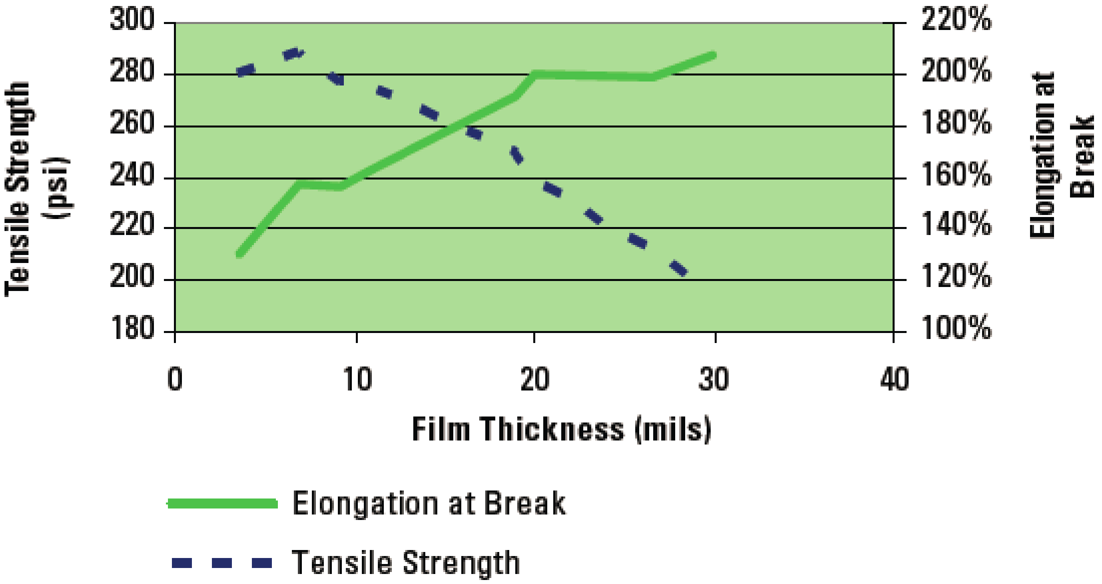

Figure 4. Relationship of tensile strength and elongation at break versus dry film thickness for a typical elastomeric acrylic roof coating.

strength, elongation, and installed dry film thickness for a typical elastomeric acrylic roof coating formulation. While a coating at 20 mils DFT will stretch almost 200% at room temperature, the same coating at 5 mils DFT will only have about 140% elongation. ASTM D6083 requires mechanical testing on films that have 20 ± 2 mils DFT, in order to provide a level playing field for evaluating different coatings, but this is not always consistent with what will be installed on the roof. In general, elastomeric acrylics should be applied at a minimum of 20 mils DFT to achieve the reported flexibility and longevity.

Film thickness also effects hiding of the substrate and the weatherability of the roof. The main opacifying agent in elastomeric roof coatings is titanium dioxide (TiO_2), which works by efficiently scattering visible light to give the white color and blocking the UV light from reaching the substrate and causing degradation. A typical elastomeric acrylic roof coating formulation is shown in Table 3, and contains about 0.7 pounds titanium dioxide per gallon and a total pigment volume concentration (PVC) of approximately 40 – 45%. This is much lower than a typical house paint, which contains about 2 pounds/gallon TiO_2 in a white coating. However, house paints are applied in much thinner films of only a couple mils per coat, so higher levels of TiO_2 are needed to provide adequate hiding. Elastomeric acrylics are applied at much higher film thicknesses, so lower levels of TiO_2 per unit thickness suffice to provide the opacity and protection of the substrate.

Coatings applied at higher film thicknesses have proven to perform better in long term weathering tests. The photo in Figure 5 shows the same coating, described in Table 3, applied at varying dry film thicknesses over polyurethane foam and exposed for 12 years in a horizontal exposure deck in eastern Pennsylvania. The coating applied at 5 mils DFT did not adequately protect the foam from the sun, and consequently the foam broke down into a powder. The

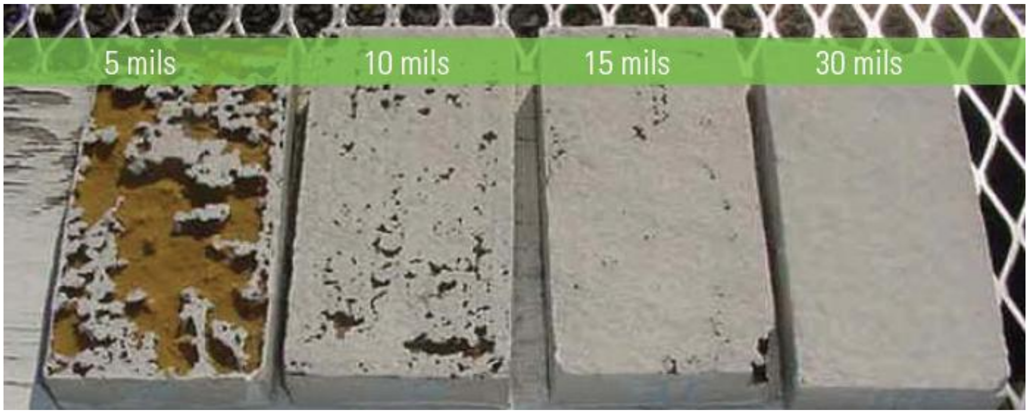

Figure 5. Polyurethane foam panels coated at varying dry film thickness with the same elastomeric acrylic roof coating, and exposed for 12 years on a horizontal face-up exposure rack in eastern Pennsylvania.

process had started in the 10 and 15 mils DFT panels, as evidenced by the holes forming in the samples. However, after 12 years exposure, the panel with 30 mils DFT of coating was unmarred and still providing protection to the underlying foam substrate. This example illustrates why thickness is often the main driver in warranty length for many different types of roofing systems.

Typical roof coating formulations, such as the one shown in Table 3, have high volume solids (e.g., 50 – 55%) which allows for low shrinkage without mudcracking of the film as it dries. Formulations are low gloss (i.e., flat), containing high levels of inert fillers such as calcium carbonate, which also helps to keep down the cost. Zinc oxide is used in many formulations because it allows the binder to achieve the proper tensile/elongation balance by contributing to crosslinking of copolymerized carboxylic acid functionality. All-acrylic binders offer the best durability, but styrene-acrylic versions are available which allow balancing cost and performance. Because the polymer has a low T_g, VOC levels are usually very low, with less than 50 g/L being achievable in a high quality elastomeric acrylic roof coating.

Other important laboratory tests that are run on roof coatings include mandrel flexibility, accelerated weathering, water permeance and swelling, and peel adhesion. Mandrel flexibility is run at room temperature and low temperature, according to ASTM D522 (Method B). Xenon arc Weatherometer (WOM) accelerated weathering is evaluated according to ASTM G155 (Cycle 1), and typical exposures are for 1000 hours, and can be followed by mechanical testing of the weathered films. Water permeance is measured according to ASTM D1653 in a face-down configuration, and values $\leq$ 50 perms are required for the important roof coatings standards ASTM D6083 and California Title 24. Water swelling according to ASTM D471is also measured, with values of $\leq$ 20% being required by ASTM D6083. Water resistance testing is designed to answer the question of whether the elastomeric coating can withstand ponding water, which can occur on a low slope roof. Evaluation of peel adhesion on specific substrates is carried out according to either ASTM C794 or D903, where a cloth strip is embedded between two coats. Among the various acrylic polymers and coating formulations available for roof coatings, it is important to choose one that is suitable for the specific roof substrate being protected, as poor adhesion can lead to blistering and delamination.

Elastomeric acrylic roof coatings are thick, monolithic, reflective, waterborne elastomeric films designed to provide both protective and aesthetic properties to a roof. Their primary purpose is to protect the existing roof substrate from further degradation, thereby extending its lifetime and increasing the sustainability of the roof system. These coatings are used in both maintenance applications and as factory-applied coatings over roofing substrates. They are flexible enough to move as the roof system moves, yet tough enough and have the adhesion to withstand foot traffic and hail impact. Elastomeric acrylic coatings are not designed to provide a total waterproofing system for the roof, but their excellent water resistance properties prevent blistering, swelling and can resist ponding water. Finally, their resistance to dirt pickup allows the films to maintain solar reflectivity, which translates into long term energy savings.

Table 3. A typical elastomeric acrylic roof coating formulation.

Material Name	Pounds	Gallons
Grind		
Water	152.5	18.3
Pigment dispersant	4.8	0.5
Potassium tripolyphosphate	1.4	0.1
Defoamer	1.9	0.3
Calcium carbonate extender	422.2	18.7
Titanium dioxide	70.4	2.2
Zinc oxide	46.9	1.0
Grind Sub-total	700.1	41.0
LetDown		
Elastomeric Acrylic resin (55%)	470.6	54.7
Defoamer	1.9	0.3
Coalescent	7.0	0.9
Biocide	2.1	0.2
Ammonia (28%)	1.0	0.1
Premix		
Propylene Glycol	24.4	2.8
HEC thickener	4.2	0.4
Premix Sub-total	28.6	3.2
Totals	1211.3	100.4
Level without additives	Volume Solids	51.2%
	Weight Solids	65.9%
	Density (lb/gal)	12.1
	VOC (g/L)	69
	PVC	42.7%
Level with additives	Volume Solids	52.3%
	Weight Solids	66.9%

EXTERIOR INSULATION AND FINISHING SYSTEMS (EIFS)

Exterior Insulation and Finishing Systems (EIFS) are multi-layer synthetic wall claddings that combine foam insulation and coatings to provide the exterior walls of buildings with an insulated and finished surface and a barrier against water infiltration. Sometimes referred to as "synthetic stucco", it is actually quite different from stucco, which is a non-insulating, cementitious cladding option. EIFS was developed in Europe after World War II to repair damaged masonry buildings. The use of EIFS in the United States started in the 1960's, and today it is a very popular cladding material for commercial buildings.

EIFS achieves an effect like that of a blanket wrapped around a building, keeping out the chill of winter and holding in the heat and similarly, keeping out the heat of summer and holding in the cool conditioned air. By insulating outside the structure, EIFS reduce air infiltration, stabilize the interior environment and reduce energy consumption. EIFS, in contrast to traditional insulation, can reduce air infiltration by as much as 55 percent. Traditional insulation at any thickness leaves gaps where the heat and cold pass freely between indoors and out. Those gaps occur at studs, wall outlets, wall joints and elsewhere. EIFS also increase the R-value of a building. R-value is the measurement of the resistance to heat flow, and the higher the R-value, the better the insulating value of the material. Most EIFS use insulation board with an R-value of 4 to 5.6 per inch. When combined with standard wall cavity insulation, the extra layer can boost wall insulation to an R-value of 20 or more. Compared to other exterior wall claddings, EIFS provides excellent insulation properties and moisture control.[10]

There are several layers within an EIFS assembly (Figure 6), including an adhesive or mechanical fastener which attaches the insulation (e.g., expanded polystyrene foam board) to the substrate (e.g., OSB, gypsum board), a basecoat with an embedded reinforcing mesh, and a finish coat which is typically textured. The traditional type of EIFS is a barrier wall system also called barrier EIFS, in which the basecoat primarily acts as a water barrier for the building. All other components must be either barrier systems or be properly sealed and flashed to prevent water from getting behind the EIFS and into the walls. In barrier EIFS, the insulation board is flush with the substrate. The second type of EIFS incorporates a drainage plane behind the insulation

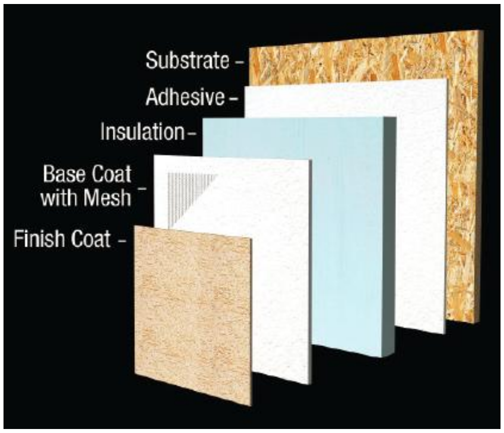

Figure 6. The multiple layers of an Exterior Insulation and Finishing System (EIFS).

board, and is known as EIFS with Drainage. In the drainage system, a water-resistive barrier is applied to the substrate before the insulation is attached. Drainage channels between the water-resistive barrier and the foam insulation allow the drainage of incidental moisture. EIFS with drainage are common on stick built construction or any wall assembly where there is a wall cavity space.

Elastomeric acrylic polymers are used in some finish coats, specifically flexible textured finish coats, which are applied as the last layer of the system, as well as in the liquid-applied water-resistive barriers that are applied first in an EIFS with drainage. Flexible textured finish coatings are similar to standard textured coatings, except that the polymer is very soft. The low T_g polymer offers better crack bridging properties compared to the standard textured coatings. Flexible textured coatings are formulated at very high PVC, typically between 70 – 80% PVC. This is much higher than in elastomeric wall coatings, which is the subject of the next section. At such high PVC, the finish coat is mainly providing aesthetics, although the elastomeric acrylic binder allows it to maintain enough flexibility to effectively bridge cracks that might occur in the basecoat. An example of a flexible textured finish formulation is shown in Table 4. Various sieve grades of sand account for most of the PVC of the formulation. A comparison of the elastomeric acrylic with a conventional (non-elastomeric) acrylic binder in the same 70 PVC

Table 4. A typical flexible textured finish coating formulation based on an elastomeric acrylic polymer and used as the final layer in EIFS.

Material Name	Pounds	Gallons
Elastomeric Acrylic Polymer (60%)	292.60	33.98
Propylene glycol	5.00	0.54
Defoamer	2.00	0.26
Titanium dioxide	65.00	3.35
Sand (#15 grade)	150.00	6.78
Sand (#30-50 grade)	850.00	38.44
Attapulgite clay thickener	10.00	0.51
Biocide	3.00	0.33
Coalescent	5.60	0.71
ASE thickener	7.50	0.85
Ammonia (28%)	2.50	0.33
Water	116.19	13.92
Totals	1509.39	100.00
Level without additives	Volume Solids	67.3%
	Weight Solids	81.9%
	Density (lb/gal)	15.1
	VOC (g/L)	22
	PVC	70.1%
Level with additives	Volume Solids	67.8%
	Weight Solids	82.3%

Table 5. Comparison of an elastomeric acrylic and a conventional (non-elastomeric) acrylic in a 70 PVC textured EIFS finish coat.

Property	Conventional acrylic	Elastomeric acrylic
Polymer T_g (°C)	13	-35
Mandrel bend flexibility		
Room temperature	Pass 1/4"	Pass 1/4"
40°F	Pass 1/4"	Pass 1/4"
0°F	Fail 2"	Pass 1/4"
Tensile Strength @ break (psi)		
Room temperature	37	39
40°F	152	74
0°F	294	118
Elongation @ break (%)		
Room temperature	126	68
40°F	17	95
0°F	1	61
Dirt pickup resistance		
% reflectance retained	68.5	89.0

formula is given in Table 5. The elastomeric acrylic offers better flexibility and elongation, particularly at lower temperatures, as well as good dirt pickup resistance.

Elastomeric acrylic binders are also used in water-resistive barriers, designed as liquid-applied membranes to replace materials such as black felt paper. The water-resistive barriers are non-cementitious coatings used in EIFS with drainage due to their excellent resistance to bulk water intrusion while allowing the passage of water vapor from the interior of the building. They have good adhesion to a variety of construction substrates, and can be roller or trowel applied. The good elongation and crack-bridging properties typical of elastomeric acrylics are important in maintaining a continuous membrane in spite of movement. Table 6 shows a comparison of a 49% PVC water-resistive barrier to 15 lb black felt paper. The water-resistive barrier was based on an elastomeric acrylic polymer with a T_g of -35°C. The results in Table 6 show good water vapor transmission, lower bulk water absorbency, and better resistance to hydrostatic pressure versus the felt paper.

EIFS are an important wall cladding option used heavily in commercial architecture, and create unique appearances and textures for buildings. Systems are designed to provide insulating properties, as well as resistance to water intrusion. Elastomeric coatings are used as part of the overall finishing system, providing bulk water resistance, good water vapor permeability and

Table 6. Typical resistance properties of a water-resistive barrier relative to 15 lb felt paper.

	Water-resistive barrier	15 lb felt paper, 1 ply
Moisture Vapor Transmission (ASTM E96, Method B):		
WRB or Paper Only:		
U.S. perms (grains/hr/ft^2/in of Hg)	5 - 7	7 - 7.5
metric WVT (gms/24 hours/m^2)	35 - 45	--
Complete system (Substrate /2" EPS /Basecoat /Finish):		
Densglas: U.S. perms/ metric WVT	6 / 42	5 / 32 (2 plies)
Plywood: U.S. perms/ metric WVT	6 / 42	4 / 27 (2 plies)
Water Absorbency (% after 23 days soak)	14	50 - 51
Hydrostatic Resistance (ASTM D5385)		
over Densglas substrate	Pass	Failed

flexibility in water-resistive barriers, and good crack bridging properties and aesthetics (e.g., color retention and dirt pickup resistance) in flexible textured finish coats. Many of these properties are also utilized in the final application to be discussed, elastomeric wall coatings for concrete and masonry walls.

ELASTOMERIC ACRYLIC WALL COATINGS

Concrete and masonry surfaces are very common in commercial architecture, and require finishes with good adhesion, particularly under wet conditions, and aesthetic durability properties such as color retention and resistance to chalking and dirt pickup. In addition, masonry surfaces are highly alkaline when fresh, often porous, and prone to efflorescence. Efflorescence is caused by the migration of calcium salts from the cement to the surface, where they react with carbon dioxide in the air to form carbonate salts that appear as a whitish substance on the surface. Concrete and masonry are also susceptible to surface cracking. Elastomeric acrylic wall coatings are designed to deal with all of these needs.[11]

From the viewpoint of finishing, one of the most troublesome characteristics of masonry substrates is their high initial alkalinity (pH ≥ 10). In concrete and mortar, the alkalinity results from the presence of calcium hydroxide which is formed as a by-product during the cement curing process. As masonry weathers, the alkaline components either leach out or are neutralized, however the process is gradual and the highly alkaline nature of the substrate can persist for a year or more. Some coating chemistries, such as alkyds or vinyl-acrylics will tend to undergo hydrolysis under highly alkaline conditions, so are not good choices especially for fresh masonry. Acrylic latex coatings have better hydrolytic stability, and thus can be applied with minimal risk of failure to damp masonry where the surface alkalinity is in the range of pH 10 - 12. The hydrophobic nature and thick applied films (10 - 20 mils DFT) of elastomeric acrylic wall coatings also offer good barrier properties, which help block the passage of salts and efflorescence through the film.

A main problem associated with masonry substrates and addressed by elastomeric acrylics is surface cracking.[12] When cracks occur in a substrate, it presents a pathway for water to infiltrate further into the structure. In fact, a 20 mil wide crack that is 3 feet long presents approximately the same area for water infiltration as a 1 inch diameter hole. Once into the crack, water can do further damage to the exterior or interior of the structure. It is important to note that cracks will also tend to expand and contract due to temperature fluctuations. If the surface coating cannot withstand the stresses when a crack forms or when the crack is expanding and contracting, the crack will propagate through the coating and barrier properties will be compromised. Very small microcracks, up to approximately 8 mils wide, can be coated with a conventional masonry coating if it is applied thick enough. However, for wider cracks, the added flexibility of an elastomeric acrylic is needed. Elastomeric acrylic wall coatings can be used over cracks that are up to approximately 16 mils wide. Above 16 mils wide, the crack should first be sealed with a caulk or sealant, and then coated with an elastomeric acrylic.

Mimicking the formation and movement of cracks in laboratory testing can be quite challenging. Although no standardized methods exist for elastomeric wall coatings, attempts have been made to find methods that can distinguish between various types of coatings over concrete and masonry substrates like stucco. [13] Our laboratory has developed several methods to simulate the response of coatings to crack generation, as well as to evaluate how coatings respond to expansion and contraction of existing cracks.[14]

To simulate the response of coatings to crack generation, a 6 inch by 36 inch x ¼ inch thick fiber cement board is used as the foundation. The board is used as the base for three reasons: 1) it is relatively flexible and can be bent into an arc without breaking, 2) it has excellent stability, and 3) dimensions can be modified to fit exterior test fences at our global exposure stations. The board is primed with an acrylic latex to make it more adhesive and ensure a good bond with the mortar layer that is applied on top. A 3/8" layer of a specific mortar is applied to the board and allowed to dry for at least a week. The mortar has been formulated to render it more brittle and susceptible to cracking when it is bent. After drying, three stripes of coatings are applied along the length of the board. Each coating is applied at its recommended spread rate, so approximately 400 - 500 square feet for thin film masonry coatings based on harder binders, and 50 - 75 square feet for elastomeric acrylic wall coatings. After drying, the board is placed into a testing apparatus which can bend the board until cracks appear in the mortar (Figure 7). The cement board is bent by applying pressure on the back of the board with a screw device. The width of the cracks in the mortar can be varied by adjusting the screw. The inset photo in Figure 7 shows three coatings on the board after cracks have been generated. The top and middle coating are based on thin film coatings which rupture when the cracks are produced. The bottom coating is a thick film elastomeric acrylic, and shows excellent ability at bridging cracks.

As with elastomeric roof coatings, tensile and elongation at break are important properties that help describe the behavior of elastomeric acrylic wall coatings. In addition to tensile and elongation tests on free films, another test developed in our labs to assess crack bridging is a modified elongation test performed with an Instron tester.[14] The back of a black vinyl Leneta chart is scored with a blade, cutting almost entirely through the chart. The coating is then applied to the front of the chart and dried. After the coating is dry, the investigator folds and unfolds the chart along the score line until the vinyl separates into two pieces, talking special care not to damage or stretch the coating in the process. The resulting specimen represents a hairline crack bridged by the coating. Each half of the chart is then attached in the jaws of the tensile testing equipment. The testing unit pulls the two halves apart, simulating the widening of a masonry surface crack as the temperature drops. The sample is pulled until it snaps, and the distance the jaws have moved represent the crack width at break. The greater the distance, the greater the ability of the coating to bridge cracks.

One other method we have developed to evaluate crack-bridging ability involves the use of an actual moving expansion joint on the side of a one-story cinderblock wall building.[15] The basic design of the test equipment is fundamentally simple. Two long aluminum strips are mounted parallel to each other on either side of a vertical expansion joint in a masonry wall (Figure 8). A series of clamps are positioned side by side along the length of each strip. The test samples are

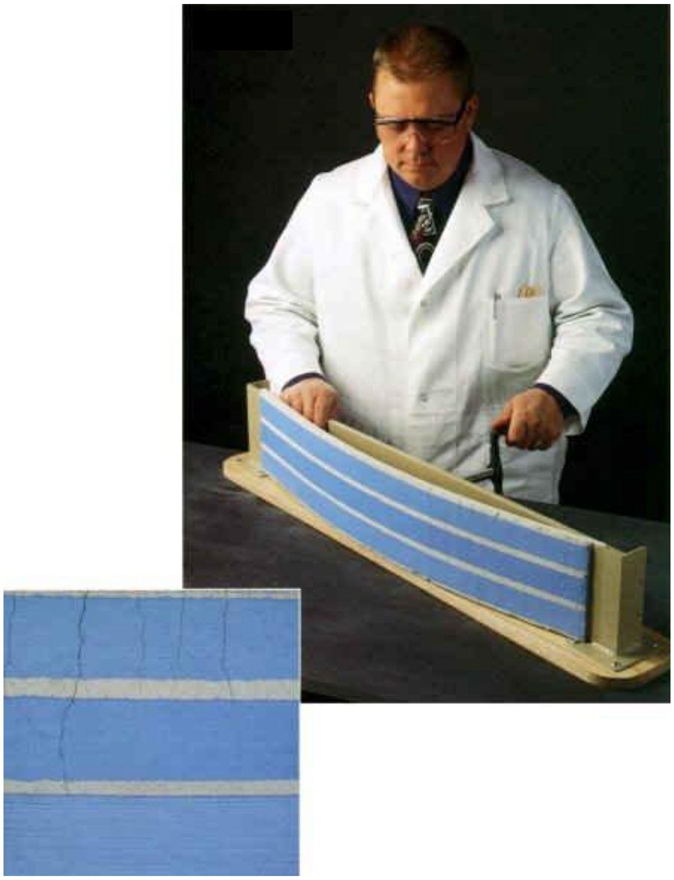

Figure 7. Testing equipment for simulating crack generation on coated masonry substrate. Inset shows three coatings on the board after cracks have been generated – the top and middle coatings are thin film masonry coatings based on harder acrylic binders, and the bottom is an elastomeric acrylic wall coating based on a more flexible, low T_g binder.

Figure 8. Photograph of the moving wall testing device. Clamps on either side of a vertical expansion joint in a cinderblock wall each hold half of a fiber cement board, connected only by the coating film bridging the gap.

pieces of fiber cement which have been broken in half and butted up against each other. The coating being tested is applied to the cement board and allowed to dry. The coating forms a bridge over the two pieces of board. The panel is clamped on both sides of the expansion joint. As temperatures rise, the masonry expands and the joint narrows. As temperatures drop, the masonry contracts, and the joint widens. Because it is clamped to both sides of the joint, the space between the fiber cement boards also expands and contracts as the joint moves with fluctuating temperature. The ability of the coating to tolerate the movement of the wall and the crack without rupturing is a measure of its flexibility and crack-bridging properties. Because this method is a exterior test and driven by the variations in climate, investigators are at the mercy of the weather. In climates where the temperature conditions are fairly constant, movements will be small and time will be needed to adequately assess crack-bridging. However, in colder climates, performance becomes even more critical as cracks widen. The problem with conventional acrylic coatings based on harder binders is that they become less flexible with the decreasing temperature. As in roof coatings, the ability of an elastomeric acrylic wall coating to maintain good elongation and flexibility at lower temperatures allows them to bridge the moving cracks, as long as they are applied in thick enough films.

To achieve high film thicknesses and prevent mudcracking, elastomeric wall coatings are formulated at high volume solids (~50%) and should not be diluted before application. A typical elastomeric acrylic wall coating formulation is shown in Table 7. The coatings are typically high PVC (35-45%) and formulated with calcium carbonate or silica extenders. To improve elongation and offer greater crack-bridging ability, formulators can lower PVC and include more binder in the coating. This would also have the effect of improving exterior durability and adhesion compared to a higher PVC analog. As with the roof coatings, TiO_2 levels are low compared to a typical exterior flat house paint, because the elastomeric coatings are put on in

Table 7. A typical elastomeric acrylic wall coating designed for use over concrete and masonry surfaces.

Material Name	Pounds	Gallons
Grind		
Water	175.29	21.00
Pigment dispersant	10.93	1.20
Propylene Glycol	25.77	2.98
Potassium tripolyphosphate	1.50	0.07
Surfactant	1.00	0.11
Defoamer	2.00	0.26
Titanium dioxide	74.41	2.30
Calcium carbonate	435.84	19.32
HEC thickener	5.16	0.48
Grind sub-total	731.90	47.72
LetDown		
Elastomeric acrylic polymer (61%)	413.85	48.07
Defoamer	2.00	0.26
Coalescent	5.05	0.64
Biocide	6.50	0.71
Ammonia (28%)	1.00	0.13
HEC thickener	20.23	2.40
Totals	1180.54	99.93
Level without additives	Volume Solids	50.1%
	Weight Solids	64.4%
	Density (lb/gal)	11.8
	VOC (g/L)	82
	PVC	43.2%
Level with additives	Volume Solids	51.8%
	Weight Solids	65.9%

thick films where the low TiO_2 levels do not hurt hiding. Textured versions can be made by including sand in the formulation. VOC levels are typically low because the soft elastomeric acrylic binder requires little coalescent for film formation.

The finishing of concrete and masonry walls with elastomeric acrylic coatings gives the building owner a wall surface that is both aesthetically pleasing and protected from the elements. With good durability, resistance to dirt pickup, resistance to bulk water intrusion while remaining breathable to allow water vapor to escape, and the flexibility to bridge moving cracks, elastomeric acrylic coatings are good choices for these surfaces.

CONCLUSIONS

The structures encountered in commercial architecture have a great variety of coating needs, many of which require high performance for demanding situations. Elastomeric acrylic coatings, based on low T_g, flexible acrylic polymers, have several unique properties which make them the coatings of choice for applications including roof coatings, exterior insulation and finishing systems, and exterior wall coatings for concrete and masonry surfaces. Excellent flexibility and a good balance of tensile and elongation across a wide temperature range, including low temperatures, allows them to offer good resistance to impact and substrate movement, and the ability to bridge expanding and contracting cracks. Their crack-bridging ability allows them to maintain their barrier properties. Elastomeric acrylics as a class of coatings have good resistance to bulk water, and yet have enough water vapor permeability that the building can “breath” and allow water vapor to escape. The bulk water resistance leads to their use as water-resistive barriers in EIFS and in roof coatings where they are exposed to ponding water on low slope roofs. Their ability to “breath” and allow water vapor to escape from the structure also aids their use in EIFS and coatings for concrete and masonry walls. Good resistance to dirt pickup offers wall coatings and EIFS with good aesthetics, and roof coatings with long term solar reflectivity that translates into energy savings for the building. In addition to these versatile properties, elastomeric acrylic coatings are also low VOC options for the protection of commercial structures.

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